# Experiential Learning Modules to study Land, Water and Atmospheric Characteristics

## Designed by

# CREST-HIRES
# Summer 2014

# Table of Contents

1 NORMALIZED DIFFERENCE VEGETATION INDEX (NDVI) .................................................. 2

2 LEAF AREA INDEX ........................................................................................................ 4

3 SURFACE TEMPERATURE USING INFRARED THERMOMETER ............................................ 5

4 SOIL MOISTURE MEASUREMENT USING L-BAND RADIOMETER ....................................... 6

5 WEATHER STATION ...................................................................................................... 8

6 USING REMOTE SENSING AND *IN SITU* DATASETS TO UNDERSTAND CLIMATE CHANGE EFFECTS ON MAPLE SYRUP PRODUCTION ...................................................................... 9

# 1 Normalized Difference Vegetation Index (NDVI)

The Normalized Difference Vegetation Index (NDVI) is a simple graphical indicator that can be used to analyze remote sensing measurements, typically but not necessarily from a space platform, and assess whether the target being observed contains live green vegetation or not. The NDVI is calculated from these individual measurements as follows:

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

Where, VIS and NIR stand for the spectral reflectance measurements acquired in the visible (red) and near-infrared regions, respectively

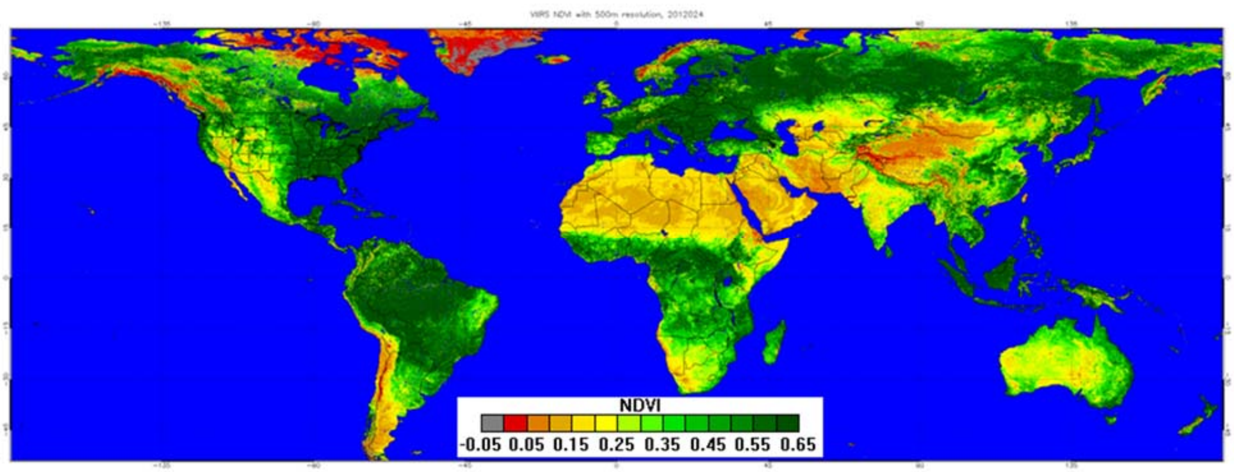



Figure 1: Global NDVI Map

Negative values of NDVI (values approaching -1) correspond to water. Values close to zero (-0.1 to 0.1) generally correspond to barren areas of rock, sand, or snow. Lastly, low, positive values represent shrub and grassland (approximately 0.2 to 0.4), while high values indicate temperate and tropical rainforests (values approaching 1)

NDVI is especially useful for continental to global-scale vegetation monitoring because it can compensate for changing illumination conditions, surface slope, and viewing angle. That said, NDVI does tend to saturate over dense vegetation and is sensitive to underlying soil color. Because of its ease of use and relationship to many ecosystem parameters, NDVI has seen widespread use in rangeland ecosystems. The uses include assessing or monitoring:

- vegetation dynamics or plant phenological changes over time
- biomass production
- grazing impacts or attributes related to grazing management (e.g., stocking rates)
- changes in rangeland condition
- vegetation or land cover classification
- carbon sequestration or $CO_2$ flux

# SpectroSense2 Meter for NDVI

- 4 or 8 channel meter for light sensors
- For 1-channel, 2-channel or 4-channel sensor types
- Displays readings from up to 8 sensors or channels simultaneously
- Displays sensor ratios and NDVI ratio
- Hold, storing & logging functions
- Ideal for ground truth measurements


Skye Instruments are specialist manufacturers of light and radiation sensors since 1983. The SpectroSense2 hand-held meter is a new addition to the range for use with several single sensors or with 2 and 4 channel sensors.

SpectroSense2 is a 4-channel meter which displays from 4 sensors or channels simultaneously. These can be either direct sensor readings or ratios between pairs of sensor channels, e.g. for incident / reflected ratios for NDVI calculations. Integration of light measurement over time is also available, e.g. to give daily values of MJ/day solar energy

The 'Hold' button allows the user to freeze the display for easy viewing of all 4 real time measurements. The meter's memory has storage for up to 16 calibration factors for straightforward interchange of sensors as required.

SpectroSense2+ is an 8-channel meter with all the functions of the SpectroSense2, but includes an automatic logging function and more complex NDVI calculations. Free software is included to download the SpectroSense2+ memory to a PC. Datafiles are simple ASCII format for direct use with Excel, Word etc.

The range of Skye sensors for use with the SpectroSense2 meter include PAR, red/far-red, total solar radiation, lux, UV and custom wavelength sensors. Please ask for details.

# 2 Leaf Area Index

Leaf Area Index (LAI) is a dimensionless quantity that characterizes plant canopies. It is defined as the one-sided green leaf area per unit ground surface area (LAI = leaf area / ground area, m2 / m2) in broadleaf canopies. In conifers, three different definitions for LAI have been used:

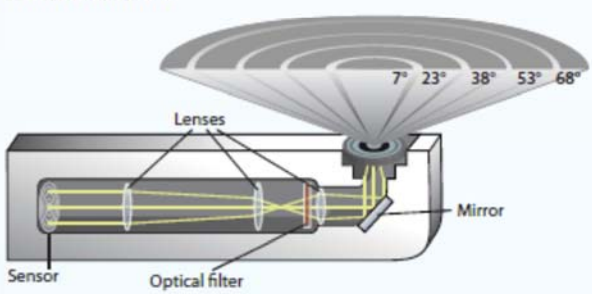
- Half of the total needle surface area per unit ground surface area
- Projected (or one-sided, in accordance the definition for broadleaf canopies) needle area per unit ground area
- Total needle surface area per unit ground area

## How it Works

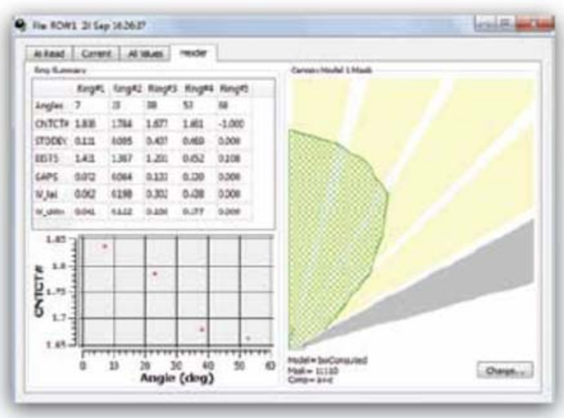
The LAI-2200 builds upon the proven technology of its predecessor - the LAI-2000. The LAI-2200 provides a modernized user interface, versatile configuration options, and improved data analysis features.

It calculates the interception of blue light (320-490 nm) at 5 zenith angles (148° field-of-view) from readings taken above and below the canopy. These data are then used to compute foliage amount and orientation using well established theory and algorithms (see references below). These are implemented in the instrument's console, so you can see results right in the field.

The underlying theory is based on assumptions of randomness in foliage position, which all real canopies violate to some extent. Simple adjustments to measurement protocol (e.g. choice of view cap, appropriate sampling scheme, etc.) can make the LAI-2200 a very effective tool in a wide range of natural and agronomic settings. The LAI-2200 also computes a clumping factor (Ryu et al, 2010), which indicates how much the canopy appears to depart from random.




Data can be read live in the field and later processed using the exclusive FV2200 software. FV2200 provides powerful data processing options, including 3 additional inversion methods, ring masking, and tools to compute canopy volume.




- USB data transfer - drag-and-drop data files to your computer
- Optimized for sensitivity to blue radiation, which is reflected and transmitted minimally by living vegetation
- Measures up to a 360° azimuthal view providing a large sample area for good spatial averaging

# 3 Surface Temperature using Infrared Thermometer

Infrared thermometers measure temperature from a distance. Infrared thermometers work based on a phenomenon called black body radiation. Anything at a temperature above absolute zero has molecules inside of it moving around. The higher the temperature, the faster the molecules move. As they move, the molecules emit infrared radiation--a type of electromagnetic radiation below the visible spectrum of light. As they get hotter, they emit more infrared, and even start to emit visible light. That is why heated metal can glow red or even white. Infrared thermometers detect and measure this radiation.

**How Infrared Thermometers Work?**

Infrared light works like visible light--it can be focused, reflected or absorbed. Infrared thermometers usually use a lens to focus infrared light from one object onto a detector called a thermopile. The thermopile absorbs the infrared radiation and turns it into heat. The more infrared energy, the hotter the thermopile gets. This heat is turned into electricity. The electricity is sent to a detector, which uses it to determine the temperature of whatever the thermometer is pointed at. The more electricity, the hotter the object is.

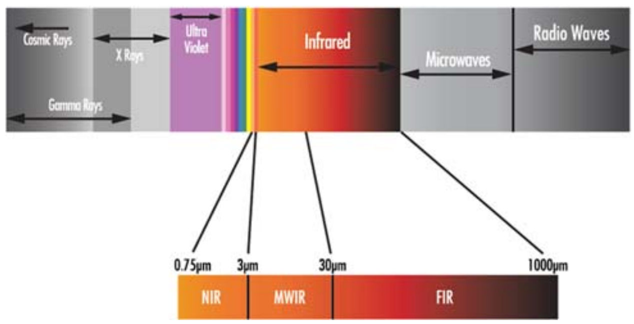



Figure 2: Infrared Region in Electromagnetic Spectrum

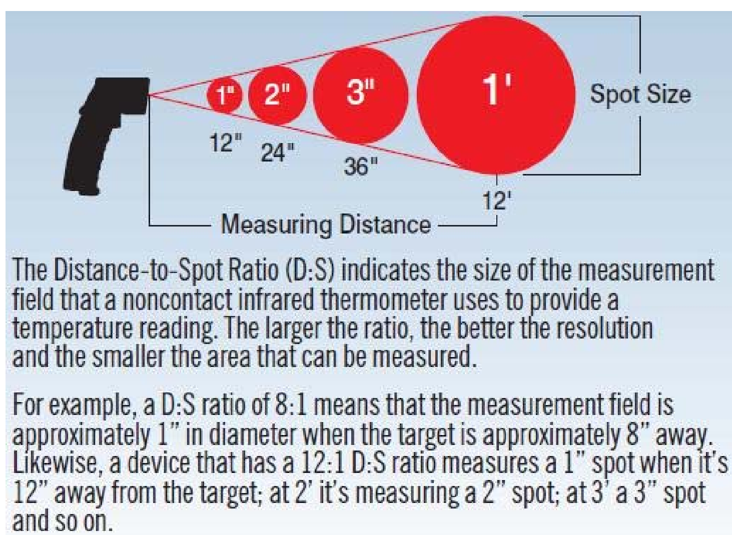



Figure 3: Distance-to-spot ratio for measuring temperature using thermal gun

# 4 Soil Moisture Measurement Using L-Band Radiometer

Soil moisture is an important variable in land surface hydrology. Soil moisture has very important implications for agriculture, ecology, wildlife, and public health and is probably (after precipitation) the most important connection between the hydrological cycle and life—animal, plant, and human.

Land surface hydrology is a well-studied portion of the terrestrial water cycle. The main variables in land-surface hydrology are soil moisture, surface temperature, vegetation, precipitation, and stream-flow. Of these, surface temperature, vegetation, and precipitation are currently observed using satellites, and stream-flow is routinely observed at in situ watershed locations. Soil moisture remains the only variable not observed (or observed very sparsely) either in situ or via remote sensing. Due to this very reason, in the past decade, satellite soil moisture has been increasingly used in hydrological, agricultural, and ecological studies due to its spatial coverage, temporal continuity, and (now) easiness of use.

NASA currently is working on a new mission to launch a satellite to exclusively measure soil moisture amount in global scale. This mission is called Soil Moisture Active and Passive (SMAP). SMAP will provide global measurements of soil moisture and its freeze/thaw state. These measurements will be used to enhance understanding of processes that link the water, energy and carbon cycles, and to extend the capabilities of weather and climate prediction models. SMAP data will also be used to quantify net carbon flux in boreal landscapes and to develop improved flood prediction and drought monitoring capabilities. The SMAP instrument includes a radiometer and a synthetic aperture radar operating at L-band (1.20-1.41 GHz). The instrument is designed to make coincident measurements of surface emission and backscatter, with the ability to sense the soil conditions through moderate vegetation cover. The instrument measurements will be analyzed to yield estimates of soil moisture and freeze/thaw state.

A soil moisture observation network approved by NASA as a core validation site for the SMAP mission is deployed in the region of Millbrook, NY. It includes an L band (1.45 GHz) dual polarization radiometer that is part of the CREST Microwave Observation Unit. The study site serves as a calibration/validation site for the NASA SMAP mission.

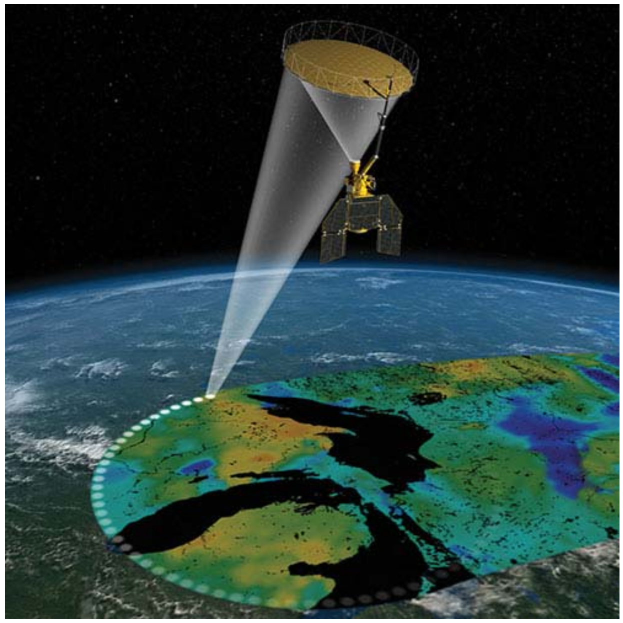


Figure 4: Soil Moisture Active and Passive (SMAP) satellite (http://smap.jpl.nasa.gov/mission)


Figure 5: NOAA-CREST L-Band radiometer for soil moisture measurements (http://crest.ccny.cuny.edu/facilities)

# 5 Weather Station

Weather is state of the atmosphere at a given point, while climate is the long-term behavior of the atmosphere at any region. Therefore, to understand and to forecast the weather and also to monitor the climate, long-term weather data needs to be collected.

In addition to temperature and precipitation data, a diverse array of solar radiation data as well as relative humidity, wind speed and direction at 10 meters height and atmospheric pressure need to be collected. Weather is driven by air pressure (temperature and moisture) differences between one place and another. These pressure and temperature differences can occur due to the sun angle at any particular spot, which varies by latitude from the tropics.

Weather experts use computer technology and data from stations and satellites all over the world to predict the weather. By carefully monitoring weather conditions it is possible to predict when change is due - what we know as weather forecasting.

The Cary Institute maintains a fully outfitted weather station at its campus in Millbrook, NY. (http://www.caryinstitute.org/science-program/research-projects/environmental-monitoring-program/weather-climate)

Figure 6: Cary Institute of Ecosystem Studies Weather Station

# 6 Using remote sensing and *in situ* datasets to understand climate change effects on maple syrup production

Maple syrup might be the oldest agricultural product in North America. Syrup production depends on sap flow in sugar maple trees prior to the springtime start of the growing season. This early season sap flow is the result of a physiologically unique process that occurs during the winter season, when daytime temperatures reach above freezing, and freezing temperatures occur at night. This freeze/thaw cycle, alternating day-night, creates pressure gradients within the tree that cause the sap to flow. This phenomenon occurs only for a limited time during the spring.

This project makes use of satellite remote sensing datasets of landscape temperature and freeze/thaw state to assess day-night freeze/thaw cycles across regions where the sap from sugar maple trees is harvested for maple syrup production. The multi-year satellite record allows us to examine its correlation with sap harvesting, including variability across multiple years. To support analysis of the remote sensing data, we collect ground reference (*in situ*) data on vegetation physiology. This stand of sugar maple trees (*Acer saccharum*) is instrumented with sensors providing measurements of vegetation and soil temperature, vegetation sap flow and growth dynamics. Our objective is to characterize processes related to the flow of sap in the sugar maple trees as well as climate drivers affecting these processes.

Xylem sap flow is monitored in several individual trees using Granier-style sap flow sensors. Tree growth is monitored using precision dendrometers. The suite of sensors is connected to a data logger powered by a 12-volt lead acid battery connected to a solar panel. A diagram of the typical instrument set-up is provided in the figure below.

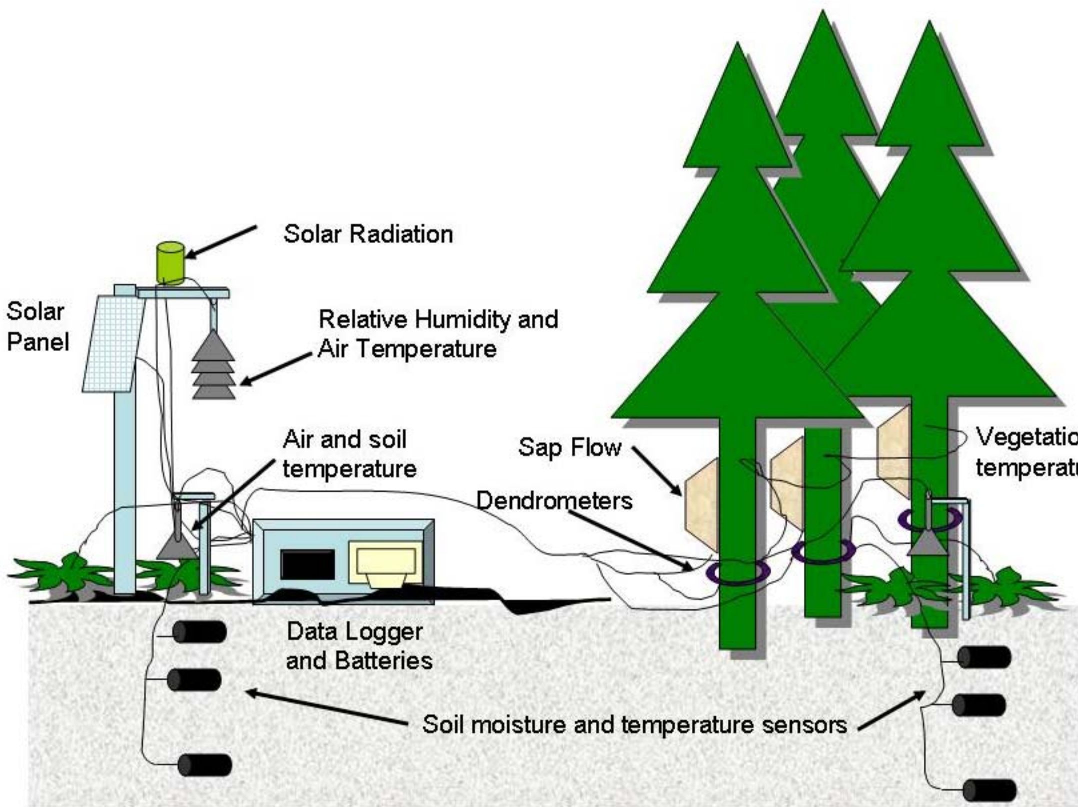



**Figure 1**: Sketch of a complete instrument set-up. The soil moisture, sap flow, dendrometer, air and vegetation temperature, and meteorological sensors are diagrammed along with the data logger, battery and solar panel. For the set-up at the Cary Institute, meteorology and soil moisture measurements are provided by the CREST weather station installed nearby.

References:

Skinner, C. B., A. T. DeGaetano, and B. F. Chabot. "Implications of twenty-first century climate change on Northeastern United States maple syrup production: impacts and adaptations." *Climatic change*100.3-4 (2010): 685-702.

http://botanistinthekitchen.wordpress.com/2013/03/18/maple-syrup-mechanics/

http://nsidc.org/data/nsidc-0477/

Activities:

1. How does satellite data help us distinguish healthy from non-healthy vegetation?

2. Rank land cover with approximate LAI values lower to higher:  Wetland, Shrub, Forest, Cropland, Dessert.

3. Why soil moisture is important in monitoring flash flood and agriculture?

4. What parameters does a meteorological weather stations normally measures?

5. How surface (skin) temperature differs from air temperature?

6. Why do some trees lose their leaves in winter?

7. How does microwave radiometer works? What frequency is used in measuring soil moisture?

8. Name all the satellites that are used to monitor surface temperature?

9. Name all the satellites that are used to monitor vegetation?

10. Name ten uses of satellites?