# - Skye eGuides -
## theory into practice

**N° 1**

# Remote Sensing Overview

www.skyeinstruments.com

## CONTENTS


| | |
|---|---|
| Introduction | 3 |
| Global Climate Change | 4 |
| Global Carbon Budget | 5 |
| Gross Primary Production | 6 |
| Ground Truthing | 9 |
| Skye Products for Remote Sensing | 11 |
| Skye Instruments | 15 |

# 1 INTRODUCTION

These Remote Sensing Guidance Notes have been written to help researchers choose which of the Skye Instruments range of sensors and systems could add valuable data and information to their monitoring projects, and also how to get the best results from the instruments. These Notes begin with an introduction to Remote Sensing, concentrating on the topics which are relevant to Skye sensors.

Remote Sensing is defined as the science and technology by which the characteristics of objects of interest can be identified, measured or analysed without direct contact. In modern usage, the term generally refers to the use of aerial sensor technologies to detect and classify objects on Earth (both on the surface, and in the atmosphere and oceans) by means of propagated signals. Electromagnetic radiation which is reflected or emitted from an object is the usual source of remote sensing data.

Remote Sensing may be split into active remote sensing (when a signal is first emitted from aircraft or satellites) or passive (e.g. sunlight) when information is merely recorded. These Notes will be discussing Passive Remote Sensing and how the Skye Product Range can be utilised to contribute to Remote Sensing data collections.

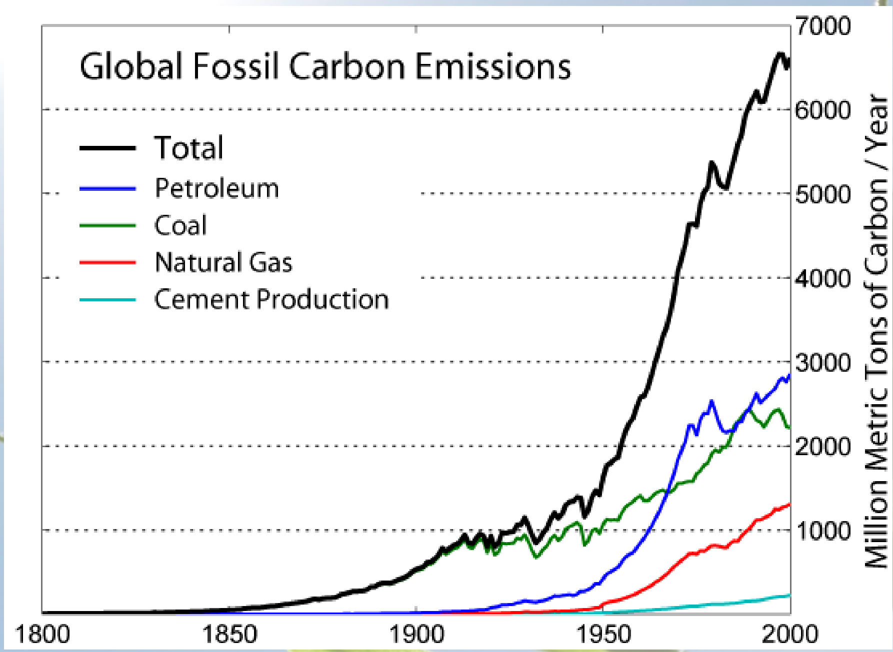
Remote sensing in many fields of scientific and research has extensive applications. It can be implied to geology, hydrology, mining, fisheries, cartography, geography, biology studies, environmental studies, geographic information systems, meteorology, agriculture, forestry, land development and totally resource management of land etc.

Remote Sensing plays a key role in monitoring the various manifestations of global climate change. It is used routinely in the assessment and mapping of biodiversity over large areas, in the monitoring of changes to the physical environment, in assessing threats to various components of natural systems, and in the identification of priority areas for conservation.

# 2 GLOBAL CLIMATE CHANGE

Climate change is a change in the statistical distribution of weather patterns when that change lasts for an extended period of time (i.e., decades to millions of years). Climate change may refer to a change in average weather conditions, or in the time variation of weather around longer-term average conditions (i.e., more or fewer extreme weather events).

The recent phenomenon of global climate change has been attributed primarily to increasing atmospheric carbon dioxide ($CO_2$) concentrations in Earth's atmosphere. The global annual mean concentration of $CO_2$ in the atmosphere has increased markedly since the Industrial Revolution, with the increase largely attributed to human interactions, particularly the burning of fossil fuels.

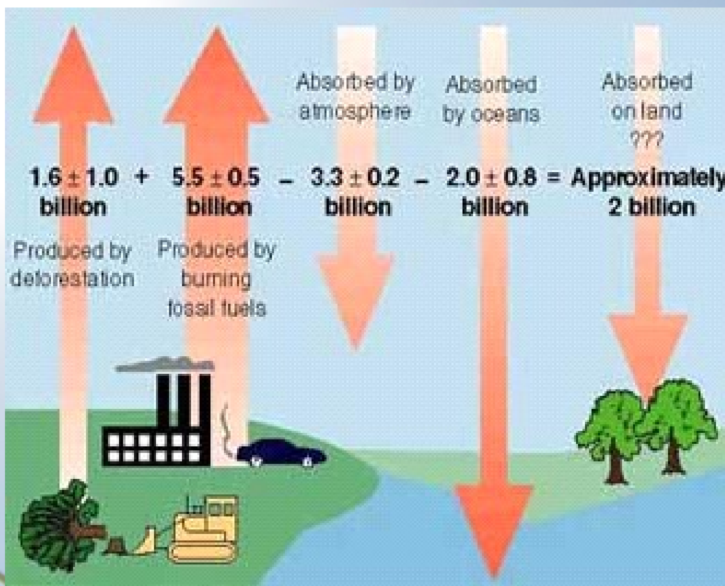



Atmospheric carbon dioxide comes from a number of natural sources, mainly the decay of plants, volcanic eruptions and as a waste product of animal respiration. It is removed from the atmosphere by photosynthesis in plants and by dissolving in water, especially on the surface of oceans.

# 3 GLOBAL CARBON BUDGET

The Global Carbon Cycle is the movement of carbon between sinks and sources. A Carbon Sink absorbs more carbon that it releases, whilst a Carbon Source releases more carbon than it absorbs. Forests, soils, oceans and the atmosphere all store carbon and this carbon moves between them in a continuous cycle.

Atmospheric carbon dioxide comes from a number of natural sources, mainly the decay of plants, volcanic eruptions and as a waste product of animal respiration. It is removed from the atmosphere by photosynthesis in plants and by dissolving in water, especially on the surface of oceans.




The amount of carbon dioxide taken out of the atmosphere by plants is almost perfectly balanced with the amount put back into the atmosphere by respiration and decay. . Small changes as a result of human activities can have a large impact on this delicate balance.

Burning fossil fuels releases the carbon dioxide stored millions of years ago in carbonate minerals, oil shale, coal and petroleum in the Earth's crust when the organisms died. Deforestation releases the carbon stored in trees and also results in less carbon dioxide being removed from the atmosphere.

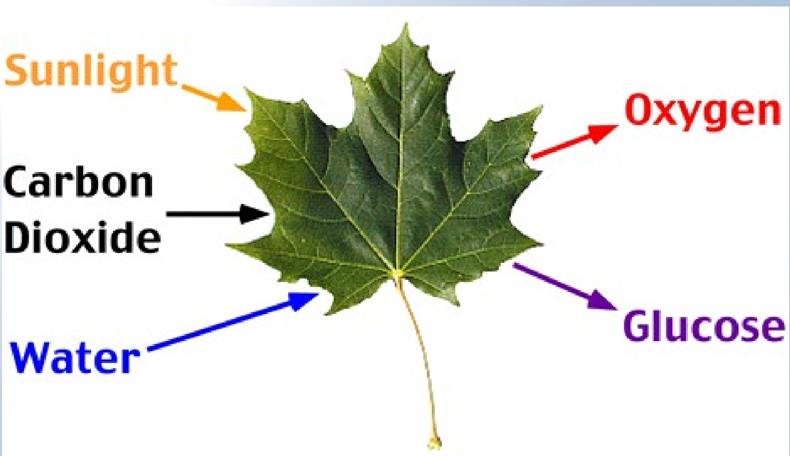
The Global Carbon Budget is the balance of the carbon exchanges in the carbon cycle. Monitoring the carbon budget of an ecosystem can provide information about whether it is functioning as a carbon source or a carbon sink.

# 4 GROSS PRIMARY PRODUCTION

Biomass is biological material derived from living, or recently living organisms. It most often refers to plants or plant-based materials.

In ecology, productivity or production refers to the rate of generation of biomass in an ecosystem. It is usually expressed in units of mass per unit surface (or volume) per unit time, for example grams per square metre per day (g m−2 d−1). The mass unit may relate to dry matter or to the mass of carbon generated. Productivity of plants is called primary productivity, while that of animals is called secondary productivity.

Primary production is the synthesis of new organic material from inorganic molecules such as water and $CO_2$. It is dominated by the process of photosynthesis which uses sunlight to synthesise organic molecules such as sugars.




Organisms responsible for primary production are called Primary Producers and include land plants, marine algae and some bacteria. The total amount of productivity in a region or ecosystem is Gross Primary Productivity or GPP.

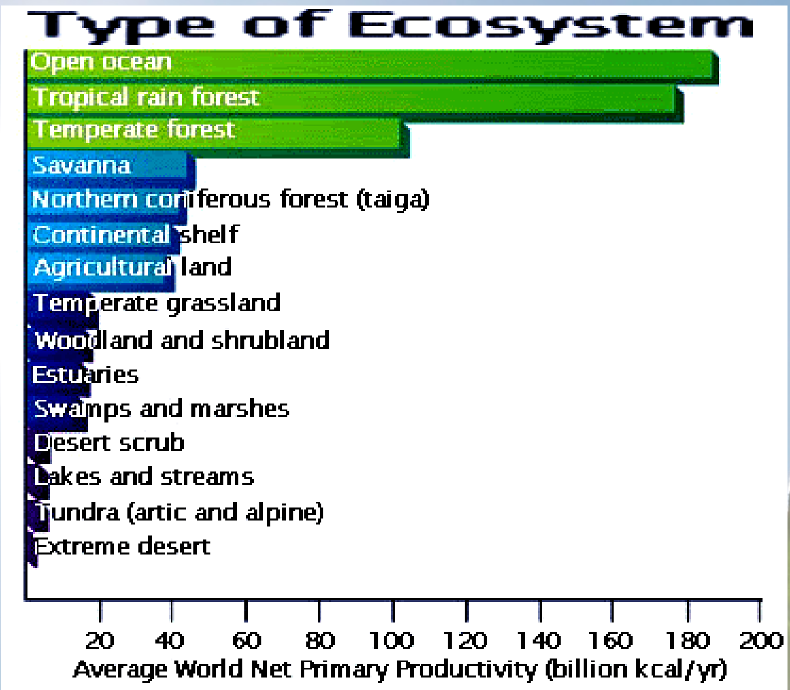
Primary production is the rate of organic biomass growth or accumulation by plants. Primary production is commonly split into two components, gross primary productivity (GPP) and net primary productivity (NPP). Gross primary productivity is the overall rate of biomass production by producers, whereas net primary productivity is the remaining fraction of biomass produced after accounting for energy lost due to cellular respiration and maintenance of plant tissue.

Thus NPP = GPP – respiration.

NPP, sometimes also called Net Ecosystem Exchange (NEE), is an indication of the Net Rate of Carbon Capture by an Ecosystem. It is often expressed in units of grams of carbon, per square meter per year (gC. $m^{-2}$. $yr^{-1}$ )

NPP is an important component of the global carbon budget and is used as an indicator of ecosystem function.

NPP can be directly assessed by measuring plant traits or harvesting plant material on the ground, but across large areas remotely sensed images are used to estimate NPP. When an ecosystem is showing a high NPP value, it is acting as a carbon sink. 70% of high NPP ecosystems are forests and savannahs, the largest areas of these exist in the equatorial regions. North America has large areas of forestry and savannahs, but due to it's latitudes the seasons when NPP is high are relatively short. Tropical areas have a higher annual NPP due to their longer productive seasons.




GPP and NPP is calculated from satellite based sensor data. The sensors are mainly spectral imagers, in that they photograph the Earth's surface in a series of spectral wavelengths.

Photosynthetically active radiation (PAR) is the spectral range from 400-700nm that is used by plants in photosynthesis. The fraction of PAR (fPAR) is a parameter used in remote sensing and in ecosystem modelling that signifies the portion of PAR used by plants. fPAR is an important parameter in measuring biomass production because vegetation development is related to the rate at which radiant energy is absorbed by vegetation. fPAR is often derived from spectral vegetation indices such as NDVI, the Normalised Difference Vegetation Index, which is explained in more detail in the Skye eGuide on Vegetation Indices.

Light use efficiency (LUE) calculations provide a measure of the efficiency with which vegetation can use incident light for photosynthesis. It is highly related to carbon uptake efficiency and vegetative growth rates, and is somewhat related fPAR.

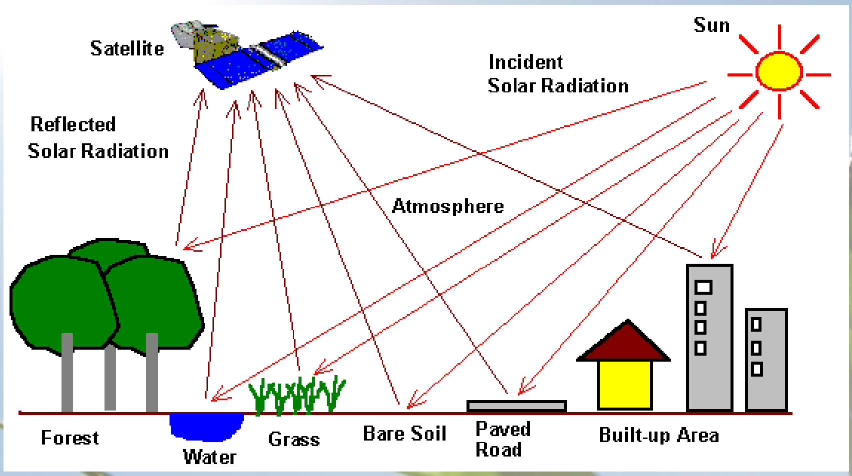
The Photochemical Reflectance Index (PRI) is a reflectance measurement that is sensitive to changes in carotenoid pigments (particularly xanthophyll pigments) in live foliage. Carotenoid pigments are indicative of LUE, or the rate of carbon dioxide uptake by foliage per unit energy absorbed. PRI is explained in more detail in "the Skye eGuide on Vegetation Indices".

NPP is often calculated as a product of fPAR, NDVI, LUE and PRI. Skye Instruments offer sensors and systems for measuring fPAR, NDVI and PRI, which are described "the Skye eGuide on Vegetation Indices".

# 5 GROUND TRUTHING

The sun provides a very convenient source of energy for Remote Sensing. The sun's energy is either reflected, as it is for visible wavelengths, or absorbed and then re-emitted, as it is for thermal infrared wavelengths. Remote sensing systems which measure energy that is naturally available are called passive sensors.

Passive sensors detect sunlight radiation reflected from the earth and thermal radiation in the visible and infrared of the electromagnetic spectrum. They do not emit their own radiation, but receive natural light and thermal radiation from the earth's surface. Most satellite based passive sensors make use of a scanner for imaging, e.g. LANDSAT. Equipped with spectrometers they measure signals at several spectral bands simultaneously, resulting in so-called multispectral images which allow numerous interpretations




The data collected by passive sensors aboard Earth observational satellites has limitations due to the radiation being measured passing through the atmosphere. Errors and missing data often occur due to cloud cover, water vapour, pollution, aerosols, dust, volcanic ash etc in the atmosphere. Satellite orbits also have limited viewing times at each ground location, and so missing / erroneous data has to be "gap filled" using mathematical models.

Mathematical models make many assumptions, and these assumptions can be improved by taking Ground Truthing measurements. A variety of field instruments can be used to take ecosystem measurements at ground level, synchronised with the passing over of the satellites, allowing comparison and verification of the satellite data.

When the field measurements are made using automatic datalogging instruments, 24 hour data is collected at each location, which is extremely useful in gap filling and improving the mathematical models.

Field measurements taken at ground level do not have the spatial coverage that satellite measurements have, but they are not effected by the problem of the reflected radiation being distorted by the atmospheric conditions. Hence these are known as "Ground Truth" measurements.

Ground Truth field instruments can be hand held devices or automatic datalogging systems. They can be utilised at any height from ground level upwards. Automatic systems are often installed on masts and towers up to 50m high. To increase the spatial resolution of the measurements, the instruments are also used onboard Unmanned Aerial Vehicles (UAVs), light aircraft and full size airplanes. A research group will often employ several methods of collecting ground truth data at different heights and spatial resolution, to improve the "Scaling Up" mathematical models.

The field instruments can be regularly calibrated, which the satellite sensors cannot. It is important that the field instruments match the specifications of the satellite sensors as closely as possible, to enable verification and calibration checks on the satellite sensors. Skye's sensors can be ordered to match particular satellite sensors for this purpose.

# 6 SKYE PRODUCTS FOR REMOTE SENSING


Skye Instruments have been specialising in Light and Radiation sensors since 1983. All are designed, manufactured and calibrated to the highest standards. Each is supplied with an individual Calibration Certificate traceable to the UK's National Physical Laboratory (NPL).

Sensors are available with Calibrated wavelength responses from 280nm (UV), through VIS, NIR to 2400nm (SWIR). There are thirteen popular models of fixed wavelengths, plus custom models where the wavebands are built and calibrated to the user's individual requirements.

The range includes single channel sensors and 2 and 4 multichannel radiometers. There is a choice of sensor design for Irradiance / Incident light measurements, and Radiance / Reflected light measurements, a pair of which is known as a Spectral Albedometer.

All Skye Light and Radiation sensors can be supplied as complete systems, with hand held SpectroSense2+ logging meters and GPS mapping, or with DataHog dataloggers for automatic recording. The sensors are also compatible with dataloggers from other manufacturers.

Skye sensors for use in Remote Sensing applications are as follows:

**fPAR Measurements**
fPAR can be recorded in two ways:

a) using the PAR Quantum sensor response in a multichannel spectral albedometer Incident and Reflected PAR is measured simultaneously, the ratio of which calculates the fraction of PAR absorbed by the area under measurement


b) using NDVI sensors and the calculation fPAR = 1.24 * NDVI - 0.168
This calculation is available as standard in the Skye SpectroSense2+ meter

Information on these sensors can be found here:

PAR Quantum Sensors
NDVI Sensors

**NDVI Measurements**
NDVI sensors include 2 wavebands, in the Red and NIR wavelength regions.
A 2 channel spectral albedometer (which consists of a pair of Irradiance and Radiance radiometers) is used to measure incident and reflected light simultaneously.
Individual measurements from all 4 channels are recorded separately, and the NDVI calculation is available as standard in the Skye SpectroSense2+ meter

Information on these sensors can be found here:

NDVI Sensors
4-Channel Sensors

**PRI Measurements**
PRI sensors include 2 wavebands, in the 531nm and 570nm wavelength regions.
A 2 channel spectral albedometer (which consists of a pair of Irradiance and Radiance radiometers) is used to measure incident and reflected light simultaneously.
Individual measurements from all 4 channels are recorded separately, and the PRI

calculation is available as standard in the Skye SpectroSense2+ meter

Information on these sensors can be found here:

PRI Sensors
4-channel Sensors

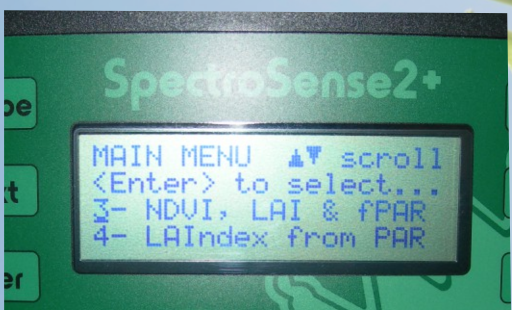
**Other Vegetation Indices**
Skye custom sensors can be matched to the wavebands of a particular satellite for Ground Truth measurements. Multichannel albedometers can be fitted with up to 4 different wavebands, allowing several VIs to be calculated using one pair of sensors. For example:

a) A 2 channel albedometer with Red and NIR wavebands can calculate:
   NDVI, RVI, fPAR, EVI2, MSAVI2 and LAI
b) A 2 channel albedometer with 531nm and 570nm wavebands can calculate PRI
c) A 4 channel albedometer with Red, NIR, 531nm and 570nm wavebands can calculate:
   NDVI, PRI, RVI, fPAR, EVI2, MSAVI2 and LAI
d) A 2 channel albedometer with 900nm and 970nm wavebands can calculate WBI
e) A 4 channel albedometer with MODIS Blue, Red, NIR, and PAR wavebands can calculate:
   NDVI, RVI, fPAR, MODIS EVI, EVI2, MSAVI2 and LAI

Information on these sensors can be found here:

New 4-Channel Sensors
Land-based Systems

**SpectroSense2+ Logging Meter**
This Skye meter is an 8 channel display meter, with automatic datalogging and GPS mapping functions. It has a 4 line display for easy viewing of data from a pair of multichannel radiometers or albedometers. Sensors can be easily interchanged using the configurable sensor library. The following Vegetation Indices can be displayed live on screen:
NDVI, PRI, fPAR, RVI, WBI, EVI, EVI2, MSAVI2, LAI from PAR sensors, LAI from NDVI sensors




Information on these meters can be found here:
SpectroSense2+

**DataHog Datalogger**

The Skye DataHog is a 16 channel datalogger designed specifically for light and radiation sensors. It is robust and waterproof, and can be linked to a GPRS remote communications module for automatic upload to a web site.


Up to 8 wavebands of Irradiance and Radiance measurements can be recorded simultaneously. Multichannel spectral albedometers with wavebands in the SWIR region can also be recorded using the DataHog, allowing calculations of other VIs as well, such as NDSI.
Information on these dataloggers can be found here:

[DataHog2]

**Published Scientific References**
Skye's sensors and systems have been used in Remote Sensing for many years, and the research they have contributed to has been published many times, in a variety of different scientific journals. Please click the link below to view a selection:

[References]

# 7 SKYE INSTRUMENTS LTD

Skye Instruments Ltd has been designing and manufacturing instrumentation for Environmental Monitoring, Plant Growth and Agricultural Research since 1983. The Company started on the Isle of Skye, Scotland and re-located to Wales in 1986.

We have a world-wide reputation for producing high quality instruments which stand up to life in the field, and for having excellent customer relationships. Although we are based in Wales, UK, we have representation in many countries as well as selling direct.

In 2009, Skye became an Employee-Owned Company. Skye has adopted the 'John Lewis' model whereby shares of the company are held in a trust, an Employee Benefit Trust. All employees are equal owners and benefit from profit-sharing.


**Quality Policy**

The Company recognises that its performance must be of a consistently high standard to secure the satisfaction, confidence and loyalty of its customer base.
It is the Policy of Skye Instruments Limited to satisfy all customers by offering a high standard of personal attention by trained and courteous employees.
It is the Policy of Skye Instruments to develop, produce and market high quality, precision instrumentation for environmental, botanical and laboratory use. The aim is to provide a first class product and service that fully satisfies the initial and continual needs and expectations of all customers.

**Environmental Philosophy**

Skye are an environmentally aware Company and strive to ensure our business activities have the minimum possible adverse impact on the environment. We are proud of the fact that many of our products will be used to improve the natural environment around the world by increasing the understanding of natural events and minimising damage caused by human activities.

Skye Instruments Ltd
21, Ddole Enterprise Park,
Llandrindod Wells,
Powys LD1 6DF UK

Tel: +44 (0) 1597 824811
email: skyemail@skyeinstruments.com

www.skyeinstruments.com