SpectroSense 2

SKL904

Skye Instruments Ltd.,
21 Ddole Enterprise Park,
Llandrindod Wells,
Powys LD1 6DF UK
Tel: +44 (0) 1597 824811

skyemail@skyeinstruments.com

www.skyeinstruments.com

Iss. 1.1

Skye Instruments Ltd.

Skye Instruments is based in the UK and we are very proud to be celebrating being in business since 1983. Our products are designed and built in the UK. We have a very wide product base and our sensors & systems are used for plant & crop research; micro-climate, global climate change studies; environmental monitoring and controlled environment installations.

Products include light sensors & systems, weather monitoring sensors, automatic weather stations, plant research systems, soil and water research systems.

Feel free to contact us via our e-mail, or any of the methods below:

Skye Instruments Ltd. **@SkyeInstruments** **Skye.Instruments** **SkyeInstrumentsVideo**

Skye Instruments Ltd.

Click on the icons to browse to the sites, or search for the usernames below.

Have a Smartphone? Scan this QR code to access our website for more information about your product:

Please be aware that the information in this manual was correct at time of issue, and should be 100% relevant to the accompanying product. We take great pride in our ever-evolving range of products, which means that sometimes the product may change slightly due to re-design.

If you have any queries, please do not hesitate to contact our technical team by any of the methods above.

CONTENTS

SpectroSense 2

1. INTRODUCTION

The SKL 904 SpectroSense2 4-channel display meter is designed for use with light and radiation sensors, either from Skye or other manufacturers. The SpectroSense2 is compatible with both current and voltage output light sensors, depending on the meter version chosen at time of ordering. Please see the Calibration Certificate in the separate booklet for the configuration of your meter.

Combinations of amplified and non amplified sensors, single and multi-channel sensors, Skye sensors and other manufacturers sensors can be used simultaneously with this meter, using the built-in auto-ranging feature.

The 4 channels of the SpectroSense2 can be used for 4 separate sensors, two 2-channel sensors, one 4-channel sensor or combinations of the above. The meter can store a Sensor Library of calibration data for up to 16 sensors or wavebands for multichannel sensors allowing easy interchange between sensors and factors.

The meter's 4 line display enables a 'live' readout of 4 sensors or channels simultaneously – with a [Hold] button on the keypad to freeze the display when taking measurements.

Ratios between sensor or channel pairs can also be displayed, as can a ratio of one sensor or channel reading against the other 3 channels currently being measured for example a ratio between a pyranometer against against 3 other discrete wavelengths.

The SpectroSense2 has one logging function of MJ/hr integration of total solar radiation. Its sister meter, the SpectroSense2+ has full logging features, including Log on Demand and integration of all sensor types.

As standard, SpectroSense2 is splashproof only. An alternative waterproof housing is also available on request at time of purchase. Sensor socket inputs are Binder sub-miniature which are waterproof when mated. Blanking dustcaps should be used to protect sockets that have no sensor attached.

Unit storage

We would advise that the SpectroSense2 meter be stored only when dry and not left for extended periods or stored in direct sunlight. The batteries should also be removed when stored.

2. PRINCIPLE OF OPERATION

2.1 Sensor Calibration Data

The SpectroSense2 meter will store calibration factors and information for up to 16 different sensors or waveband channels in memory in the Sensor Library.

The information for each sensor or channel consists of:

Sensor / Channel Number	00 to 15, one for each sensor or channel
Sensor Units	5 characters to describe units, e.g. umols, watts
Sensor Description	8 characters to describe the sensor or channel e.g. PAR_Quan, Skye_UVA, SWIR, 660_UP, etc.
Sensor Type	Current (C.) or Voltage (V)
Sensor Output*	Sensitivity or calibration factor e.g. +20.1234 µmols / µA
Sensor Offset	Zero offset of sensor / amplifier e.g. -0.12 watts

*NOTE – Sensor output is required to be entered in the format:
"Units per µA" or "Units per mV" as appropriate. Each sensor has its own unique calibration/ scaling factor – please see the calibration certificate that accompanied your sensor(s).

If you have purchased your SpectroSense2 meter with light sensors directly from Skye, then your sensor calibration data will have already been programmed in the meter ready for use. Full details are shown on the Calibration Certificate in the separate booklet.

If you have purchased the meter separately or for your own sensors, please enter the calibration data using **Menu Option 8 – Set Sensor Data**. Please see **Chapter 6.11** for details.

2.2 Active Sensors

The SpectroSense2 is a 4-channel meter meaning it has inputs for measuring from 4 different sensors or channels simultaneously. These can be made up of various combinations, for example 4x 1-channel sensors, 2x 2-channel sensors, 1x 4-channel sensor, etc.

SpectroSense can store the configuration details for a total of 16 sensors in the Sensor Library. As such it

is necessary to let SpectroSense know which 4 sensors are presently connected for measurement, and to which sockets they are attached. These 8 are called the 'Active Sensors' and are numbered 0 to 7. The meter sockets are labelled C1, C2, C3, or C4 for current inputs or V1, or V2, for voltage inputs. This label will vary according to which SpectroSense meter version you have purchased. Please see Appendix 5 for details of the different versions available.

To allocate Active Sensors to the appropriate input socket use the Menu Option 6 - Set Active Sensors. It is just as simple to change the Active Sensors when using the SpectroSense2 with more than 4 sensors or sensor channels. Please see Chapter 6.9 for details.

2.3 Sensor Ratios

If you wish to use the ratio features, it is useful to take time to understand how the SpectroSense2 meter displays sensor ratios before setting up Active Sensors.

2.3.1 Ratio Of Sensor Pairs

In Menu Option 1 'Ratio of Sensor Pairs' the meter display will show live measurements of the ratio between 2 sensor pairs. If you wish to view a ratio between sensor pairs, ensure they are set up as the appropriate "Active Sensors".

i.e. the ratio of Active Sensors 0 : 1 and Active Sensors 2 : 3

Example - if you wish to measure the Red / Far-Red ratio of incident solar radiation, then you should choose Active Sensor 0 as the Red channel and Active Sensor 1 as the Far-Red channel.

i.e. To measure incident light Red / Far-Red ratio
Active Sensor 0 Red channel
Active Sensor 1 Far-Red channel
The SpectroSense2 display shows ratio of Active Sensors 0 : 1 (Red : Far-Red).

NOTE: Each waveband of a Skye 2 or 4-channel sensor is calibrated individually and an absolute calibration factor is given for measurement of incident light when the cosine correcting head is fitted. However, when the sensor is used without the cosine head, for narrow angle or measuring reflected light, calibration factors are only given for one channel relative to each of the other channels, not as absolute values. So it is not valid to make a direct ratio measurements between a cosine corrected incident light measuring sensor and a narrow angle (cosine head removed) reflected light measuring sensor. This does not apply for the 2-channel SKR 110 sensor which has a fixed (non-removable) cosine corrector head.

However, it is possible to take incident and reflected light measurements with the SpectroSense2 meter for later calculating Vegetation Indices such as NDVI, please see Chapter 2.3.2 below and also Appendix 2 for full details.

The SpectroSense2+ logging version of this meter does offer display features of NDVI calculations as standard amongst its many other extra features.

2.3.2 Ratio of 4 Channels

In Menu Option 2 'Ratio of 4 channels', the meter display will show live measurements of the ratio of 3 sensors or channels relative to the first.

i.e. the ratio of Active Sensors 1 : 0, 2 : 0 and 3 : 0

Example – using a Skye 4-channel sensor with 4 different wavebands of blue, green, yellow and red light to measure the ratio of the colours in incident solar radiation (cosine corrected head fitted).

i.e. To measure incident light from a Skye 4-channel sensor
Active Sensor 0 Reflected Blue
Active Sensor 1 Reflected Green
Active Sensor 2 Reflected Yellow
Active Sensor 3 Reflected Red

The SpectroSense2 display shows ratio of Active Sensors 1 : 0 (green : blue) , 2 : 0 (yellow : blue) and 3 : 0 red : blue).

NOTE: Each waveband of a Skye 2 or 4-channel sensor is calibrated individually and an absolute calibration factor is given for measurement of incident light when the cosine correcting head is fitted. However, when the sensor is used without the cosine head, for narrow angle or reflected measurements, calibration factors are only given for one channel relative to each of the other channels, not as absolute values. So it is not valid to make a direct ratio measurements between a cosine corrected incident light measuring sensor and a narrow angle (cosine head removed) reflected light measuring sensor.

However, if the *RELATIVE* sensitivities between channels (with the cosine head removed) are each entered in the meter's Sensor Library as additional 'sensors', then it is perfectly valid to measure the ratio between these reflected channels.

Example – using a Skye 4-channel sensor with 4 different wavebands of blue, green, yellow and red light to measure the ratio of the colours of reflected light (cosine corrected head not fitted). Use Sensor Numbers from the sensor Library which contain only the Relative Calibration Factors between channels entered as Sensor Output.

i.e. To measure reflected light from a Skye 4-channel sensor
Active Sensor 0 Relative Blue
Active Sensor 1 Relative Green
Active Sensor 2 Relative Yellow
Active Sensor 3 Relative Red

The SpectroSense2 display shows ratio of Active Sensors 1 : 0 (green : blue) , 2 : 0 (yellow : blue) and 3 : 0 red : blue).

3. KEYPAD AND DISPLAY

The SpectroSense2 meter has a 4 line, 20 character alphanumeric liquid crystal display, plus an 8 button waterproof membrane keypad with audible keypress.

This meter includes auto-ranging functions and is designed to measure light levels from full sunlight very low light, even moonlight. The last significant digits of the display will constantly be changing because if this high sensitivity, so it is advisable to use the [HOLD] button on the keypad to freeze the display to take a measurement, or note down 3 or 4 measurements and take an average. Ensure to quote sensible significant figures.

The fluctuations of the last significant digits on the display may be more noticeable at low light levels or high scaling factors, indoors and under artificial light sources, also when using long cables on light sensors. To minimise these fluctuations, try to avoid movement of the meter and sensor cables whenever possible by placing on a solid surface and leaving to settle for a moment without disturbance.

In the display modes of Menu options 0 to 3, the meter display is refreshed every second and the measurement shown is an average of the previous 2 seconds. Hence it may be noticeable when moving from a high light level to a low light level area that the display appears slow to change due to this 2 second averaging feature. Under natural sunlight conditions it is advantageous to take measurements in this way to even out rapidly fluctuating light levels. At all times, wait 3 to 4s at a sampling location for the reading to stabilise before storing. Keypad buttons are described below:

ON Switches on power to the meter.

OFF Switches off power to the meter

ESCAPE Escapes from any mode or menu without changes
Escape will also return to start or top of the Main Menu (Option 0)

NEXT Proceeds to next menu option, moves cursor to the next sensor number, next letter, choice etc

ENTER Chooses menu option or confirms entries

HOLD Active in Menu Options 0, 1 and 2 only. Freezes the display for easy viewing. Repeated keypress toggles the freeze display on and off

UP Scrolls up through menu options
Increases number or letter when editing data entries

DOWN Scrolls down through menu options
Decreases number or letter when editing data entries

The menu screens shown on the meter's display are described in detail in Appendix 1 and Chapter 6.

4. POWER

The SpectroSense2 meter is powered by a 9V PP3 battery, fitted into thecompartment at the rear of its case.

Take care to insert the battery in the correct orientation. However no damage to the meter will occur if the battery in inserted incorrectly by accident.

The expected battery life of a good quality alkaline cell, e.g. Duracell or Procell is approximately 40-50 hours of continuous use at 20°C. Longer lifetime is possible with different use, e.g. in MJ/hr integration mode battery life may be up to 300 hours. Rechargeable batteries may be used if preferred, but these will usually require recharging at more frequent intervals.

Menu Option "13 – Test the Battery" shows a display of actual battery voltage plus a statement of battery 'health', such as 9 volts "good", 7.5 volts "medium" or 6 volts "low". When the battery voltage shows approximately 5.9 volts, the battery health statement will also warn the user that this level is too low to make accurate measurements.

The SpectroSense2 has an 'Auto Off' feature in Menu Option 11 where the meter will automatically switch itself off if no key presses are detected for a set period of time. The user may choose from time intervals of 15 seconds, 5, 10, 15 or 30 minutes, 1, 2 or 4 hours, or choose to disable this feature.

5. SPECTROSENSE 2 MENU

5.1 Menu Overview

MAIN MENU ▲▼ scroll
[Enter] to select...
0 - Display 4 Sensors
1 - Ratio sensr pairs
2 - Ratio 4 channels
3 - MJhr-1 integratn
4 - Test the battery
5 - View Active Snsrs
6 - Set Active Sensrs
7 - View Sensor Data
8 - Set Sensor Data
9 - Display Settings
10 - Set the units ID
11 - Set AutoOff time
12 - Set the Clock...
13 - Display Version
14 -
15 - **********

The SpectroSense 2 menu structure is shown above, as seen on the meter's display. Each menu item and its function is described fully in the following sections.

5.2 Switch on and Welcome Screen

When the SpectroSense2 meter is first switched on, a Welcome Message appears showing the meter's firmware version and its Identifier or ID string.

After showing the Welcome Message for 3 seconds, the screen changes to either the Main Menu, or it gives the user a 10 second option to resume operation in the last used function. If [Enter] is not pressed within this 10 second option, then the Main menu is displayed as usual.

5.3 Menu Option 0 – Display 4 sensors

This menu option displays live readings from the 4 sensors or channels which are currently set as Active Sensors (see Chapter 5. 9).

Each of the 4 line display shows the Sensor Number, live reading and units of measurement. The last significant digits of the display may be constantly changing because of the high sensitivity of the SpectroSense2 meter, so it is advisable to use the [HOLD] button on the keypad to freeze the display to take a measurement.

5.4 Menu Option 1 - Ratio of Sensor Pairs

This menu option measures the 4 sensors or channels which are currently set as Active Sensors (see Chapter 5.9), and displays the live readings as ratios between 2 sensor pairs.

i.e. the ratio of Active Sensors 0 : 1 and Active Sensors 2 : 3

Please see Chapter 2.3 for examples of use of this feature.

The last significant digits of the display may be constantly changing because of the high sensitivity of the SpectroSense 2 meter, so it is advisable to use the [HOLD] button on the keypad to freeze the display to take a measurement.

5.5 Menu Option 2 - Ratio of 4 Channels

This menu option measures the 4 sensors or channels which are currently set as Active Sensors (see Chapter 6.9), and displays the live readings as the ratios of 3 sensors or channels relative to the first sensor or channel.

i.e. the ratio of Active Sensors 1 : 0, 2 : 0 and 3 : 0

Please see Chapter 2.3 for examples of use of this feature.

The last significant digits of the display may be constantly changing because of the high sensitivity of the SpectroSense2 meter, so it is advisable to use the [HOLD] button on the keypad to freeze the display to take a measurement.

5.6 Menu Option 3 – MJ.hr-1 integration

This menu option displays an accumulative integration of total solar radiation in MegaJoules per hour (MJ/hr or $MJ.hr^{-1}$). This function is only valid for sensors calibrated in Watts/m^2, e.g. pyranometers.

MJ/day (or MJ/24hr) is a value of total solar radiation reaching the Earth's surface in a 24 hour period and is useful for monitoring plant growth and photosynthesis rates.

The SpectroSense 2 display shows the start time and date of the integration measurement, total MJ value, plus the number of hours elapsed in steps of 0.01 hour (or 36 seconds). When the period of

measurement is finished, please make a note of the data on screen as this meter does not store the values.

NOTE – if the [Escape] button is pressed twice to leave this menu, all integration data is lost, so must be noted before returning to Main Menu.

The SpectroSense 2+ meter version has full data storage and logging modes for this feature.

5.7 Menu Option 4 – Test the Battery

This menu option shows a display of actual battery voltage plus a statement of battery 'health', such as good, medium or low. See Chapter 4 for more information.

5.8 Menu Option 5 – View Active Sensors

Menu Option 5 allows the user to view a summary of the Sensor Numbers, Sensor Description and Input socket current set as the Active Sensors.

To edit any Active Sensor data please use Menu Option 6 – Set Active Sensors.

5.9 Menu Option 6 – Set Active Sensors

Before setting any Active sensors using this menu option, it is advisable to ensure that your sensor calibration data has been entered into the meter's Sensor Library using Menu Option 8 – Set Sensor Data. See Chapter 5.11 for details.

If you have more than 4 sensors or channels in your Sensor Library, then you will need to choose which ones to make 'Active'. A maximum of 4 sensors can be Active at any one time.

If you have less than 4 sensors connected, then you may choose to 'switch off' some Active Sensor channels, so that the display is less cluttered and easier to read.

Each Active Sensor must be allocated to an input socket. The meter sockets are labelled C1, C2, C3 or C4 for current inputs or V1 or V2 for voltage inputs. This label will vary according to which SpectroSense 2 meter version you have purchased. Match the Sensor Number and Sensor Description to the socket you have connected the sensor to.

Edit each Active Sensor 0 to 3 in turn. Choose a Sensor Number from the Sensor Library (00 to 15) to allocate to each Active Sensor, or choose or Sensor Number '_ _' for no sensor connected and to switch an Active Sensor channel off.

For the chosen Sensor Number the Sensor Description and its units of measurement will be displayed as a reminder whether it is a current or voltage output sensor. Then choose an input socket (i/p channel) to use e.g. C1 or V1 as appropriate. Please see Chapter 2.3 for explanations and examples of choosing Active sensors for ratio measurements.

5.10 Menu Option 7 – View Sensor Data

Menu Option 7 allows the user to view a summary of all data stored in the Sensor Library. Including Sensor Numbers, Sensor Description, Sensor Output, Units and Offset.

To edit any sensor data please use Menu Option 8 – Set Sensor Data.

5.11 Menu Option 8 – Set Sensor Data

In order to view accurate, calibrated measurements from light sensors, the SpectroSense2 meter must be configured with the sensor's calibration data. This meter can store a Sensor Library of data for up to 16 sensors in total, for easy interchange between Active Sensors.

Menu Option 8 leads the user through a step by step process of entering the Sensor Library Number (00 to 15), Sensor Description, Sensor Output, Units and Offset.

Use the [NEXT] and ▲ ▼ keys on the meter's keypad to move the cursor, scroll through numbers 0 to 9 plus decimal place, and upper and lower case letters. [ENTER] confirms.

5.12 Menu Option 9 – Display Settings

Menu Option 9 allows the user to view a summary of the SpectroSense 2 meter settings. Includes the meter identifier or ID, Auto Off time set, date and time.

5.13 Menu Option 10 – Set the Units ID

Menu Option 10 allows the user enter a unique meter identifier or ID for each SpectroSense 2 meter. As default this ID is factory set to include the meter's serial number.

Use the [NEXT] and ▲ ▼ keys on the meter's keypad to move the cursor, scroll through numbers 0 to 9 plus decimal place, and upper and lower case letters. [ENTER] confirms.

5.14 Menu Option 11 – Set the Auto-off Time

The SpectroSense2 meter has an 'Auto Off' feature where the meter will automatically switch itself off if no key presses are detected for a set period of time. In Menu Option 11 the user may choose from time intervals of 15 seconds, 5, 10, 15 or 30 minutes, 1, 2 or 4 hours, or choose to disable this feature.

5.15 Menu Option 12 – Set the Clock

The SpectroSense2 meter has real time clock which it uses in the MJ/hr integration function, Menu Option 3. Use the [NEXT] and ▲ ▼ keys on the meter's keypad to move the cursor, scroll through numbers 0 to 9 plus decimal place, and upper and lower case letters. [ENTER] confirms.

The format for the clock entry is hh:mm:ss (for hours, minutes and seconds), DD.MM.YY (for day, month and year) and the last digit d is for day of the week. This last digit is for use in later versions and it's setting not used and so not important on this SpectroSense 2 meter.

5.16 Menu Option 13 – Display version

Menu Option 13 allows the user to view the SpectroSense2 meter firmware version. Please quote this version number to Skye if you have any questions about your meter. The screen also includes the meter identifier or ID, which is also useful if it still contains the meter's serial number.

6. SENSOR CONNECTION

SpectroSense2 sensor socket inputs are Binder sub-miniature type. To connect a light sensor align the locating pin, push home and screw up gently – finger tight is sufficient as these connectors are waterproof and contain a rubber O ring seal.

There are several different types of socket inputs on the SpectroSense2 meter, although not all types may be fitted to your model. Combinations include 1, 2 or 4-channel current inputs and 1-channel voltage inputs.

6.1 WIRING DETAILS

6.1.1 1-Channel Current Inputs

These socket inputs are 5 pin female types and labelled C1, C2, C3 or C4

PIN NUMBER	FUNCTION
Pin 1	Not connected
Pin 2	Not connected
Pin 3	Not connected
Pin 4	Negative current input
Pin 5	Ground and cable screen

6.1.2 2-Channel Current Inputs

These socket inputs are 5 pin female types and labelled C1/C3, or C2/C4

PIN NUMBER	FUNCTION
Pin 1	Not connected
Pin 2	Not connected
Pin 3	Channel 2 negative current input
Pin 4	Channel 1 negative current input
Pin 5	Ground and cable screen

6.1.3 4-Channel Current Inputs

These socket inputs are 5 pin male types and labelled C1/C2/C3/C4

PIN NUMBER	FUNCTION
Pin 1	Channel 1 negative current input
Pin 2	Channel 2 negative current input
Pin 3	Channel 3 negative current input
Pin 4	Channel 4 negative current input
Pin 5	Ground and cable screen

6.1.4 1-Channel Voltage Inputs

These socket inputs are 5 pin female types and labelled V1, or V2

PIN NUMBER	FUNCTION
Pin 1	Positive 5V power supply to sensor
Pin 2	Not connected
Pin 3	Negative voltage input
Pin 4	Positive voltage input
Pin 5	Ground and cable screen

7. TROUBLESHOOTING

Q: The SpectroSense2+ display reading is higher than I would expect

A: Is there more than one sensor connected to a single hardware input?

For example a 1-channel sensor connected to socket C1 / C5 plus a 4-channel sensor connected the socket C1 / C2 / C3 / C4.In this example both sensors are connected to hardware socket C1, giving an inaccurate measurement

If you continue to have problems using your SpectroSense2+ meter, please do not hesitate to contact Skye's technical help team via telephone, email or web site using the details below:

SKYE INSTRUMENTS LIMITED
21, Ddole Enterprise Park
Llandrindod Wells
Powys, LD1 6DF
UK
TEL: +44 1597 824811
skyemail@skyeinstruments.com
www.skyeinstruments.com

7. SPECIFICATIONS

Operating Range:	-20 to +70°C, 0-100% RH
Construction:	Black ABS, sealed to IP54
Dimensions:	150 x 100 x 55 mm
Weight:	700g
Display:	20x4 line alphanumeric LCD
Keypad:	Membrane keypad with audible key press. 8 keys.
Connections:	Binder sub-miniature waterproof sockets. 5 or 8 pin for sensors.
Power:	1x 9V PP3 Lifetime 40-50 hours in display mode, 300 hours in log mode,
Resolution:	Minimum 16 bit (1 part in 65536), better than 1 nA
Accuracy:	Typically 0.008% at 20°C for mid range
Sensor inputs:	Maximum 4 inputs, dependant on model. Combinations of 4 x current and / or 2 x voltage
Sensor input ranges:	Current: ±20 nA to ±2 mA Voltage: ±2 mV to ±2 V
Sensor power supply:	5V to voltage sockets only, permanently switched on in display and logging modes
Memory:	Sensor Library for 16 calibration factors. Non-volatile EEPROM memory, no data loss if main power fails
Clock:	Real time clock powered by internal 10 year Lithium battery. Keeps date and time if main power fails.
Modes:	2 x 4 sensor / channel displays 2 x ratio displays $MJ.hr^{-1}$ integration Set up

APPENDIX 1 – APPLICATION NOTES FOR NDVI

Skye 2 and 4 channel radiometer light sensors are ideal for making 'ground truth' observations and comparing with measurements made by Earth observing satellites, such as LANDSAT, MODIS, AHVRR etc. These satellites map the Earth's surface according to the reflection of various wavelengths throughout the electromagnetic spectrum.

The SKR 1800 2-channel and SKR 1850 4-channel light sensors are in effect 'multiple sensors-in-one'. They will monitor light from multiple wavebands at a single point.

The exact wavelength and width of the band in each channel can be chosen individually by the user between 400nm (UV- Ultra Violet) and 2400nm (Infra-Red). Each waveband channel within the sensor is individually calibrated to National Standards and is supplied with a response curve and calibration certificate.

For example, Channel 1 at 570-680 nm and Channel 2 at 725-1020 nm is ideal to match the broadband Red and NIR channels on the AHVRR satellite. Narrow bandwidths can also be chosen, e.g. 5, 10, 25, 50, 75, 100 nm or larger as required.

These sensors have a removable diffusing head. With the head fitted the sensors are fully cosine corrected (will accept incoming light from an 180° hemisphere above them according to Lambert's Cosine Law), as is required for the measurement of incident solar radiation.

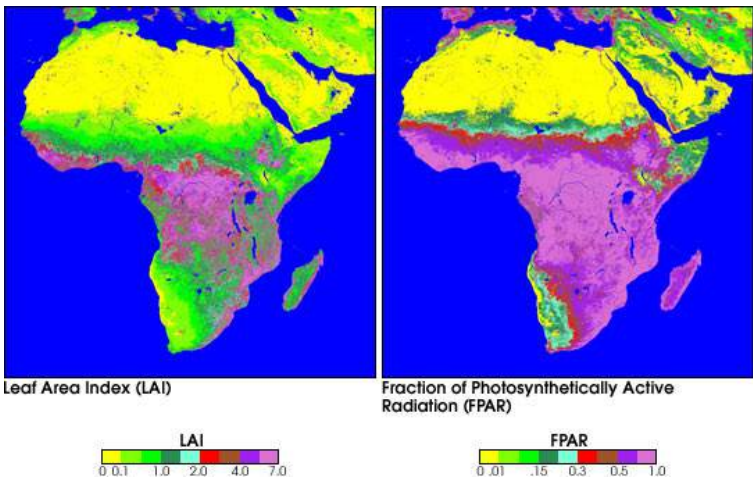
When the diffuser head is removed, the light acceptance of the sensor becomes a narrow angle (25°) cone shape. This makes it suitable for measuring radiation reflected up from the ground, and the geometry of the cone shape acceptance and the height of the sensor defines the exact area of the ground being monitored. 2 or 4 channel light sensors are generally used in pairs, one sensor measures incident solar radiation while the second simultaneously measures radiation reflected upwards. This is necessary to eliminate fluctuations in solar radiation.

SpectroSense 2

It is essentially reflected solar radiation which is being mapped by the Earth observation satellites. However errors are often introduced into these extra-terrestrial measurements by natural climatic conditions, especially scattering effects caused by cloud cover and dust particles in the atmosphere. Hence Skye 'ground truth' sensors are used to improve spatial resolution of the measurements and to correct for the climatic condition errors.

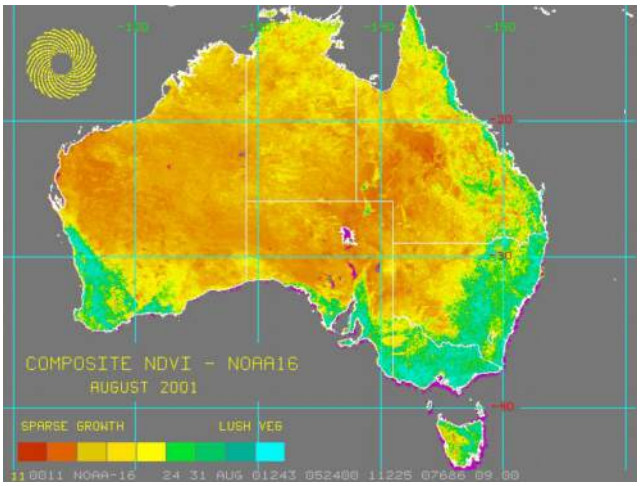
There are many useful phenomena which can be studied by the satellite maps, from rates of deforestation or desert encroachment, to vegetation productivity, area coverage of primary crops, flood and drought monitoring to insect breeding ground identification. Different ground types, desert, forests, crops, water etc. absorb and reflect different amounts of different wavelengths of radiation, and so are easily identified.

Vegetation Indices are produced by calculating the ratios of different wavebands of reflected radiation, and are related to the abundance and activity of radiation absorbers such as water and plant chlorophyll. These indices enable the estimation of biomass, percentage cover, absorbed PAR (Photosynthetically Active Radiation) and Leaf Area Index.



NDVI or Normalised Difference Vegetation Index is calculated from the Red and NIR wavebands and is defined as:

$$NDVI = \frac{(NIR - Red)}{(NIR + Red)}$$



SpectroSense 2

Skye's 2 and 4 channel light sensors are calibrated to National Standards when the diffusing cosine correction head is fitted. An exact calibration for the sensor with the diffuser head removed is not supplied, it is possible only to give a relative calibration of one channel to another.

However, this does not hinder the NDVI calculations as follows:

If NIR_I = NIR (incident) in $\mu mol.m^{-2}.s^{-1}$
Red_I = Red (incident) in $\mu mol.m^{-2}.s^{-1}$
NIR_R = NIR (reflected) in nA
Red_R = Red (reflected) in nA

Then
$$NDVI = \frac{[(NIR_R/NIR_I) - (Red_R/Red_I)]}{[(NIR_R/NIR_I) + (Red_R/Red_I)]} \quad \text{.....[1]}$$

$$= \frac{[(NIR_R*Red_I) - (Red_R*NIR_I)]}{(NIR_I*Red_I)} * \frac{(NIR_I*Red_I)}{[(NIR_R*Red_I) + (Red_R*NIR_I)]}$$

$$= \frac{[(NIR_R*Red_I) - (Red_R*NIR_I)]}{[(NIR_R*Red_I) + (Red_R*NIR_I)]}$$

$$= \frac{NIR_R[Red_I - (Red_R/NIR_R)*NIR_I]}{Red_R[(NIR_R/Red_R)*Red_I + NIR_I]}$$

$$NDVI = \frac{NIR_R}{Red_R} * \frac{[Red_I - (Red_R/NIR_R)*NIR_I]}{[(NIR_R/Red_R)*Red_I + NIR_I]} \quad \text{.....[2]}$$

The Skye sensor Calibration Certificate states that Ratio Sensitivity without the diffuser head fitted (in nanoamps) is

NIR : Red = 1 : Z

For the NDVI to be correct then NIR_I, NIR_R, Red_I and Red_R must all be true values in micromoles /m2/sec. The Skye sensor will measure NIR_I (say X □mol.m^{-2}.s^{-1}) and Red_I (say Y □mol.m^{-2}.s^{-1}).

For the reflected values :

$$\frac{NIR_R\ \mu mol.m^{-2}.s^{-1})}{Red_R\ \mu mol.m^{-2}.s^{-1})} = \frac{Z^*\ NIR_R\ (nanoamps)}{Red_R\ (nanoamps)} \qquad (nanoamps = nA)$$

From [2]:

$$NDVI = \left\{\frac{Z^*\ NIR_{R(nA)}}{Red_{R(nA)}}\right\} * \left[Y - \frac{Red_{R(nA)}}{\{Z^*\ NIR_{R(nA)}\}} * X\right] \Big/ \left[\left\{\frac{Z^*\ NIR_{R(nA)}}{Red_{R(nA)}}\right\} * Y + X\right]$$

Hence:

$$NDVI = \frac{(Z * NIR_{R(nA)} * Y) - (Red_{R(nA)} * X)}{(Z * NIR_{R(nA)} * Y) + (Red_{R(nA)} * X)}$$

Where:
- X = NIR_I incident reading (in µmol.m^{-2}.s^{-1})
- Y = Red_I incident reading (in µmol.m^{-2}.s^{-1})
- Z = Ratio Sensitivity of reflected NIR : Red
- $NIR_{R(nA)}$ = reflected reading in nanoamps (or direct current output)
- $Red_{R(nA)}$ = reflected reading in nanoamps (or direct current output)

A NOTE ON EXPECTED VALUES:

NDVI values range from -1 to +1, where

-1 values are generally from snow, ice or cloud
Zero values represent no vegetation
+1 values represent the highest possible density of green leaves.

APPENDIX 2 – HAND-HELD POLE FOR SPECTROSENSE2+

SKL 910/2 and SKL 910/4 SpectroSense2 hand-held pole

Skye can supply a hand-held pole that holds the SS2 meter plus 2 or 4 sensors. This allows the user to be able to take concurrent measurement and logging of all active sensors of a sample site as accurately as possible. This is especially useful for large sampling areas, or teamed/grouped data collection, where data collection methodology consistency is important.

Please see the manual for this product for assembly and usage instructions, here.

Taking Light Measurements

1. Attach the sensors and meter and adjust the pole to the required height
2. Place the pole's rubber 'foot' in front of your own feet (or tucked between your feet to secure if more comfortable)
3. Lean the pole away from you until the level bubble is showing that the light sensors are level.
4. Use the SpectroSense2+ meter to take readings as required.

IMPORTANT

The light sensors must be protected from damage when not in use, especially the light collecting diffuser as any scratches may effect the sensor calibration. It is advisable to remove the sensor mounting arm from the top of the pole during transportation and storage.

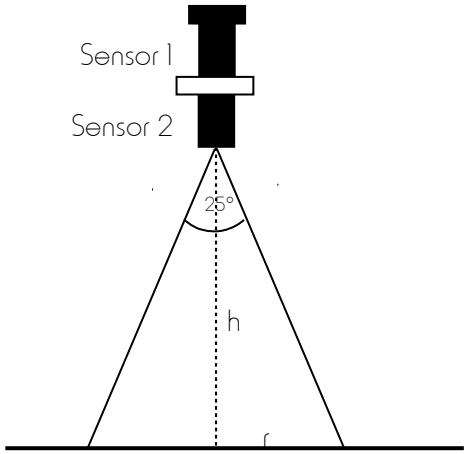
This product is not intended for continuous outdoor use, and should not be exposed to the elements for long periods of time.

APPENDIX 3 – AREA OF MEASUREMENT BY REFLECTED SENSORS

Skye SKR 1800 series 2 and 4 channel light sensors are fitted with a removable cosine correcting light acceptance head. When taking incident or down-welling light measurements, the head is left in place so that the sensor is fully cosine corrected (accepts light in accordance with Lambert's Cosine Law).

For the measurement of reflected or up-welling light, the cosine head is removed converting the sensor into a narrow angle acceptance instrument. The sensor has a smaller, defined field of view and can accurately measure from a defined ground area.

Without the cosine head, both 2 and 4 channel sensors have a 25° cone field of view (12.5° off perpendicular). The area of ground in view to the sensor is then defined by the height above the ground, as shown below:



Sensor 1 is fitted with the cosine correcting head and is measuring incident light.

Sensor 2 is narrow angle and is measuring reflected light.

Both incident and reflected light is measured simultaneously by 2 identical sensors, to eliminate fluctuations in solar radiation

EXAMPLES OF MEASUREMENT AREA

HEIGHT OF SENSOR **h**	RADIUS OF CIRCLE **r**	AREA OF MEASUREMENT
0.5m	0.11m	0.04m^2
0.75m	0.17m	0.09m^2
1m	0.22m	0.15m^2
1.25m	0.28m	0.24m^2
1.5m	0.33m	0.35m^2
1.75m	0.39m	0.47m^2
1.8m	0.40m	0.50m^2
2m	0.44m	0.62m^2

APPENDIX 4 - WAVELENGTHS FOR NDVI SYSTEMS

There are no 'typical' wavelengths for NDVI systems, each system can be tailored to match the user's own research project as necessary. However, examples of popular wavelength configurations are listed below:

PROJECT	WAVELENGTHS
Red / Far-red ratio	Channel 1 – 660 nm (20 nm bandwidth)
	Channel 2 – 730 nm(20 nm bandwidth)
Weed cover mapping	Channel 1 – 650 nm (20 nm bandwidth)
	Channel 2 – 800 nm (20 nm bandwidth)
Crop Density	Channel 1 – 650 nm (20 nm bandwidth)
	Channel 2 – 800 nm (20 nm bandwidth)
Ground truth for	Channel 1 – 570-680 nm
AHVRR satellite	Channel 2 – 725-1100 nm
Ground truth for	Channel 1 – 450-500 nm
Landsat satellite	Channel 2 – 500-600 nm
	Channel 3 – 650-700 nm
	Channel 4 – 750-900 nm
Ground truth for	Channel 1 – 459-479 nm
MODIS satellite	Channel 2 – 549-565 nm
	Channel 3 – 620-670 nm
	Channel 4 – 841-876 nm