Guidelines for multispectral data collection

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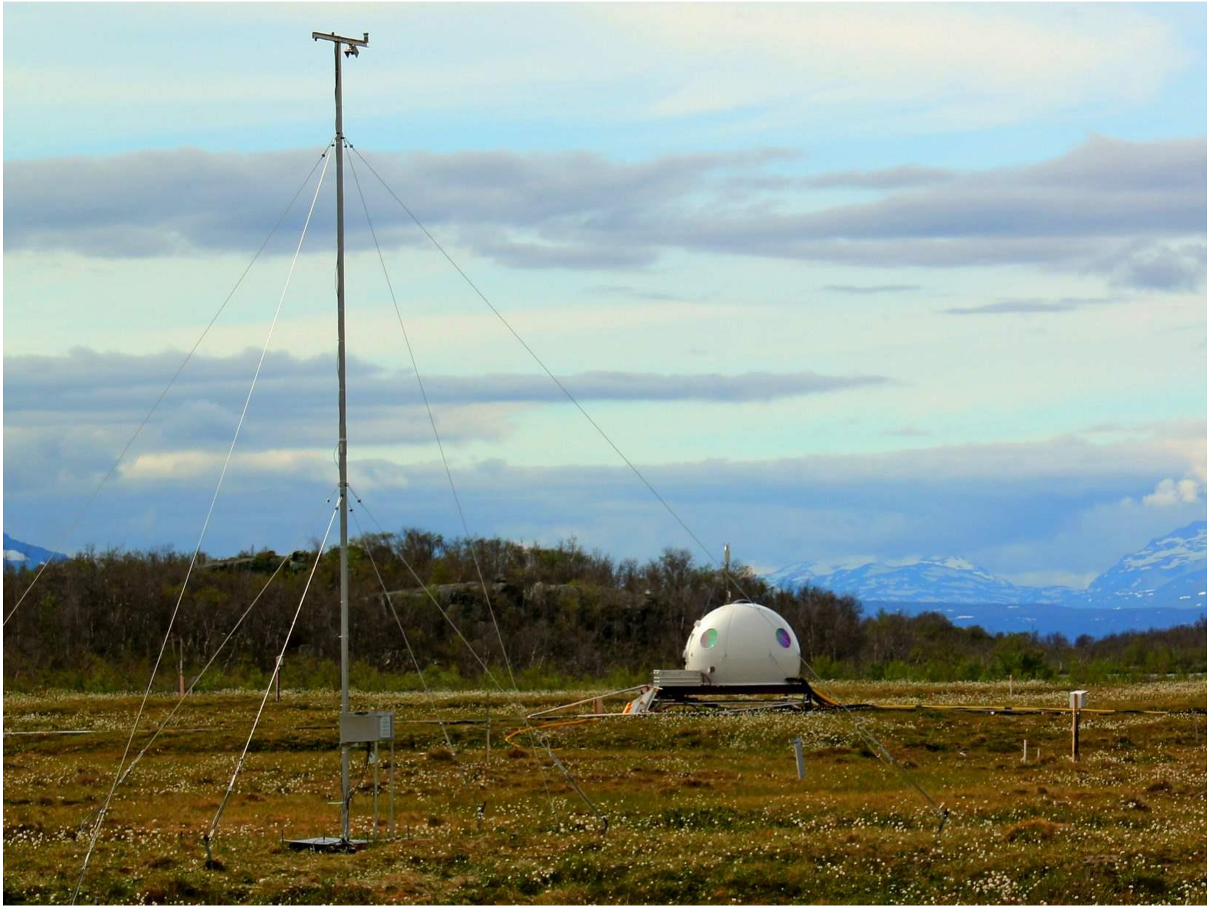
SITES

NordSpec
a spectral data infrastructure



The NordSpec and ICOS installations in the Stordalen site, Abisko, N. Sweden.

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1. Introduction

This manual describes technical aspects of multispectral data collection at ecosystem or community level. It is to be used within the NordSpec[1] and SITES[2] research networks for defining spectral installations for multispectral data collection. The aim of these measurements is to provide data that are

- related to plant processes (e.g. phenology, photosynthesis, and carbon assimilation)
- stable for long term monitoring purposes
- well-defined
- carried out in parallel and as a complement to other on-going measurements (gas fluxes, meteorology, remotely sensed data, etc.).

The aim of the measurements is to increase our ecosystem understanding, more specifically to add insights and reference information relevant to:

- vegetation phenology
- relationships between vegetation growth and environmental conditions
- forestry and agriculture management (intensive farming, vegetation disturbance, forest clearcutting and regeneration)
- plant biochemical processes (photosynthesis, transpiration)
- carbon fluxes
- light use efficiency
- scaling of vegetation processes to larger areas
- satellite and airborne remote sensing.

Near-ground spectral measurement (sometimes called proximal sensing) has its basis in the field of spectroscopy and has a long history for investigating spectral properties of different land materials. One of the original aims was to develop spectral libraries to be used for training algorithms to detect different land cover and vegetation types in remotely sensed data. In later years there has been a trend towards regular monitoring of ecosystems using fixed installed field sensors. *Hyperspectral* instruments (*spectrometers*) can be used for measuring in narrow wavelength bands from visible to short-wave infrared wavelengths. However, these instruments are usually expensive, delicate and not so well adapted for extended field use, as well as difficult to calibrate.

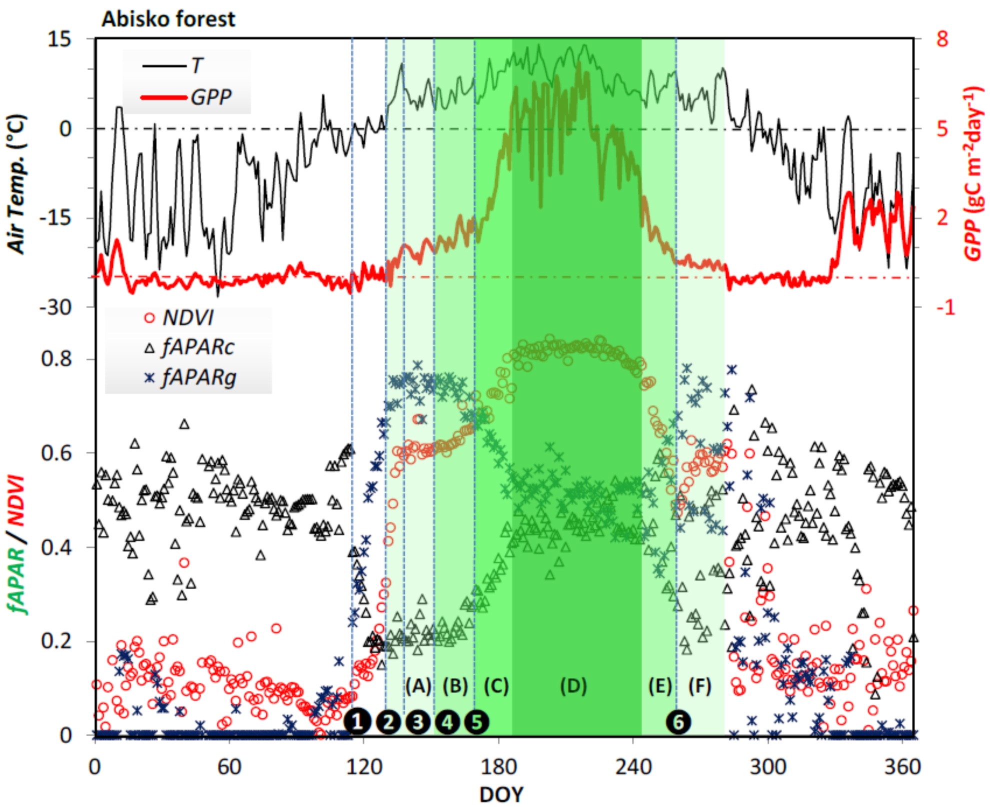
As robust and cost-effective alternatives to spectrometers, simpler *multispectral radiometers* can be used. These sensors record radiation in selected wavelength bands known to be interesting for monitoring of vegetation and other land covers. Typical wavelength regions are visible (including red, green and blue), near infrared (NIR), short-wave infrared (SWIR), and PAR (photosynthetically active radiation – a broad visible band).

[1] NordSpec is a Nordic infrastructure for collection of spectral data at flux tower sites and ecological stations. More information can be found at http://www.xxx

[2] SITES (**S**wedish **I**nfras**T**ructure for **E**cosystem **S**cience) is a Swedish network of ecological field stations. Several Nordspec sites are co-located with SITES. More information can be found at http://www.fieldsites.se.

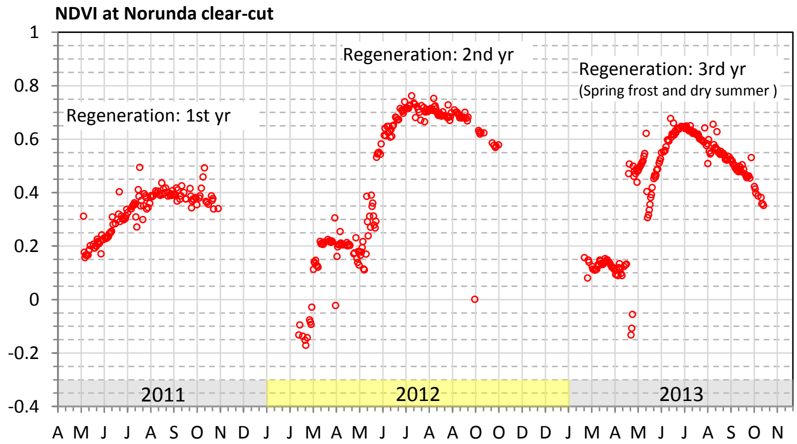
Visible bands respond to changes in vegetation pigmentation, NIR to vegetation structure (e.g. leaf cellular structure), and SWIR bands to canopy water content. These bands can be used for forming vegetation indices, e.g. NDVI (related to canopy fractional absorbed PAR), EVI (related to plant canopy dynamics), PPI (related to plant phenology and leaf area index), PRI (related to photosynthetic light use efficiency), NDSI (related to snow seasonality), and NDWI (related to canopy water content). Equations are given in Appendix 10.1.

The first international network for regular field spectral measurement in relation to flux tower sites was SpecNet[3] (Gamon et al. 2006). In Europe an EU COST Action ES0903 (Eurospec) was formed as a collaborative platform between researchers involved in similar activities in spectral measurement of vegetation. Reviews of the work by Eurospec are given in Balzarolo et al (2011) and Porcar-Castell et al. (2015). In Sweden, multispectral measurements started at flux-tower sites around 2009 (Eklundh et al. 2011).

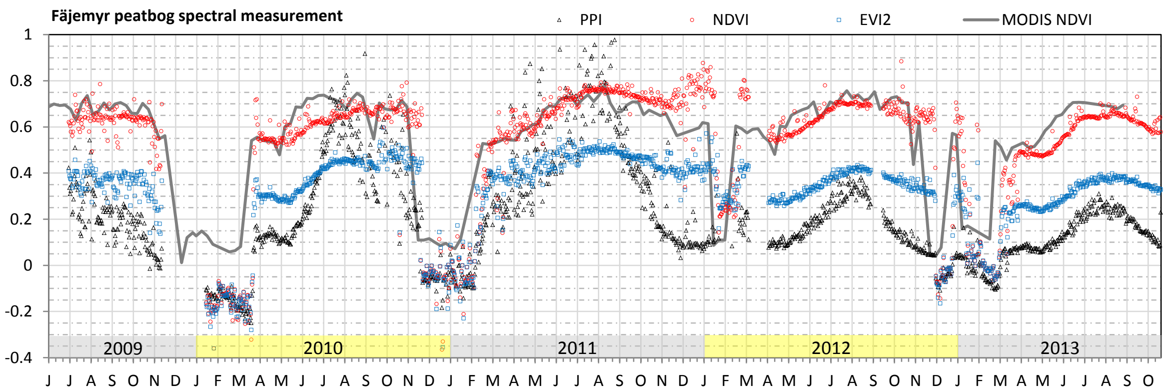


Graph showing (from the top) temperature, GPP, NDVI, and fAPAR of the canopy and ground, for a deciduous forest in N. Sweden (Abisko). The growing season is marked in green, and different phenological stages are marked by the numbers 1-6. From Eklundh et al. (2011).

[3] http://specnet.info/



Graph showing *NDVI measurement of three years' regeneration process at a clear-cut of Norunda pine forest.*



Graph showing *spectral measurement at Fäjemyr peatbog since 2009.*

This manual provides practical advice for installation of multispectral sensors, methods for data calibration, and devices for data collection and storage. It was developed as part of the development of spectral sampling capability of the SITES network under a grant from SITES to Lars Eklundh of Lund University. The project is in collaboration with Gunhild Rosqvist of Stockholm University, Leif Klemedtsson of University of Gothenburg, and Matthias Peichl of Swedish University of Agricultural Sciences, with support from many site managers and research engineers of involved field research stations.

2. Site selection

Several things should be considered when selecting a site for long term continuous spectral measurement of vegetation:

- **Research interests.** The site should be located at the research target, with relatively homogenous vegetation cover. If there is a flux tower or similar facility available, the already-existing tower may be used for mounting spectral sensors. The spectral measurement target should be located within the flux tower footprint area and have good representativeness of target vegetation. Any additional measurements or observations (meteorology, plant growth, phenology, ecophysiological measurements, etc.) carried out in the vicinity will be beneficial for interpreting the measurements and better understanding the ecosystem processes. It is therefore important that the selection of measurement sites is made on the basis of broad research interests. It is also important to choose a site that will be relevant also in a longer time perspective and for future researchers.

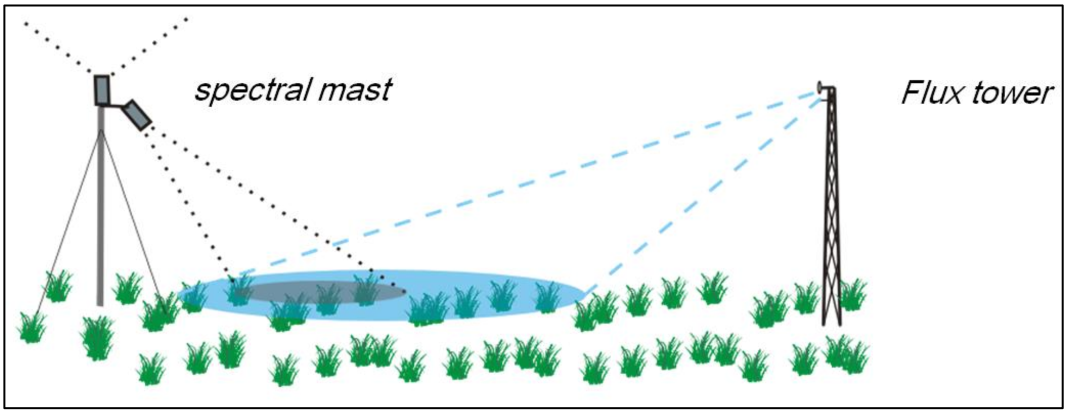
- **Safety**. The selected site should have necessary free space on the ground for tower to be safely placed, including free space for guy wires and anchors. To prevent damage from possible falling items or collapsing masts, there should be no sensitive items, e.g. power lines, within the area of a radius of 1.5 times of the tower height. The tower base and anchors should be located on firm ground.

> NEVER install a mast near AC power lines! All points of the installation including guy wires MUST be at a safe distance from power lines. Also avoid being too close to traffic routes.

- **Disturbances**. The observation target should be free from frequent disturbance by frequent visitors or animals. There should be no other shining objects or surfaces, like water bodies, light coloured bare ground, or walls in the vicinity of the tower site (10 times the tower height).

- **Accessibility.** The site should be easily accessible to facilitate maintenance, calibration, and data downloading under minimum cost. The accessibility to mains power supply should also be in consideration. Some sensors and dataloggers require mains power, whereas some others can be powered with batteries for several months.

- **Representativeness.** To facilitate comparisons with satellite data and to upscale ground measurements to a larger area via satellite observations the site should be within a homogenous area of at least 50 x 50 metres. If possible this size should be increased to match also coarse resolution sensors (250 x 250 m).

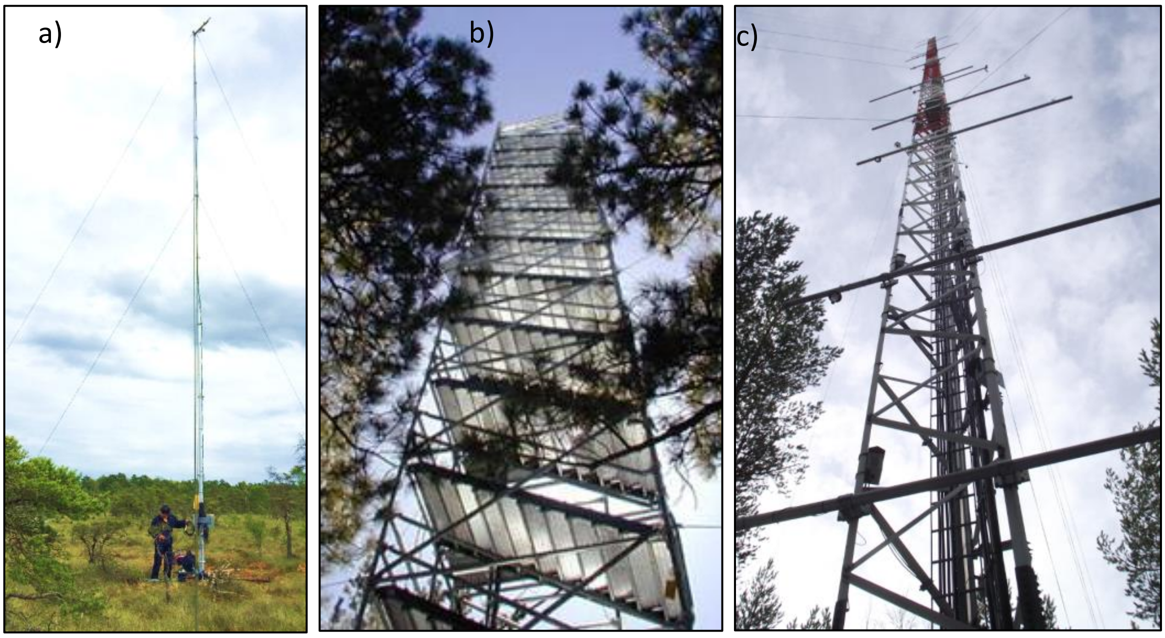


Principle of the spectral mast recording data from the flux tower footprint area.

Tower site with a 250 m grid

3. Towers and masts

A tower or mast for spectral measurement can be a guyed aluminium telescope mast (unclimbable), a guyed steel tower (climbable for authorized climbers) or a scaffold tower (climbable, with stairs). If there is an already-built tower available, it is only necessary to fix a horizontal boom at the top level so that the spectral sensors can be mounted. It is necessary to consider that it must be possible to reach the sensors regularly for maintenance and calibration. A practical and cost-effective solution is a telescope mast that can be raised and lowered easily. Here we will further describe the installation of telescope masts.

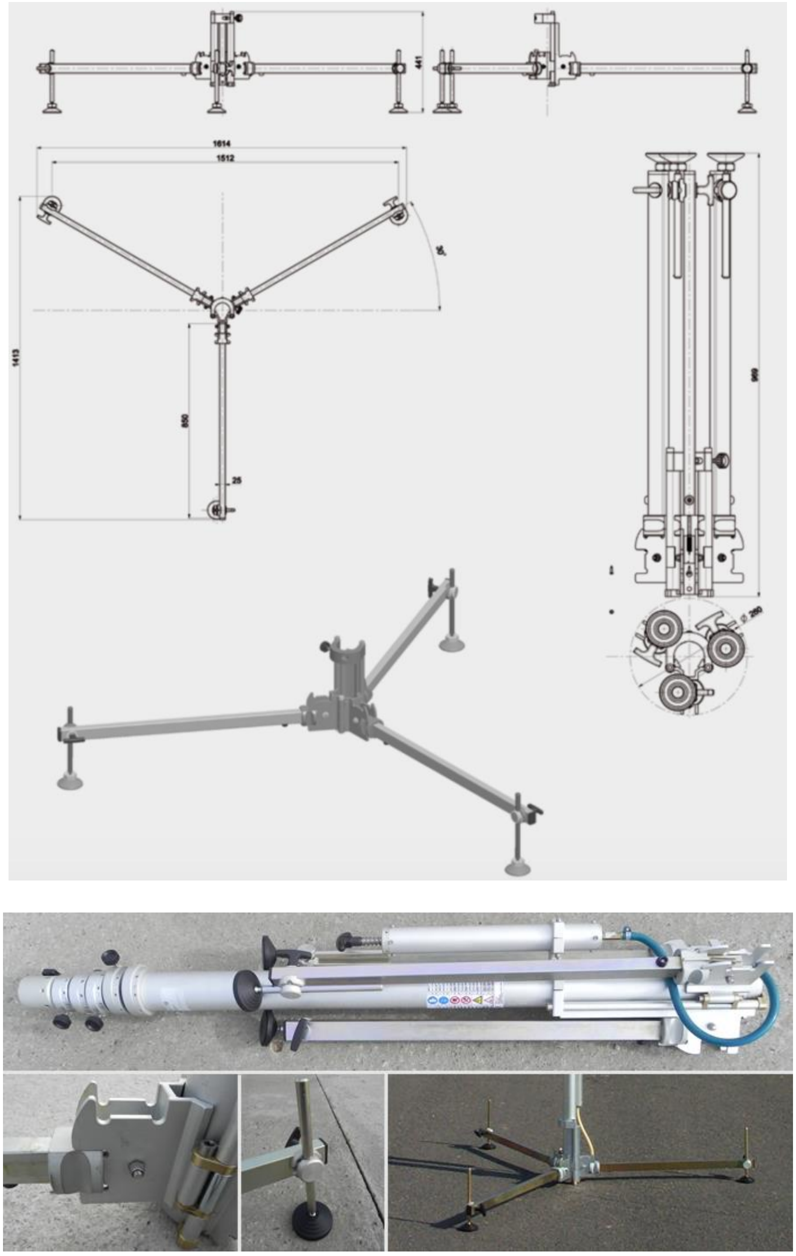


Tower type: a) guyed telescope mast, b) scaffold tower, and c) guyed steel tower.

3.1 Telescope mast

A telescope mast is made of several sections of aluminium tube. It is erected using wire or pneumatic pressure to reach its full height, around 5-20 meters depending on the type of mast.

An example of a mast model currently in use at several field sites is the Maxi Primo with tripod made by Fireco S.r.l., Italy. This mast comes in different versions with diameters of 80 – 115 mm, and with heights from 6 to 20m. The masts can be equipped with a hand pump or an electric pump. The 8 section model (Part Number CM.5811) mast has an extended height of about 15m and retracted height of 2.5m. It weighs 30.5 kg and has a max head load of 9 kg. The mast has two or three levels of guy wires and can endure wind speeds up to 120 m/s. Both lighter and heavier models are also available.



The Fireco telescope mast

Procedure of raising a light telescope mast (preferably > 2 persons):

1. Prepare the mast base, make the ground surface as level as possible. Put flat wood planks (impregnated wood) beneath the mast pole and the three feet.
2. One person stands on a 2-meter ladder; put a circular bubble level on the mast top to check if the mast top is perfectly level, i.e. the mast is perfectly plumb,. The other persons adjust the three feet.
3. Mount a boom with all the sensors on to the mast (for further details see the section Mounting Sensors). Make sure all the sensors are not blocking the views by each other.
4. Use plastic cable ties to fasten the sensor wires to the boom and mast nicely.
5. Re-check the level of upward looking sensor using the circular bubble; adjust the boom or mast feet if the sensor surface is not level. Use a protractor to check the oblique angle of down-ward looking sensors.
6. Pump up the telescope mast segment by segment, bind cables on to the mast and fasten the segment when it is fully extended. Also smear lubricant grease or Vaseline at the joint of each segment. Grease can contribute to sealing the mast against solid and liquid contaminants as well as moisture. It is also suggested to put lubricant grease when lowering a telescope segment, so as to avoid premature bearing failure due to metal-to-metal contact of moving parts.

A box of 40g Vaseline is enough for lubricating an 8-segement tower.

The person working in the vicinity of a ladder MUST wear a hard hat to protect the head from falling tools or nuts. Follow safety rules when working on the ladder, like the three points of contact rule, and no leaning out sideways on the ladder.

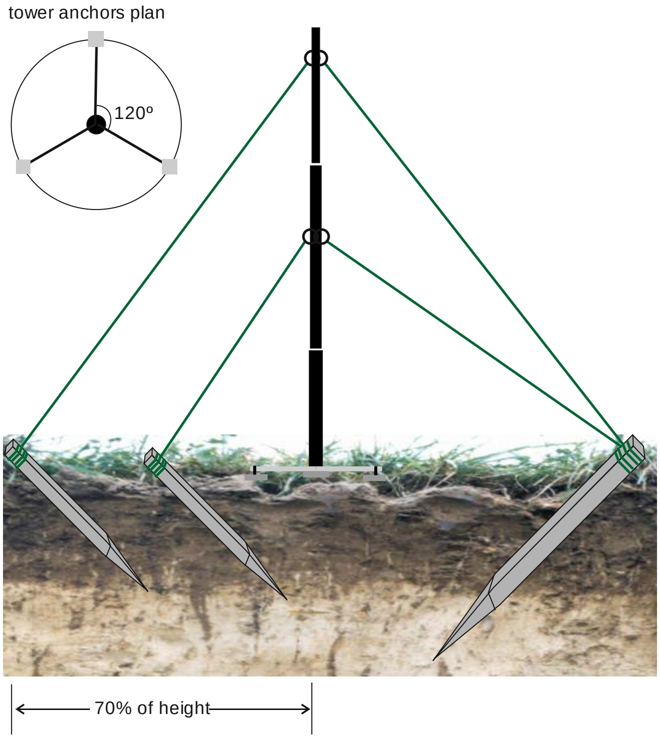
3.2 Guy wires

For lightweight masts, nylon ropes can be used as guy wires. However, the condition of the ropes needs to be regularly checked, and new ropes need to be retightened a short while after the first use.

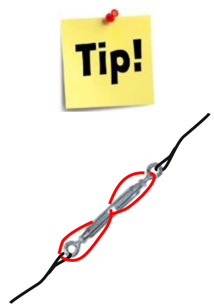
Two or three levels of guy wire should be used for a mast of 15~20 meters high. Three guys at 120° apart or four guys at 90° apart can be used at each guy level. If using three guys, the angle of 120° apart should be exactly followed.

The suggested outer guy radius is 70% of the overall tower height. Larger radius than this will increase guying cost and elasticity of guy wires. Shorter than this will increase downward force on the mast and upward force on anchors, and therefore increase the necessity for increasing the stability of the tower base and the guy anchoring system.

The three guy wires at the same level should have equal tension, and not too much pre-load should be applied to the guy wires. Otherwise their capacity to absorb additional load from tower movement before reaching the breaking strength may be reduced.



Guy wires at different level should have different tension. The higher the guy wire, the less tension is applied. For the guy wires that are attached at the top of the tower, the tension should be about 8% of the tensile strength. For the anchor point that is attached at 65% of the tower height, about 15% tension can be applied. Start tightening all three guy wires moderately at lower level, and then check the vertical accuracy of the tower while tensioning the higher level guy wires. Moderate movement of the mast due to wind does not affect the multispectral measurements severely.



Put a separate wire, or one of the long loose rope ends, through all the turnbuckles to prevent them from loosening.
Loop a cable through all of the thimbles (in a circle) in case one of the turnbuckles breaks.
The guy tension changes with temperature due to expansion and contraction. It also changes with the soil freezing and thawing due to the shift of tower base and guy anchors. Regularly check the tension of the guy wires.

3.3 Guy anchors

Solid steel or aluminium rods, or impregnated wooden poles can be used as a guy anchors. Each anchor is suggested to be hammered into undisturbed soils at least 1.5 m, but this also depends on tower height and the soil. In hard clay or frozen ground a machine hammer/breaker, e.g. Atlas Copco Cobra, can be used for pushing down the steel rods (see the front page illustration). Guys at two levels of different heights can be fastened on to a single anchor if the anchor is strong enough, or separately in order to divide the pull load among two anchors. The anchor should be at a proper angle tilt from the horizontal. The tilt angle is within 45° to 60° and the anchor should be perpendicular (75° - 105°) to the guy wire.

Tie the guy ropes securely to the anchor. Loosely tied rope may slide off the anchor by wind or running animals.

Here an accidentally falling tower due to a loose anchor tie is shown.

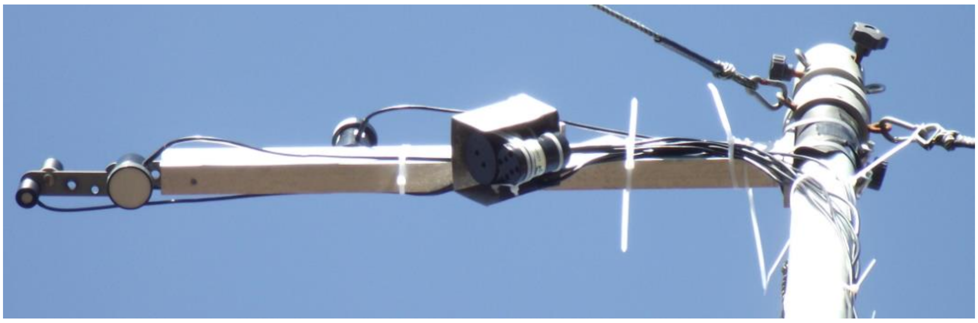
3.4 Mounting sensors

Spectral sensors are mounted on a horizontal boom on top of the tower. The boom can be any metal bar that can be fixed on to the tower. The length of the boom should extend at least 0.5 meter from the mast in order for the mounted downward-looking sensor to have minimal view of the tower and tower base.

The bar should be strong enough to hold around 3 kg load and extra wind load.

The boom should be fixed onto the tower as horizontally as possible (tilt angle less than 3° from the horizontal).

The upward-looking sensor should be firmly mounted at the top of the mast with an accuracy of ±3° from the horizontal and without any obstruction towards the upper sky. The downward-looking sensor should view into the target area. It is suggested that it is mounted obliquely, 45° from nadir direction away from the tower. The preferred azimuthal direction is towards east or west. Northwest is preferred to southwest and northeast is preferred to southeast. Avoid southerly direction. More information about calculation of the sensor footprint area is given in Appendix 10.2.



The boom should be mounted as horizontally as possible.

A tilt angle larger than 3° from the horizontal may lead to large measurement error of incoming light.

Examples of sensor mountings

The downward looking sensor should be mounted as to avoid seeing direct sky light, sun glint or any other light sources or shining surfaces, like metal or water surfaces. It should be set in a rainproof housing with open bottom, and a matt black inside colour. Sensors should be easily dismounted for re-calibration and cleaning maintenance. Therefore, it is advisable to have a set of connectors mounted on the wire close to the sensor.

Skye sensors are mounted using M6 size bolts. The length of the bolt depends on the mounting base. Prepare some long bolts and washers for some unexpected situations. The Decagon sensor is mounted using an M4 size bolt, short length (ca. 7 mm).

M6 bolt

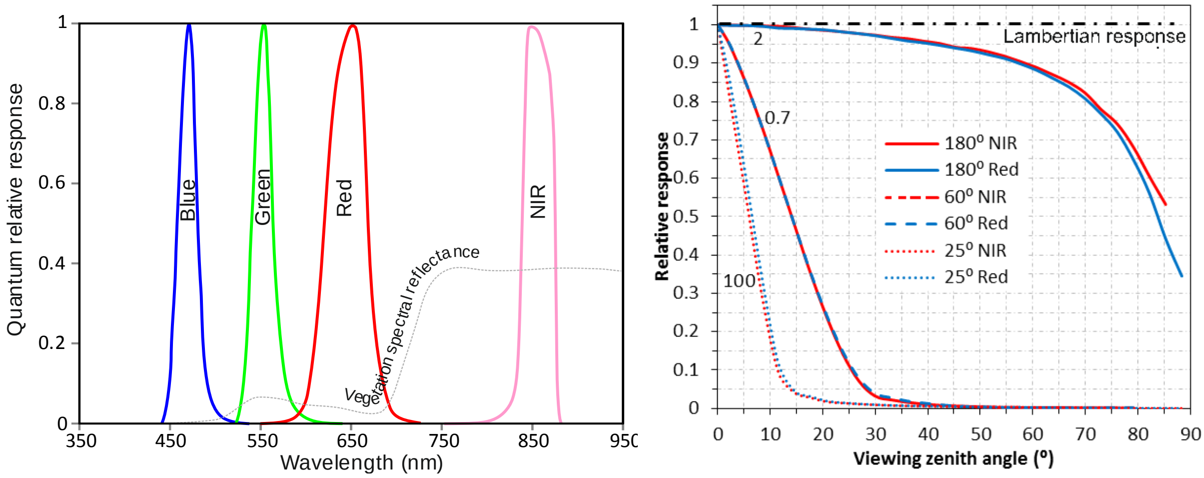
M4 bolt

4. Sensors

4.1 Multispectral sensors

Sensors used for long-term field measurements should be robust, durable and waterproof, and have good sensitivity and a dynamic range, better than 60 dB, to capture both small and large natural light signals. The sensor should be calibrated in spectral response and directional response. The spectral response and directional response of the photo-detector, light filter, and geometry constraint of the sensor housing should be known to the user. Sensors normally come in pairs, one for measuring incoming radiation and one for measuring reflected radiation from the ground target area.

In the NordSpec infrastructure we mainly use multispectral sensors manufactured by Skye instruments Ltd and Decagon Ltd; these will be further described below.



Graphs of spectral (left) and directional (right) response curves of Skye SKR 1800 sensor.

4.2 Skye Instruments Ltd sensors

Skye Instruments sensors are manufactured in some different models and with customized band specifications. Usually the wavelength bands match those of common satellite sensors, e.g. Landsat or MODIS. Specification of band widths are given in attached calibration documents delivered with the sensors. Skye sensors have two or four bands and are manufactured with or without amplifier. An amplified sensor is necessary when measuring under low-light conditions, such as during Swedish winter months. Sensors mounted upwards have a built-in diffusor providing hemispherical view. Sensors mounted downwards have a 25 degree directional view. In rare cases sensors equipped with hemispherical diffusor are mounted downwards to increase the field-of-view, although this is not generally recommended. Skye sensors generate current signals for near-continuous measurements.

Refer to your Skye sensor document for detailed band information.

SKR 1800 2-Channel Light Sensor

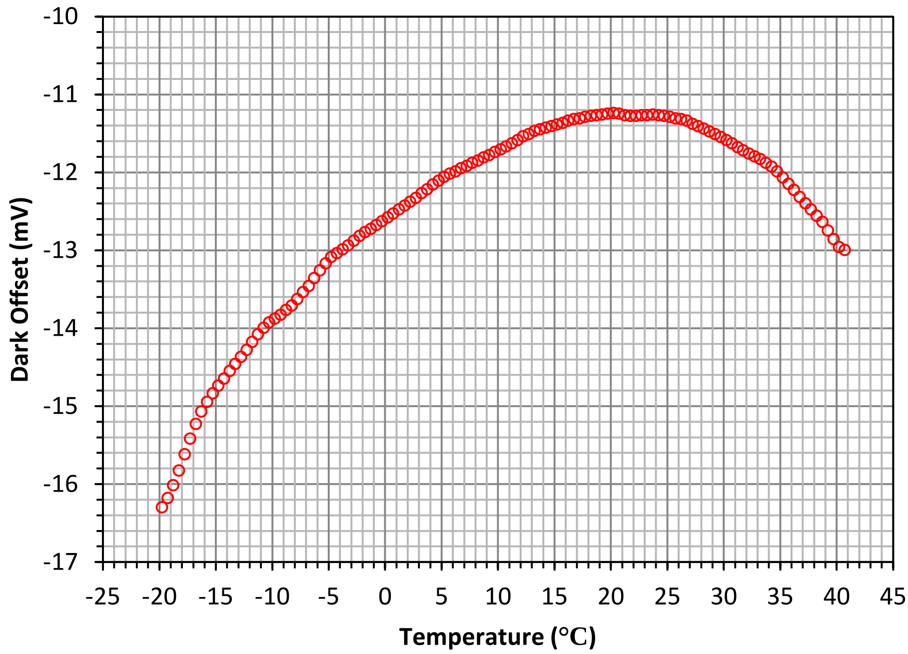
SKR 1860 & 1860A 4-Channel Light Sensor

"A" stands for in-built operational amplifier

> ⚠ The Skye sensor cables have different color codes for different channel wires, power, ground, and screen. The coding system is complicated and differs between sensors with and without extension cable. Please refer to Skye manuals for detailed color code for the correct sensor type and extension cable.

Sensor with SWIR band

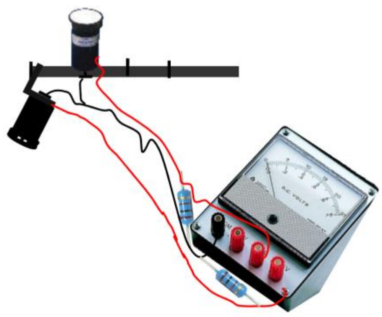
The detectors used in SWIR band are of the InGaAs and Extended InGaAs types. When amplified, these detectors produce a temperature-dependent dark current. The dark offset varies from sensor to sensor, and should be correct based on dark test.



A typical dark offset of a Skye SWIR band sensor from –20°C to +40°C

Skye SWIR band comes with an inbuilt temperature sensor, and the temperature output channel gives a reading in mV with a coefficient of 10 mV/°C.

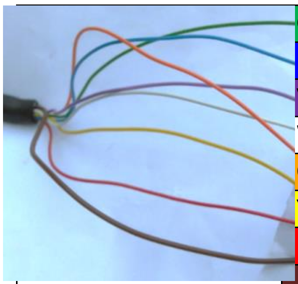
How to measure current using a data logger that measures voltage?
A resistor is needed!
A precision resistor should be used with:
- tolerance better than 0.1%.
- temperature coefficient better than ±15 ppm/°C



4.3 Extension cable for Skye sensor

Black	Channel 1 positive current output
Red	Channel 2 positive current output
Yellow	Channel 3 positive current output
Green	Channel 4 positive current output
Blue	Ground
White	Cable screen / sensor body

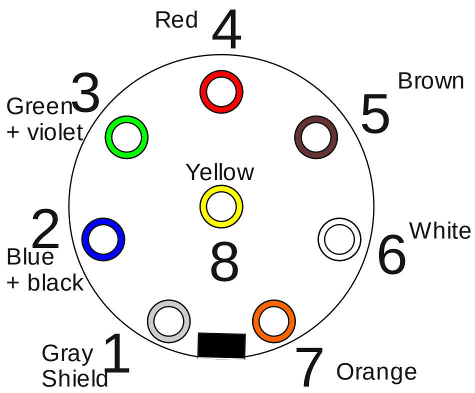
Color code for SKR 1860 current output with extension cable



Green	Channel 1 positive voltage output	Pin 5	Green
Blue	Channel 2 positive voltage output	Pin 6	Blue
Violet	Channel 3 positive voltage output	Pin 7	Black
White	Channel 4 positive voltage output	Pin 8	White
Orange	Sensor signal ground	Pin 3	Orange
Yellow	Power supply positive	Pin 4	Red/Black
Red	Power supply ground	Pin 2	Red
Brown	Cable screen / sensor body	Pin 1	Screen

Extension cable from RS-online

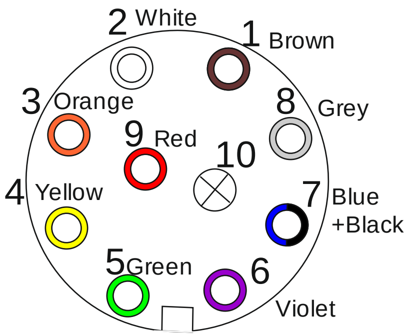
Color code for SKR 1860A voltage output with extension cable *and Skye 8-pin connector*



Wire Colour	Function	Skye Connector
Grey	Cable screen / sensor body	Pin 1
Blue + black	Power supply ground	Pin 2
Violet + green	Sensor signal ground	Pin 3
Red	Power supply positive	Pin 4
Brown	Channel 1 positive voltage output	Pin 5
White	Channel 2 positive voltage output	Pin 6
Orange	Channel 3 positive voltage output	Pin 7
Yellow	Channel 4 positive voltage output	Pin 8.

Front view of a 8-pin female connector
(on sensor side)

Color code for SKR 1860A (also for 1850A) voltage output with 8-Pin connector (metal connector).



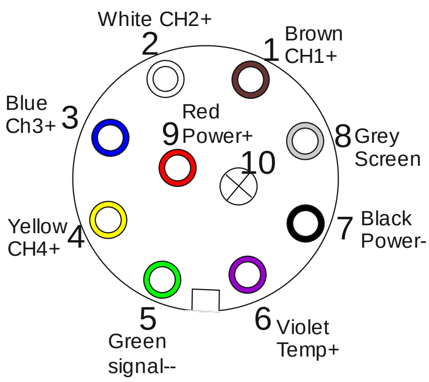
SKR 1860D/A. SKR 1860ND/A
- Voltage Output Sensor with Internal Amplifier and Channels incorporating Wavelengths over 1000nm

Wire Colour	Function		Skye Connector
Brown	Channel 1 positive voltage output	Brown	Pin 1
White	Channel 2 positive voltage output		Pin 2
Orange	Channel 3 positive voltage output	Blue	Pin 3
Yellow	Channel 4 positive voltage output	Yellow	Pin 4
Green	Sensor signal ground	Green	Pin 5
Violet	Temperature positive voltage output	Violet	Pin 6
Blue + black	Power supply ground	Black	Pin 7
Grey	Cable screen / sensor body	Screen/Grey	Pin 8
Red	Power supply positive	Red	Pin 9
-	NOT USED		Pin 10

Home made

Front view of a 10-pin female connector
(on extension cable side)

Skye 4-channel SWIR band sensor color code and pin number of Skye connector (blue plastic connector)



Front view of a 10-pin female connector
(Home made extension cable)

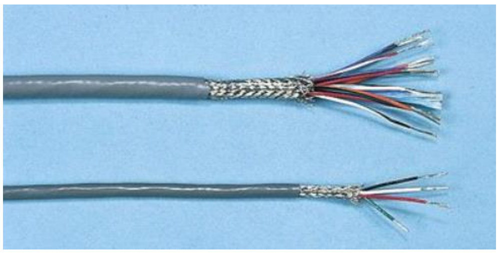
See for further information about *SKR 1860* 4-channel light sensors in Appendix 10.4.

Home-made extension cable for Skye sensors from Alpha Wire 8 Core Screened PVC cable and

Cable plug female: Cable socket, 712 series 8-pole, Binder
Cable plug male: Cable plug, 712 series 8-pole, Binder

Pin 5	Green
Pin 6	Blue
Pin 7	Black
Pin 8	White
Pin 3	Orange
Pin 4	Red/Black
Pin 2	Red
Pin 1	Screen

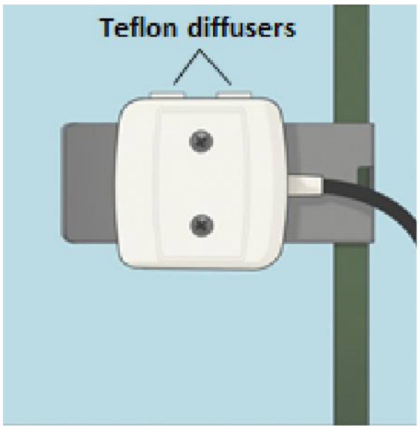
White/Black not used

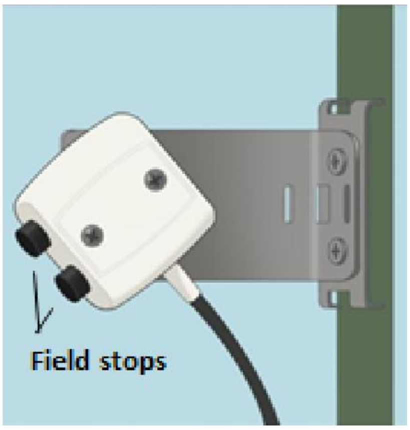


Colour code for home-made extension cable with connector

4.4 Decagon sensors

The Decagon Ltd. Spectral Reflectance Sensor SRS series consists of two-channel sensors in two versions: for measuring NDVI (red and NIR channels) or for measuring PRI (531nm and 570nm channels). Upward–looking sensors have Teflon diffusor to enable hemispherical view, and downward-looking sensors have view stops (35 degree field of view angle) to enable directional conical view.





Decagon SRS sensor is an intelligent sensor, which has inbuilt AD convert, microcontroller, and modules supporting SDI-12 (Serial Data Interface at 1200 baud) protocol. It directly gives a digital signal in physical unit (radiance).
The sensor can be connected to a Decagon datalogger using a 3.5 mm stereo plug connector, or connect to a digital input channel of CR1000 datalogger, or other microcontrollers, like an Arduino.

Note that the digital output with claimed physical unit from a Decagon sensor cannot be directly used. The sensor has to be calibrated again against a reflectance reference panel (e.g. Spectralon) in order to measure reflectance correctly. See section *Maintenance and calibration*.

Any 2-wire shielded cable can be used as extension cable for Decagon sensors. For SDI-12 interface decagon sensor, the cable can be up to 300m long. Longer than this, there may be power problem with the internal element of the SDI-12 module.

In order to connect Decagon sensors to the CR1000 logger, a 3.5mm stereo female connector is needed, which can be bought from a hardware shop. Otherwise the male 3.5mm stereo connector has to be cut off.

A 3.5 mm female connector

See Appendix 10.5 for further information about Decagon 2-channel light sensors with SDI-12 protocol interface.

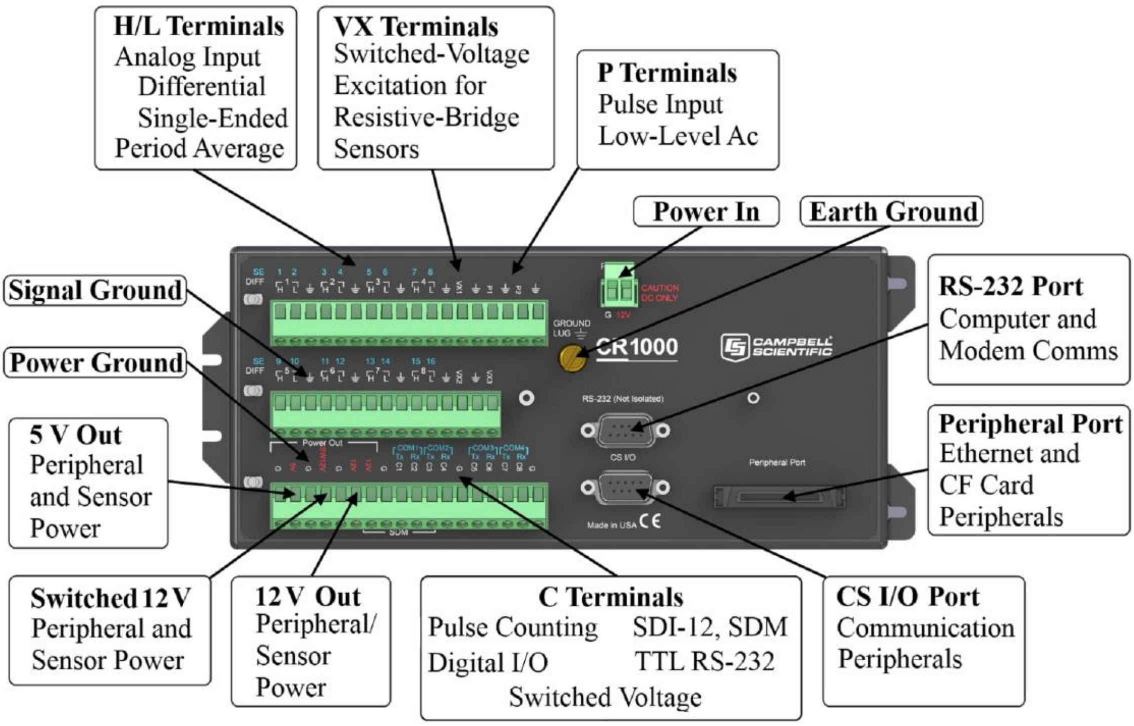
Use a digital multimeter to check if a spectral sensor works properly (not for Decagon sensors). This can be done outdoors in the sun or indoors with a filament bulb lamp (not a fluorescent light due to its narrow spectrum). Connect the two wires to a multimeter using crocodile clips. Remember paralleling a resistor of the same resistance value for field measurement use, if there is no built-in amplifier used. The negative wire of the sensor should be connected to the red (positive) clip of the multimeter, and the other wire connects to the black (common) clip. Turn the multimeter to “DC 2V” option, and if the reading is 0, turn it to “DC 200mV. The multimeter readings should change as the sensor is moved closer to or away from the light.

5. Data loggers

Dataloggers are used for storing the spectral measurements. We recommend 10-min averages of measurements of 10-second sample interval to be stored for the regular measurements. The white noise can be minimized with these 60 samples over the 10 min period. This is not possible with the Decagon EM50 data logger since its minimum sample interval is 1 minute and only 10 samples are averaged over 10 minutes sampling. For special purposes, e.g. calibration, higher frequency could be used. Data downloading from the logger should be done as frequently as possible to reduce the risk of data loss in case of equipment failures. We recommend automatic download at least once every day for the CR1000 datalogger, and once every week or bi-weekly for dataloggers without automatic download function.

5.1 CR1000 data logger

The Campbell CR1000 data logger is a flexible, multifunctional and fairly robust data logger for environmental measurement. It is compatible with nearly every available sensor: voltage signal sensors (lowest range 2.5 mV and resolution of 0.33 µV), SDI-12 sensors, and thermocouples. It is the first choice for spectral tower measurements when there is mains power supply.

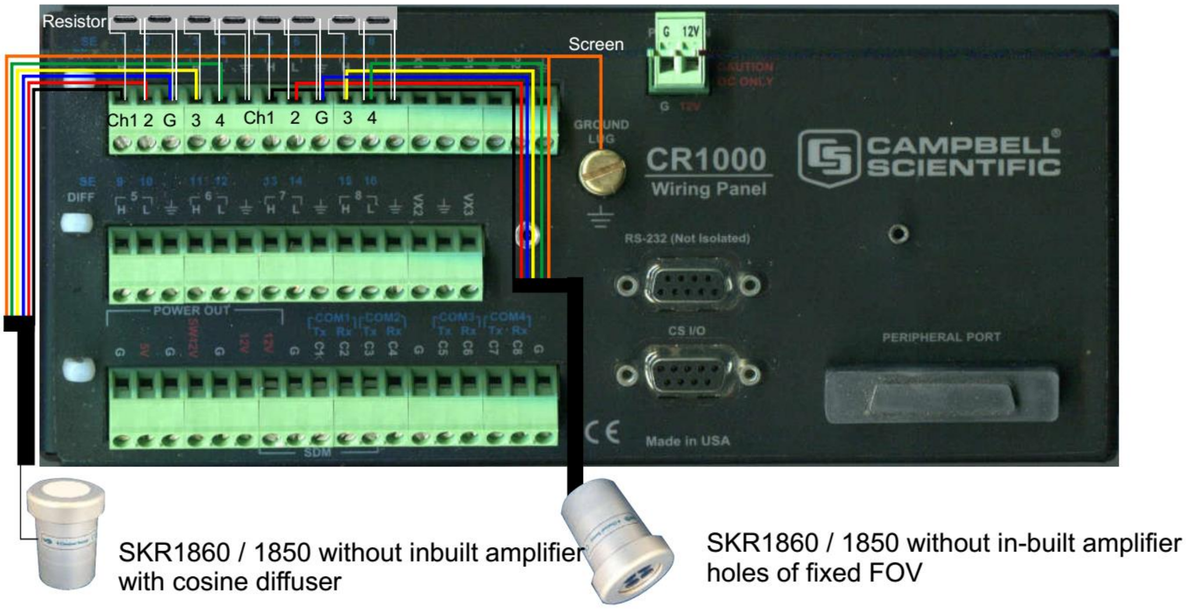


CR1000 has 16 single-ended (or 8 differential) voltage input channels. The maximum sampling rate is 100 Hz and the AD is 13 bits.

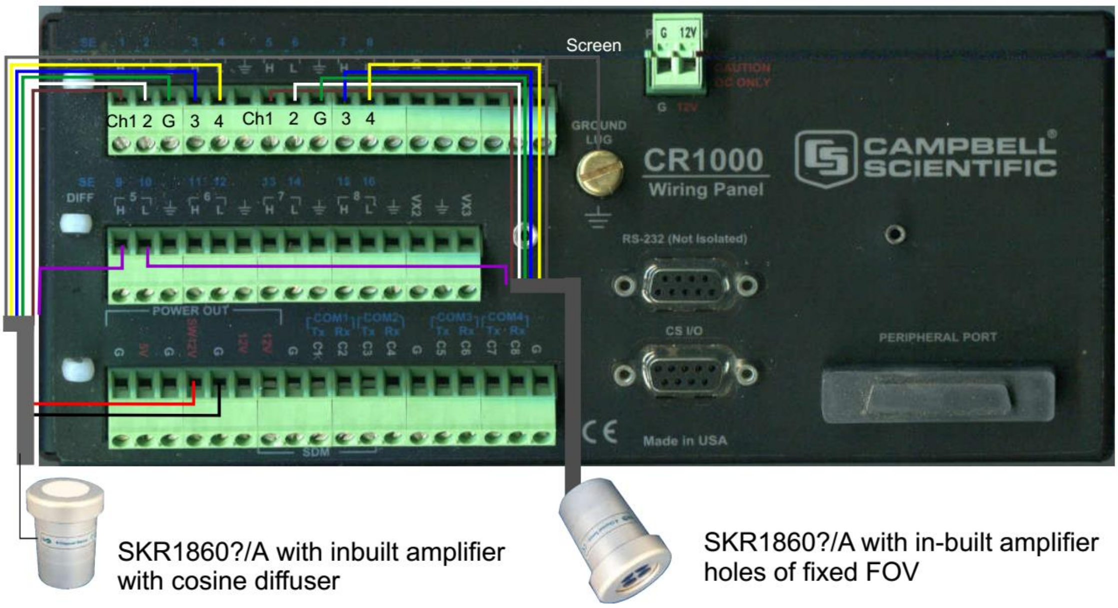
The CR1000 data logger supports the on-board scripting language CRBasic for data processing and analysis. It simultaneously carries out measurements, stores data, controls other devices, and communicates via TCP/IP, email, FTP, or a web server. Refer to the CR1000 data logger manual for further information.

Connecting Skye sensors to CR1000 data logger

Below is an example of connecting SKR-1860 current output sensors (without amplifier) to a Campbell CR1000 data logger. For SKR-1860A sensors with inbuilt amplifier and thus voltage output, no resistor is needed. However, there are two extra wires that need to be connected to POWER OUT SW12V and G. For a SWIR band sensor, there is an inbuilt temperature sensor with mV output, and thus a channel is needed to measure temperature simultaneously with the SWIR band.



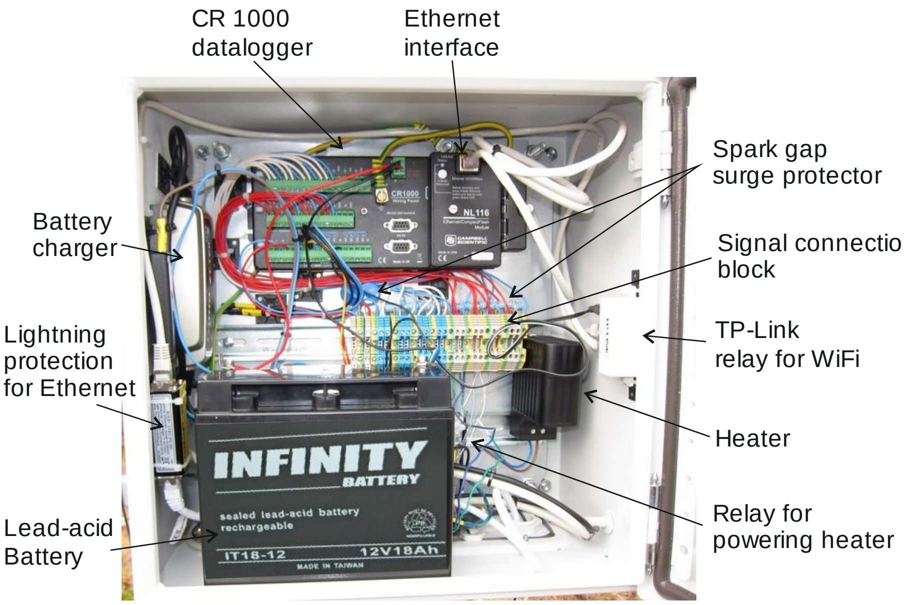
Note: Color of wires in the sketch figure is for illustration purpose, may not be the same color as used in actual sensor



Note: Example of SWIR sensors with temperature channel. Color of wires in the sketch figure is for illustration purpose, may not be the same color as used in actual sensor

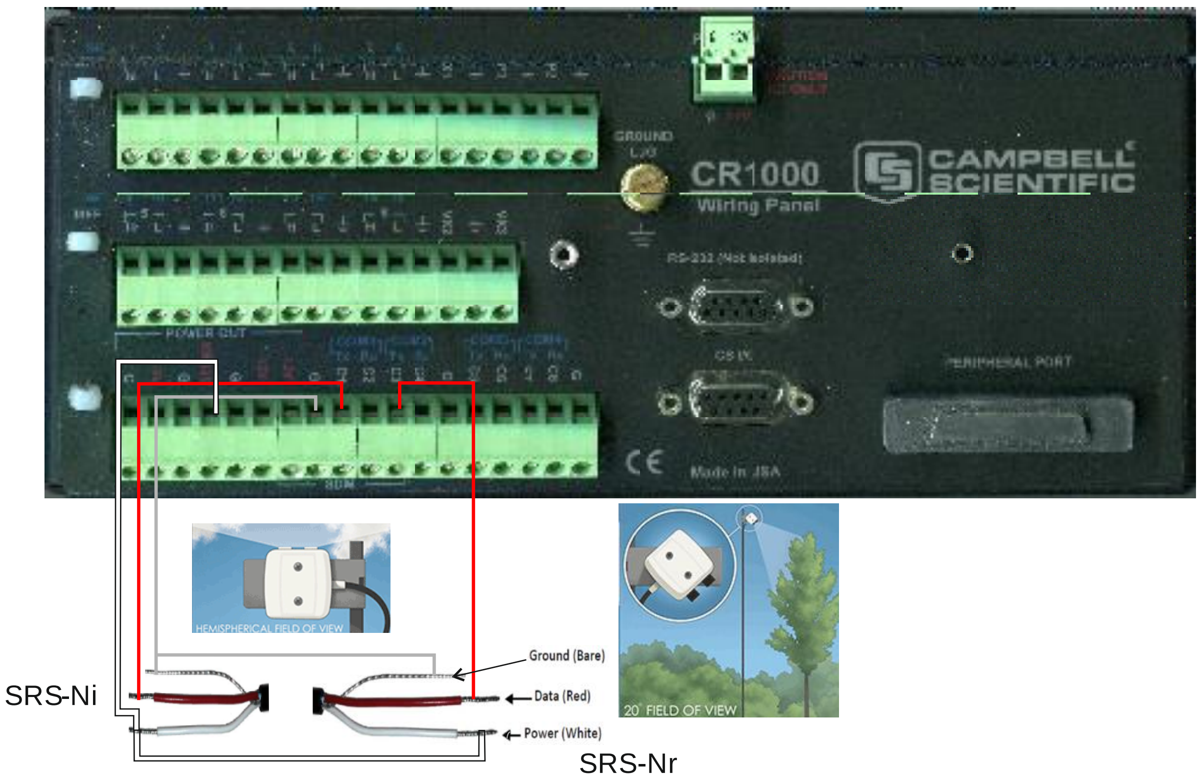
A lead-acid battery is used to keep measurements continuing for about 2 to 3 days when mains power is down.

An example of datalogger enclosure connections



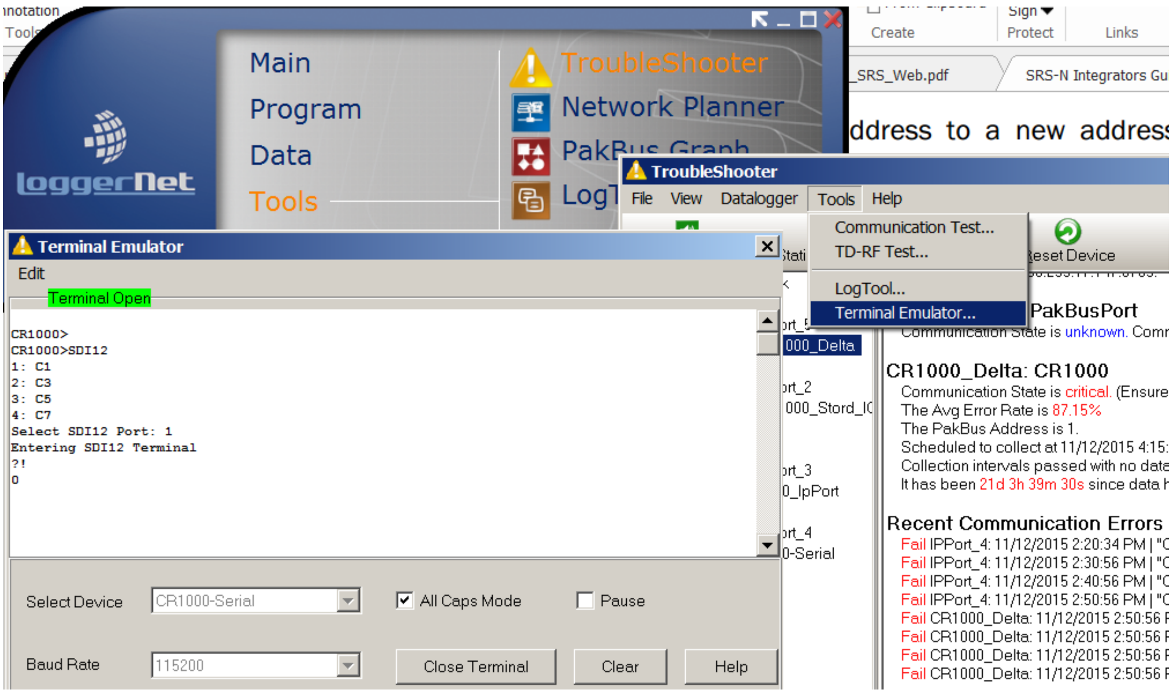
Connecting Decagon SRS sensors to CR1000 data logger

C terminals of a CR1000 data logger are used to connect SDI-12 sensors (data wire). The sensor power wire is connected to SW12V (we do not suggest using continuous 12V in order to save power and for other benefits), and ground wire to G (any G terminal will be OK since all G's are connected together. Do NOT connect to the signal ground ⏚, since it is separated from the power ground G).



One or many Decagon SRS sensors can be connected to one Control (C) terminal. The Control terminals on CR1000 are digital output channels, which send out only two states, 0V or 5V. If all the sensors are connected to ONE C terminal of a CR1000 data logger, each sensor should have a unique address. Letter a to z, A to Z and 0 to 9 can be used as SDI-sensor address, and in total 62 unique addresses can be used for one C terminal; i.e. a C terminal can connect up to 62 sensors.
The default Decagon sensor address is 0 for all SRS sensors from factory. The SDI-12 sensor address can be modified using the Campbell LoggerNet terminal simulator.

1. Press Enter until the CR1000 responds with the prompt CR1000>.
2. Type "SDI12" next to the prompt. Note: the data logger will exit this mode relatively quickly so if the logger does not respond, repeat steps 1 and 2 again.
3. The data logger will respond Port C1 C3C5 C7 and prompt Select SDI Port.
4. Enter the control port that SRS sensor is plugged in to.
5. Query sensor address by typing: ?!
6. Change address e.g. 0A1! means change address to 1 from 0.
7. Other commands, like getting sensor information: 0I!



Example CRBasic scripts for the CR1000 data logger are given in Appendix Example CRBasis scripts 10.3.

Automatic data downloading using networked CR1000 datalogger
If CR1000 is equipped with a NL-115 or NL-120 Ethernet interface, the data can be downloaded regularly via internet connection.

An example CR1000 program for push IP address and data to ftp server using dynamic IP mobile broadband is shown in Appendix 10.3.

5.2 Decagon data logger EM50

For Decagon sensors, the Decagon EM50 data logger can be used. It is very easy to connect, just to plug the 3.5 mm stereo plug connector into the data logger. Five sensors can be connected to one logger. The EM50 data logger is powered by 5 AA alkaline or lithium batteries, typically good for 8 - 12 months. The logger has 1 M memory and can store 36000 scans on all five ports. The Decagon data logger is the first choice when using Decagon SRS series sensors and there is no mains power supply.

A Decagon EM50 data logger is an interface between the Decagon intelligent sensor and a computer. It receives/ stores digital signal from the sensor. The analogue-to- digital signal conversion is carried out by the Decagon sensor.

A *USB to 3.5mm Male Stereo Microphone Cable* is used to connect the data logger to a computer. Keep the cable in a safe place since such cable types are rare on the market.
The software ECH2O System is used to setup measurement parameters. There may be problems if the port number of the serial port has been changed.
The minimum sampling interval of an EM50 data logger is 1 minute, thus it is not optimal to use such a data logger for sensor calibration purposes.

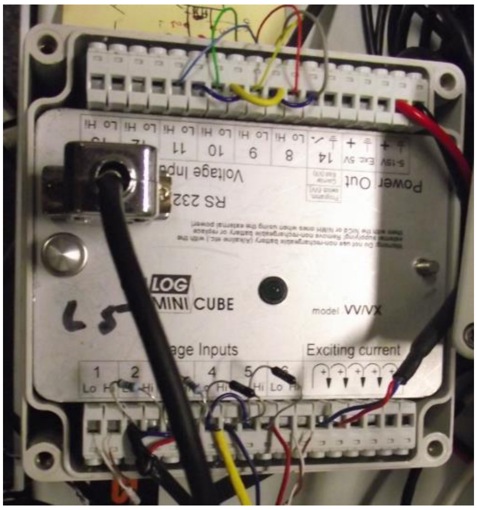
Decagon EM50 data logger usage

1. A driver for the USB Cable Adapter (UCA) must be installed on a device (computer or laptop) before it is used to communicate with the EM50 logger. If this is not done, the appropriate communication port containing “Decagon UCA” will not be available. The driver installer can be found on the ECH2O System Software CD or from Decagon's website at http://www.decagon.com/support/decagon-usb-cable-adapter-driver/
2. It is important to have the correct date and local time on a computer that is being used for configuration. When moving across time zones, make sure to update the time zone on your device (if this is not automatically done). Do not use summer time light-saving adjustment.
3. When replacing batteries, it is essential to immediately connect to the data logger directly via the ECH2O Utility to synchronize the time and avoid an incorrect date /time stamp on the measurements are being stored.
4. Small measurement intervals consume data logger battery and memory fast. As the Em50 loggers collect data every minute for most sensor types and average and store that data. The measurement interval chosen should consider these facts and the resolution required for the data to be collected.
5. The Em50 stores “raw” data for each sensor. The stored values are not in millivolt units. The raw value has to be converted to a meaningful measurement depending on the sensor type and calibration.
6. Firmware updates to data loggers erase data. So, make sure to download and backup data first. When re-deploying data loggers for a new study or if changes are made on sensor configuration at any point, download and erase old data and start new.
7. The Em50 stores 36,864 data scans. When the logger has filled its data memory, it begins overwriting the oldest data in the memory.
8. Plug the sensor’s stereo jack firmly and all the way into the Em50 sensor ports. A slightly pulled out sensor does not take any measurement.
9. In field installations, make sure to install the Em50 upright to avoid water entering the data loggers’ enclosure. Check the thin rubber seal around the Em50 casing to ensure that it is firmly seated and not crimped.

Other sensors with analogue output, like Skye sensors cannot be connected to Decagon data logger. In that case, data loggers that can measure low voltage (μV resolution) should be used, such as the Campbell CR1000 data logger. Refer to the Em50 data logger manual for further information.

5.3 EMS Brno data loggers

EMS Brno manufactures dataloggers that can be used with Skye sensors. One model is the MiniCube datalogger, however a MiniCube data logger cannot support a SDI-12 (Decagon) sensor. Connecting a current output Skye SKR-1860 sensor to MiniCube is straightforward. Connect the sensor signal wire of a channel to the positive terminal (Hi) of a channel on the datalogger, and the sensor ground to the negative terminal (Lo). All the negative connectors should be short connected together using a piece of wire. The resistors are needed for current output sensors. For voltage output sensors, no resistor is needed, but voltage excitation connection is needed. The Minicube is today replaced by the EdgeBox V12, which is a battery operated equipment for automatic data recording in both field and laboratory applications. The logger is powered by two alkaline AA 1.5 V batteries although an external power supply can be used, too. EMS loggers are lower cost than Campbell CR-1000, but less versatile.

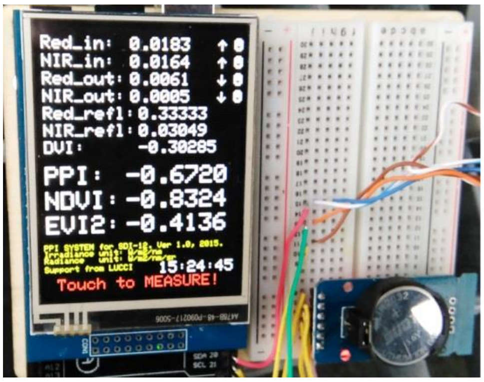


5.4 Arduino for Decagon sensors

A cheap solution (< 2 kSEK) for connecting a Decagon SRS sensor is to use an Arduino board, an open source hardware. An example of home-made version SDI-12 datalogger using Arduino Mega2560, 3.2’’ TFT touch screen LGDP4535, and a real time clock DS3232 is shown below. It has an inbuilt SD card slot that can store up to several years of data measured every 10 minutes.

If an Arduino is to be used for voltage measurement (μV level), a low noise ADC with PGA is also needed.

Contact Hongxiao Jin (geotester@hotmail.com) or www.arduino.org for further information.



6. Lightning and surge protection

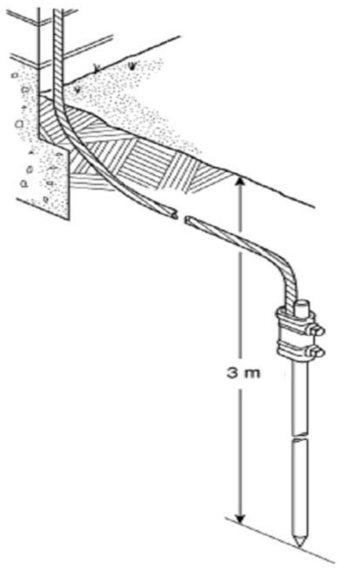
A spectral measurement tower is a tall, pointed structure, thereby prone to lightning strikes. Lightning protection is a must for any structure elevated above the surroundings and it must be prevented as far as possible.

Do NOT work at the tower site in thunderstorm weather!

There are generally two types of lightning strikes, direct and indirect. To protect a tower from direct strikes, lightning conductors are installed on top of the tower and a low resistance cable is used to properly connect the lightning conductor with a ground rod. Metallic guy wires should also be grounded at the guy anchor points. Bolting, clamping, brazing, or welding can be used for the connection between lightning cable and ground rod. Only using low-temperature soldering connection is not useful since a large lightning current will melt the soldering connection. Unfortunately, even with a proper lightning conductor and ground rod, if the lightning directly hits the tower or sensors, there is very little chance that the lightning protection system can save these facilities.

For indirect nearby strikes, induction currents can cause damages to measurement equipment. Surge protectors can be used to prevent damages to dataloggers and mains power system. However the surge protectors cannot prevent sensors from damages by inductive currents.

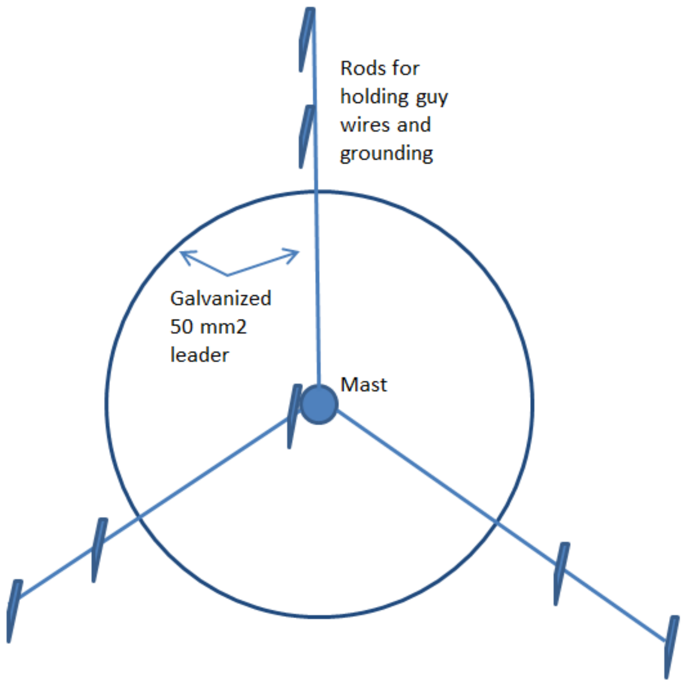
6.1 Ground wiring and rods



According to the Standard for the Installation of Lightning Protection Systems (NFPA 780), ground rods shall be not less than 12.7 mm in diameter and 2.4 m long, and shall extend vertically not less than 3 m into wet earth and below the frozen line.

For a high spectral tower with metal anchors, it is recommended to lay out a conductive 50 mm^2 metal wire forming a ring around the tower. If possible it should be placed 0.3 m below the ground. Ground rods and the tower are connected to the ring, forming a common ground (equipotential) (see the following figure). Campbell Scientific suggests that all components of the measurement system (dataloggers, sensors, external power supplies, mounts, housing, etc.) should be connected to ONE common earth ground. This is also a good practice in order to reduce digital signal sampling noise. Mericon, a company specialized on lightning-protection have advised us to use several ground rods to ensure maximum connection with ground and the rods should be close enough to avoid the build-up of electrical potentials among rods. The wire connected to the grounding rod should be

12 AWG wire (cross section $3.31mm^2$) or larger. Long mains lines should be grounded at both ends.



Layout of grounding wire around a tower (vertical view). The metal tower is connected to a ground leader encircling the site and connecting all guy rods that also serve as grounding points.

For further information see web document: "Notes on lightning protection" by Ford Cropley.

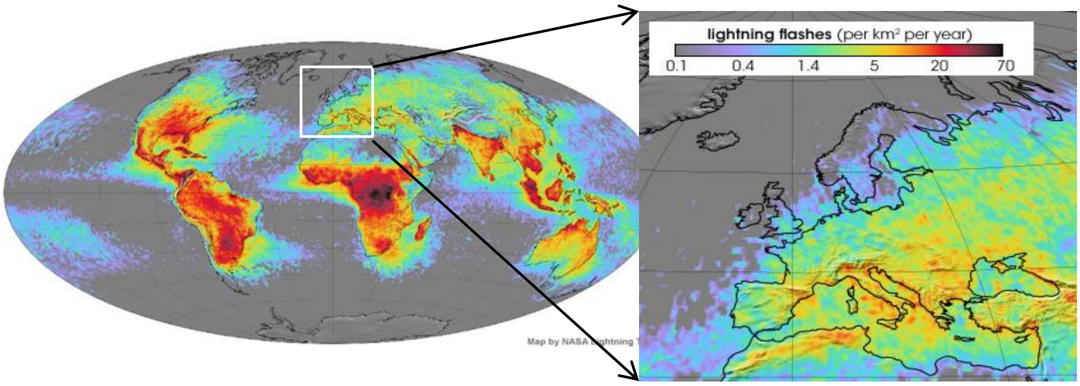
6.2 Surge protection

Efforts should be taken to protect the installation from electrical surges. An electrical surge within the measurement system—power cable, sensor signal cable, Ethernet cable—may be induced by nearby lightning, an indirect lightning strike, or by the sudden fluctuation of mains power. Gas discharge tubes (GDT) can be used to connect between signal wires and the ground. A GDT can responses to high voltage impact within microseconds, acting as a short pass for large current surge between the signal wires and the ground. By discharging the excessive current surge to ground, the measurement facilities are saved from indirect hit. There are special devices in the market to countermeasure the induced surge in mains power line and Ethernet cables. See Appendix **Error! Reference source not found.** for urther information.

How frequent are lightning strikes in Sweden?

http://geology.com/articles/lightning-map.shtml

NASA's Lightning Imaging Sensor on the Tropical Rainfall Measuring Mission satellite collected data and showed the average yearly counts of lightning flashes per square kilometre between 1995 and 2002. Compared with southern European countries in the Mediterranean region, Sweden has few lightning strikes.

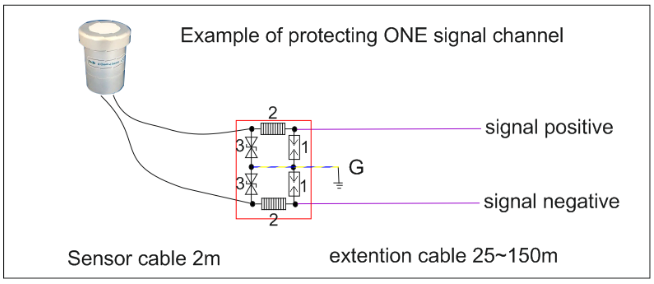


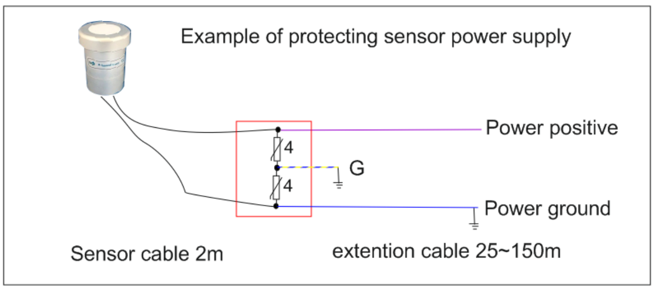
A notable historical lightning strike in Sweden is that on July 12 1970, when the central mast (250m high) of the Orlunda radio transmitter in central Sweden collapsed after a lightning strike that destroyed its foundation insulator.

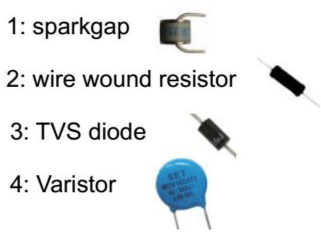
6.3 Surge protection elements and circuit

At the sensor side

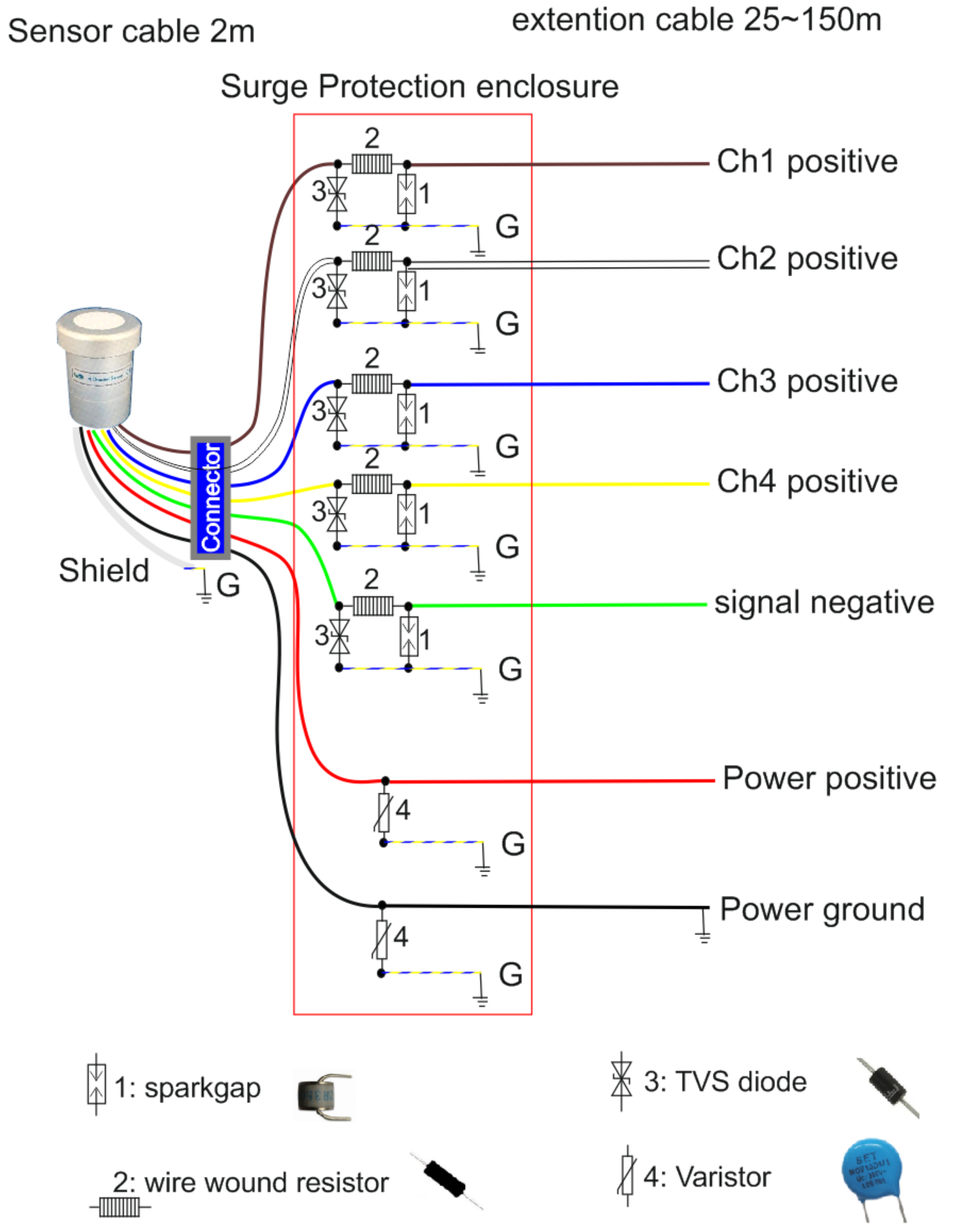
If the sensor extension cable is longer than 30m, extra surge protection device is connected to the sensor cable, so as to protect sensor from lightning surge damage. This is particularly suggested for expensive sensors, like Skye sensor. Here is the circuit of surge protection at the sensor side.







Example of a 4-channel Skye sensor

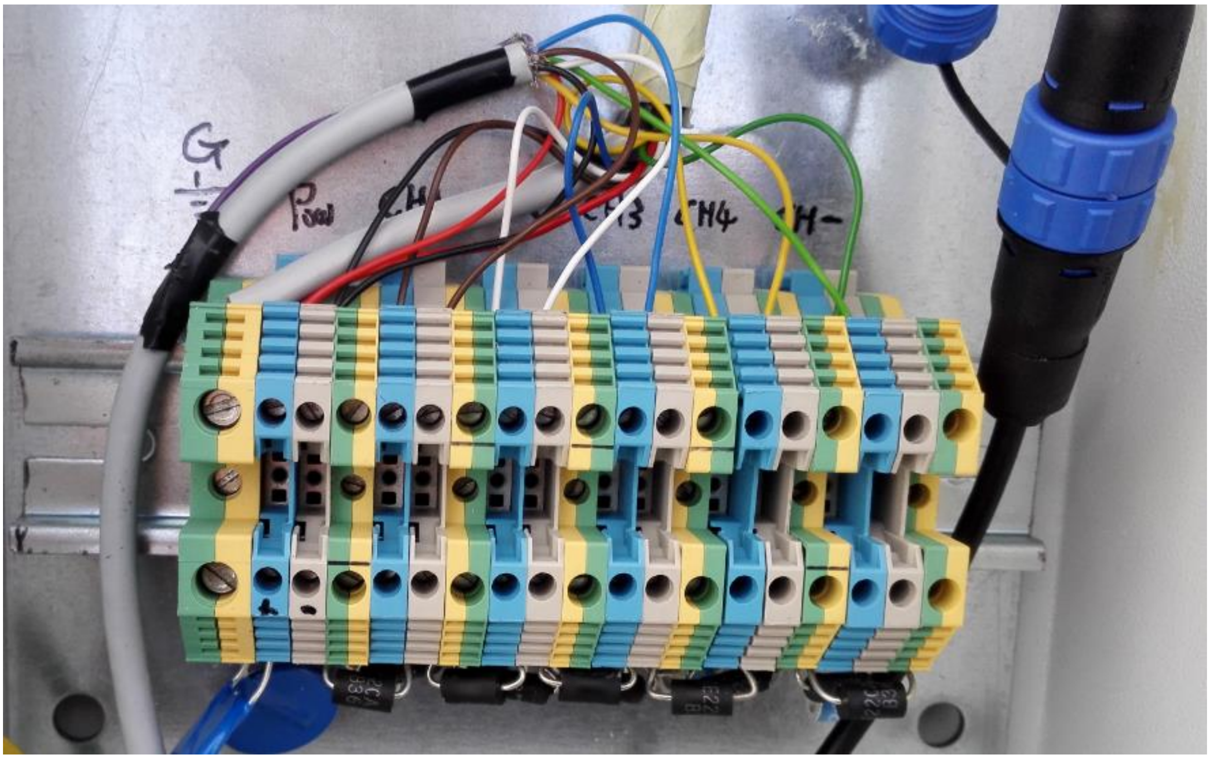


Note: for sensors with an extra channel for temperature measurement, the surge protection should be done in the same way as CH1 (or 2,3,4) positive wire.

The following shows an example picture of the inside of home made surge protection box. Note, for Skye sensor with SWIR band, 5 of such connection channels are needed, and the 5th is used for temperature signal channel.

Notice the cable screen, only ONE end is connected to ground. Since the cable screen at logger side is connected to ground already, the screen end at the surge box sider should leave open.

Surge protection boxes on top of 150m tower at Hyltemossa. The one box is for the upward-looking sensor of 150m high, the other is for the downward-looking sensor at 100m high. The logger box is on the ground at the tower base.

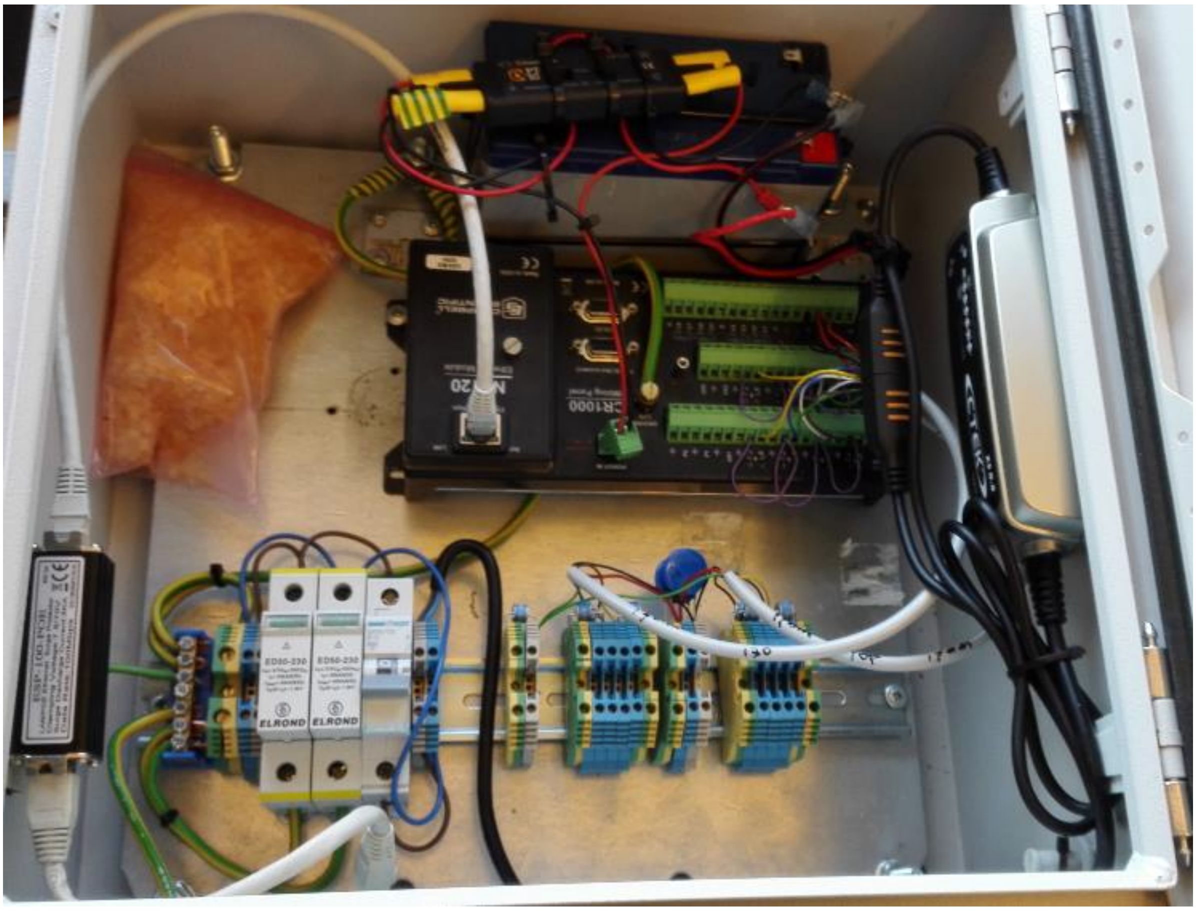


Details of surge protection box for sensors.

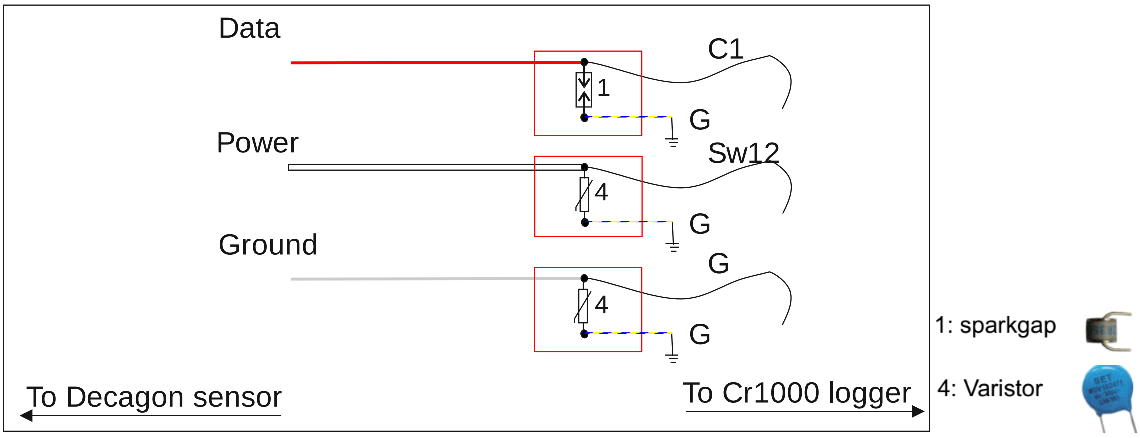
At the logger side

CR1000 datalogger and multiplexer have inbuilt spark gaps already to protect each channel from surge damage. Extra protection can also be added for further protection.

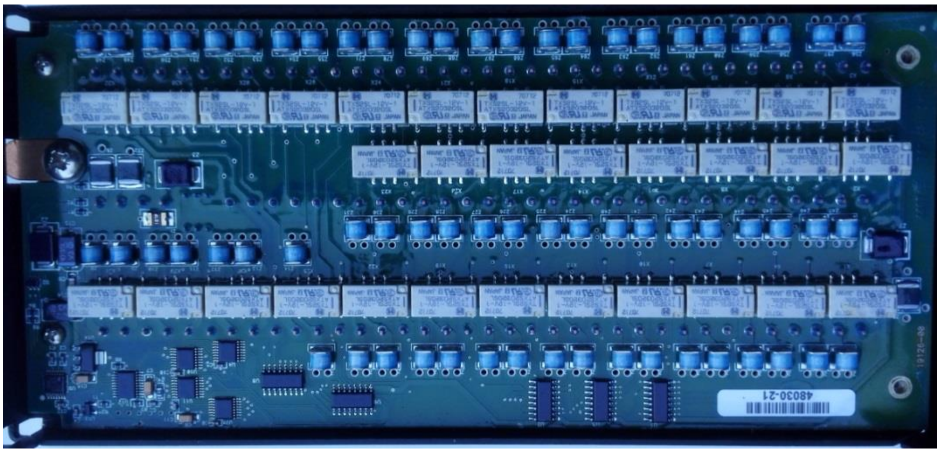
The following shows an example picture of such sparkgaps and varistor connections insde of enclosure box for data logger.



Here is the circuit of surge protection at the data logger side if Decagon sensors are used.



CR1000 and its multiplexer have surge protection elements already, like this



7. Data management

The raw spectral signals are averaged in the data logger into 10-minute intervals. To convert these into useful information for research the following steps are undertaken:

- Export from the data loggers into a generic format or database system for backup, storage and further data processing.
- Quality control. Visual check and automated range check to identify outliers and erroneous data.
- Application of calibration coefficients to obtain physical units.
- Computation of spectral reflectance by dividing reflected radiance bands by corresponding incoming radiance bands.
- Computation of spectral vegetation indices (see equations in Appendix).
- Computation of daytime averages by averaging all values within +- one hour from solar noon.
- Version management – for handling of quality and calibration versions.
- Metadata generation for the measurement site, instruments, data, and measurement events.
- Export to user-friendly file format.
- Dissemination of metadata and data to users.

Currently a database system with web interface for database storage, management (quality control, display, computation of vegetation indices, data export, etc.) is under development.

8. Maintenance and calibration

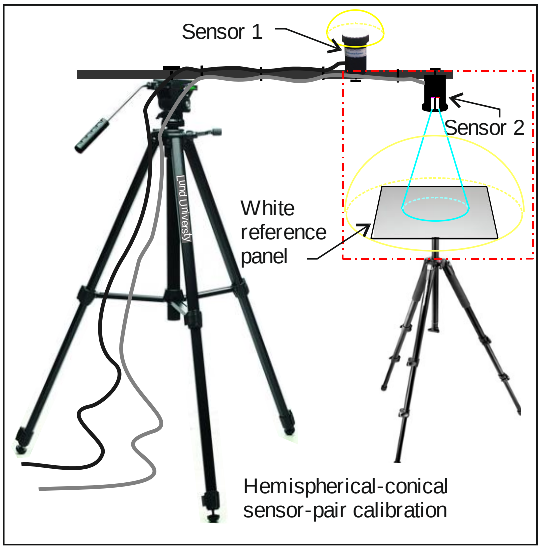
Multispectral sensor installations should be checked at regular intervals to ensure good condition of cables, masts, guy-wires and other items. There is also need for annual cleaning and calibration of the sensors to ensure reliable measurements.

In the field, sensor diffusor or glass cleaning is done using lens cleaning paper or an air brush blower. In the lab, cleaning is done by wiping the sensor surface using deionized water and neutral detergent with a clean cloth. Never clean or touch the sensor diffusor or glass with naked hands.

Calibration is the process of converting measured electronic values into useful physical units. Usually, manufacturer-provided calibration coefficients are applied to convert the sensor units into *radiance* (unit: $W \cdot m^{-2} \cdot sr^{-1}$ or quantum unit $\mu mol \cdot m^{-2} \cdot sec^{-1} \cdot sr^{-1}$) or *irradiance* (unit: $W \cdot m^{-2}$ or quantum unit $\mu mol \cdot m^{-2} \cdot sec^{-1}$) (absolute calibration). In the case of Decagon, the sensors directly report values in physical units. Irradiance and radiance from sensors measuring incoming and reflected radiation are then used for computing a *reflectance factor* (no unit). The reflectance (factor) is the required quantity as it relates to ground properties. Reflectance can also be used for computing vegetation indices, e.g. NDVI. In some cases manufacturers do not supply absolute calibration coefficients but relative calibration coefficients for directly computing NDVI from the measurements. In that case it is not possible to compute red or NIR reflectance values from the data, and the choice of vegetation indices is limited.

Manufacturers offer regular recalibration of their sensors, at a cost of about half of the sensor price. However, it should be noted that calibration differences may be caused by different factors than aging, including dirt on the sensors. Frequent enough recalibration by sending sensors to manufacturers can be costly and disruptive to the measurement program.

A useful alternative is to carry out a relative calibration between pairs of sensors in order to compute reflectance directly from the measurements. This is a cost-effective method as it can be done in the field or at a very simple facility. Tests have shown that the accuracy of this method is very good (Jin & Eklundh, 2014). We recommend cleaning and relative calibration to be carried out annually. This requires that the sensors are dismounted for the calibration process.



Simple calibration setup for relative sensor calibration. The reference panel is made of Spectralon and has near-lambertian properties. Sensors need to be connected to adjacent logger channels measuring at high frequency, and calibration coefficients are derived from a linear regression between the measurements. See Jin and Eklundh (2014) for further details.

9. References

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NFPA 780 Standard for the Installation of Lightning Protection Systems 2004 Edition, National Fire Protection Association, USA. Web page

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10. Appendix

10.1 Vegetation indices.

The following tables displays some common vegetation indices that can be computed from multispectral data.

Name	Formulation	Reference
NDVI *Normalized Difference Vegetation Index*	$NDVI = \frac{NIR - Red}{NIR + Red}$	Rouse et al. 1973
EVI *Enhanced Vegetation Index*	$EVI = 2.5 \cdot \frac{NIR - Red}{NIR + 6 \cdot Red - 7.5 \cdot Blue + 1}$	Huete et al, 2002
EVI2 *2-Bands Enhanced Vegetation Index*	$EVI2 = 2.5 \cdot \frac{NIR - Red}{NIR + 2.4 \cdot Red + 1}$	Jiang et al. 2008
PPI *Plant Phenology Index*	$PPI = -K \times \ln \frac{(NIR - red)_{\max} - (NIR - red)}{(NIR - red)_{\max} - (NIR - red)_{Soil}}$ K is a gain factor depending on others.	Jin and Eklundh, 2014
PRI *Photochemical Reflectance Index*	$PRI = \frac{R_{531} - R_{570}}{R_{531} + R_{570}}$	Gamon et al., 1992, 1997
NDWI *Normalized Difference Water Index*	$NDWI = \frac{NIR - SWIR}{NIR + SWIR}$	Gao 1996
NDSI *Normalized Difference Snow Index*	$NDSI = \frac{SWIR - Green}{SWIR + Green}$	Hall et al. 1995
RENDVI ***Red edge** Normalized Difference Vegetation Index*	$RENDVI = \frac{R_{740} - R_{704}}{R_{740} + R_{704}}$	Gitelson and Merzlyak 1994

10.2 Viewing footprint of a spectral sensor

An illustration of a typical conical viewing spectral sensor is given in the following figure. The sensor is mounted at height *H* with an oblique angle *α*. The sensor viewing beam angle (field-of-view) is *β*. The hemispherical downward looking sensor is a special case of *α* =0°, and *β* = 180°.

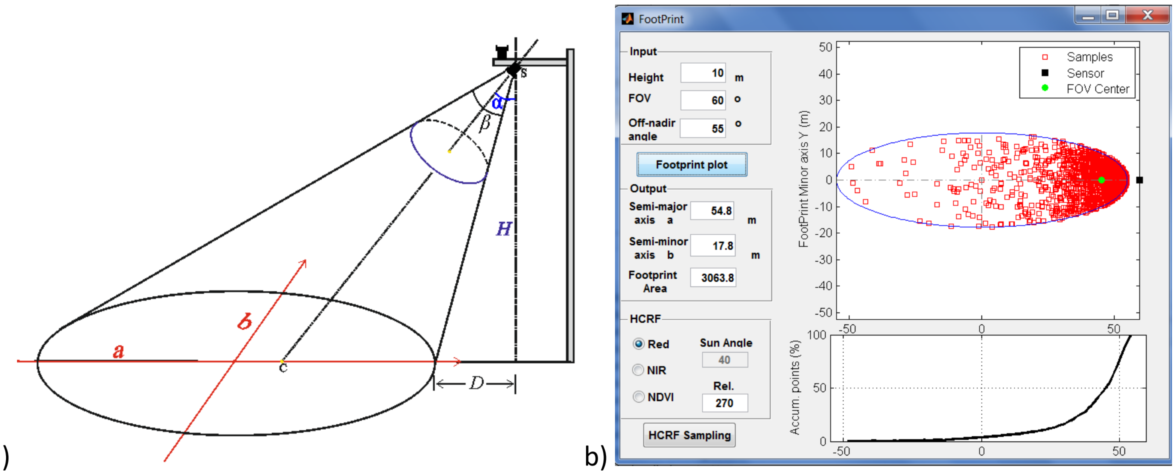
- The sensor viewing footprint ellipse:
  Semi-major axis: $a = H \cdot [\tan(\alpha + \beta/2) - \tan(\alpha - \beta/2)]/2$,

  semi-minor axis: $b = H \cdot \{[\cos(\alpha) + \sin(\alpha) \cdot l/H]^2 / \cos^2(\beta/2) - l^2/H^2 - 1\}^{1/2}$,

  where $l = H \cdot [\tan(\alpha + \beta/2) + \tan(\alpha - \beta/2)]/2$.

And the spectral sensor viewing area is πab. The distance from the closest viewing point to the mast is $D = H \cdot \tan(\alpha - \beta / 2)$.

You can obtain Matlab scripts online for the spectral footprint calculation: http://www.mathworks.com/matlabcentral/fileexchange/35503 or from http://hongxiaoj.nateko.lu.se/SpecFootprint/. An example with a 10m mast and a 60° FOV sensor with 55° off-nadir oblique angle is shown in Figure 1.



a) Illustration of a typical field spectral sampling mast. b) The spectral sensor footprint geometry and ground point contributions from the FootPrint Matlab scripts.

- For a nadir viewing sensor, the oblique angle *α*=0° and the sensor footprint is a circular area; for hemispherical nadir viewing sensor *β*= 180° and over 99% of the sensed radiant flux is from a circular area with a radius of 10 times of the sensor height *H*.

Mast and mast shadow influences on the downward looking sensor

- For hemispherical downward looking sensor, the mast influence is twofold; the sensor views both the mast and the mast shadow. The mast shadow covers an area of *d·L*; where d is the mast diameter and *L* is the shadow length within the sensor viewing footprint. Thus the fraction of shadow in the hemispherical-viewing footprint is *d/πR*, and the hemispherical footprint radius *R* is about 10 times of the mast height *H* (contributes over 99% to the sensed reflected radiant flux). So for a 2 meter mast of 15 cm diameter, the mast shadow influence is 0.16%. The shadow influence is hence minor.
- The mast influences directly by blocking part of the viewing angle $\Omega = \frac{d/l}{\sqrt{1+(l/H)^2}}$ steradian out of the total solid angle *π* steradian when hemispherically viewing a horizontal surface. The value Ω depends on the mast diameter *d*, the boom length *l*, and the mast height *H*. For the same example of a 2 meter mast of 10 cm diameter, and with a horizontal 0.5 meter boom, the fraction of blocked solid angle is 6.2%. Several other cases are given in Table 4. The actual influence on the measurements depends on the colour and gloss of the mast, whereby a glossy or bright mast will result in a positive bias on the reflected radiant flux measurement. We suggest using matt dark paint for the spectral mast. This also applies to the surface of the mast basement, fastening strings, and other adjacent items.
- For restricted-FOV sensors with oblique viewing geometry, the mast should be out of the sensor view. The shadow influence in the example in Figure 10b is 0.36% for a telescope mast with 10cm diameter, in the worst case when the shadow is along the major axis. The mast does not block the view, and the shadow influence can be considered as negligible.

How to choose between nadir and oblique viewing?

There are arguments against or in favour of vertical (nadir) vs. oblique (off-nadir) viewing angles for fixed-angle installations. The strongest argument against oblique measurements is that they are not identical to vertical measurements due to the BRDF effect, particularly if the sensor has a narrow FOV, and if the vegetation has pronounced vertical structure (like trees and bushes). To avoid off-nadir angles narrow-FOV sensors should preferentially be mounted vertically down, as long as they do not view the mast. However, for wider FOV sensors it is necessary to mount the sensor at an off-nadir angle to avoid seeing the mast or tower. Wider FOV sensors have the benefit of viewing a larger area, and this effect increases as the off-nadir angle is increased. The off-nadir angle should be chosen so that viewing the sky is avoided. There may also be deliberate reasons for viewing off-nadir, e.g. to conform with average off-nadir angles of satellite instruments, or to collect data that is more sensitive to phenological tree canopy variations by viewing the canopy rather than the ground. As for the azimuthal direction, an easterly or westerly direction conforms with the viewing azimuth of most satellite sensors, and avoids the strong variations near the solar principle plane.

10.3 Example CRBasis scripts

Decagon SRS sensor for measuring incoming and reflected radiation

```
'Wiring:
'Upward-facing, hemispherical SRS-NDVI
'White wire (power) -> SW12V
'Red wire (data) ->    C1
'Bare wire (ground) -> G

'Downward-facing, 20 degree field-stop SRS-NDVI
'White wire (power) -> SW12V
'Red wire (data) ->    C3
'Bare wire (ground) -> G
Public UpOut(3)
Public DownOut(3)
Alias UpOut(1) = UpRed
Alias DownOut(1) = DownRed
Alias UpOut(2) = UpNIR
Alias DownOut(2) = DownNIR

Alias UpOut(3) = Ind1
Alias DownOut(3) = Ind2
'Main Program
BeginProg
      Scan (5,Sec,0,0)

'Apply power to white wire of both sensors through SW-12
      PortSet (9,1)
'Delay for at least 250 mSec for sensors to enter SDI-12 mode.
      Delay (0,1,Sec)
'Query sensor for 3 SDI-12 outputs.  Default address for all Decagon
Digital sensors is 0.
      Move (UpOut(),3,NAN,1)
      Move (DownOut(),3,NAN,1)
      SDI12Recorder (UpOut(),1,0,"M!",1.0,0)
      SDI12Recorder (DownOut(),3,0,"M!",1.0,0)
      'Turn SW12V off
      PortSet (9,0)
      'Call Output Tables
```

```
        NextScan
EndProg
```

Skye sensors for measuring incoming and reflected radiation

Power is needed for sensors with inbuilt amplifier using function `SW12(1)`. Also notice the range will be small if without amplifier.

```
BeginProg

        'Main Scan
        Scan(10,Sec,1,0)
        'The Skye sensor with inbuilt op-amp need 5-15V power up for at least
        0.5 Sec
        SW12(1)
        Delay(0,500,mSec)
        'Generic Single-Ended Voltage measurements 'Dw_Ch1'
        VoltSe(Dw_Ch1,1,mV2500,1,True,0,_50Hz,1,0)
        'Generic Single-Ended Voltage measurements 'Dw_Ch2'
        VoltSe(Dw_Ch2,1,mV2500,2,True,0,_50Hz,1,0)
        'Generic Single-Ended Voltage measurements 'Dw_Ch3'
        VoltSe(Dw_Ch3,1,mV2500,3,True,0,_50Hz,1,0)
        'Generic Single-Ended Voltage measurements 'Dw_Ch4'
        VoltSe(Dw_Ch4,1,mV2500,4,True,0,_50Hz,1,0)
        'Generic Single-Ended Voltage measurements 'Up_Ch1'
        VoltSe(Up_Ch1,1,mV2500,5,True,0,_50Hz,1,0)
        'Generic Single-Ended Voltage measurements 'Up_Ch2'
        VoltSe(Up_Ch2,1,mV2500,6,True,0,_50Hz,1,0)
        'Generic Single-Ended Voltage measurements 'Up_Ch3'
        VoltSe(Up_Ch3,1,mV2500,7,True,0,_50Hz,1,0)
        'Generic Single-Ended Voltage measurements 'Up_Ch4'
        VoltSe(Up_Ch4,1,mV2500,8,True,0,_50Hz,1,0)
        SW12(0)
        CallTable DataTable
        NextScan
EndProg
```

Push IP address and data to an ftp server using dynamic IP mobile broad band service

```
'CR1000 logger example program for Delta forest Sept 29 2015 Hongxiao Jin
'new function: stop restarting Huawei modem every day, so as that the Ip
keeps unchange when the modem is on
'                    restart the modem when the sending out email failed,
which means when the modem is kicked off the mobile network
'                            or every month the first dat hour
'                   sending out email of IP when modem start or IP  changed
'2015-09-30 23:41  correct the mistake logic codes for heater control. Bad
example from CR basic
'2015-12-04 09:47  push logger IP address to ftp server. Gmail email
function not working
'                  save datatable Delta to ftp server every 24 hours.
'2015-12-06 06:51  Check on line every mid  night, instead of every 30min
of slowscan sequence, to aviod frequently restart modem
'                  push IP to ftp server only when IP changed
...

'Get Public IP
Public MyIP As String * 18, MyLastIP As String * 18
```

```
Public OnlineCheck As Boolean, PingOK As Boolean, PingMe ' for testing
online or not
Public SentOK 'ftp wrinting flag -1 sucesses, 0 fail, -2 other conditions
not meet
Public SentIPOK As Boolean,WriteIPflag As Boolean, tries 'These variables
control the ftp process
Public OpenIPFile As Long, WriteString As String * 60 'for IP address file
Public CloseStat
' for output measurement file
Public Newfilename As String *50, TStamp As String *22 'holds the
timestamped destination filename
Dim MinIntoDay

'Define constants - these are values with names that can be accessed by the
program, but cannot be changed
Const ServerIP = "130.235.98.208:5555" 'This is the address of the FTP
server that you want to send files to
Const User = "larseklundh" 'This is the user name needed to login to the
FTP server. Note fake one here in example
Const Password = "modis321" 'This is the password needed to login to the
FTP server. Note fake one here in example
Const DestPath = "Fenologi/CR1000/" 'This is the destination directory
where the FTP'ed file will be saved on the FTP server
Const IPfileName = "IP_Delta.txt"
Const SampleInterval = 10 'in minutes
Const SlowInterval = 30 'in minutes
Const SaveFTPInterval = 24 'in hours


...
  SlowSequence
  Scan (SlowInterval,Min,3,0)

  ' Test if online when first start the program (default 0 for variables)
and every midnight
  'Get minutes into current day Relay
      MinIntoDay=Public.TimeStamp(4,1)/60
      If (MinIntoDay>=0 AND MinIntoDay<60)  Then  OnlineCheck = false
      If (NOT OnlineCheck) Then ' implement online check when midnight
            PingOK = false
            tries = 0
            Do While (NOT PingOK AND tries<4) 'check if online up to
maximum 4 times
                  PingMe = PingIP("www.google.com",500) 'longger response
time need for mobile broadband
                  tries = tries + 1
                  If PingMe Then PingOK = true
            Loop
            WriteIPflag = false
            If PingOK  Then ' if online then test if IP changed or not
                  HTTPGet("http://myip.dnsdynamic.org/",MyIP,"")
                  If MyIP <> "" AND MyIP <> MyLastIP Then
                        MyLastIP = MyIP
                        WriteIPflag = true ' if IP changed then next write
to file
                  EndIf
            Else           ' if not on line then shut done modem for 5 min
then restart
                  PortSet(2,1) ' Turn OFF modem 0=on and 1=off
                  Delay(1,5,min)
                  PortSet(2,0) 'Turn ON modem
```

```
                  OnlineCheck = false  'in order to do online check at the 
next scan
            EndIf  ' end if no internet connection

            ' Push IP to ftp server
            If WriteIPflag Then
                  OpenIPFile = FileOpen ("USR:" + IPfileName,"w",-1)
                  WriteString = "IP address at Delta CR1000 datalogger: " + 
CHR(10)
                  FileWrite (OpenIPFile,WriteString,0)
                  WriteString = MyLastIP + CHR(10)
                  FileWrite (OpenIPFile,WriteString,0)
                  WriteString = "On " + Public.TimeStamp(4,0) + CHR(10) 
+CHR(10)
                  FileWrite (OpenIPFile,WriteString,0)
                  CloseStat=FileClose (OpenIPFile)
                  SentIPOK = FTPClient (ServerIP,User,Password,"USR:" + 
IPfileName,DestPath + IPfileName,9)
                  If SentIPOK Then OnlineCheck = true   ' online checked
            EndIf
      EndIf 'the online check

   'Stream data from the "Delta" table every 24 hours into a file named 
"Ex1_YYYY-MM-DD_HH-MM-SS.FS.dat"
   ' formulate a filename using time
      If SentOK <> -2 Then    ' get name when ftp sucess (-1) or failed. 
Not given new name when other conditions not meet
            TStamp = Public.TimeStamp(4,0) 'A quick way of generating a 
timestamp
            TStamp =Replace(TStamp,"-","") 'Get rid of - in date YYYY-MM-DD
            TStamp = Left (TStamp, 8 )    'only keep YYYYMMDD
            Newfilename = DestPath + "Delta/" + TStamp + ".dat"  'add file 
path and a fixed suffix
    EndIf
    SentOK = FTPClient 
(ServerIP,User,Password,"Delta",Newfilename,2,0,SaveFTPInterval,hr,1008)
  NextScan
  EndSequence

EndProg
```

10.4 Skye 4-channel light sensor SKR1860 Skye Instrument Ltd. UK

10.5 Spectral Reflectance Sensor for NDVI, Decagon Devices, Inc., US

Suppliers

Telescope mast

Manufacturer	Swedish representative
FIRECO S.r.l. ITALY	Halmstad Flygfoto
info@fireco.eu	*mats@halmstadflygfoto.se*
www.fireco.eu	http://www.halmstadflygfoto.se

Skye sensor

Contact information of the manufacturer	**Skye Instruments Ltd** United Kingdom TEL 00 44(0)1597 824811 skyemail@skyeinstruments.com www.skyeinstruments.com

MiniCube data logger

Contact information	**Manufacturer** **Environmental Measuring Systems** Contact person : Jirí Kucera www.emsbrno.cz jiri.kucera@emsbrno.cz