Using Pyranometer Data to Understand Earth's Radiative Balance and Clouds

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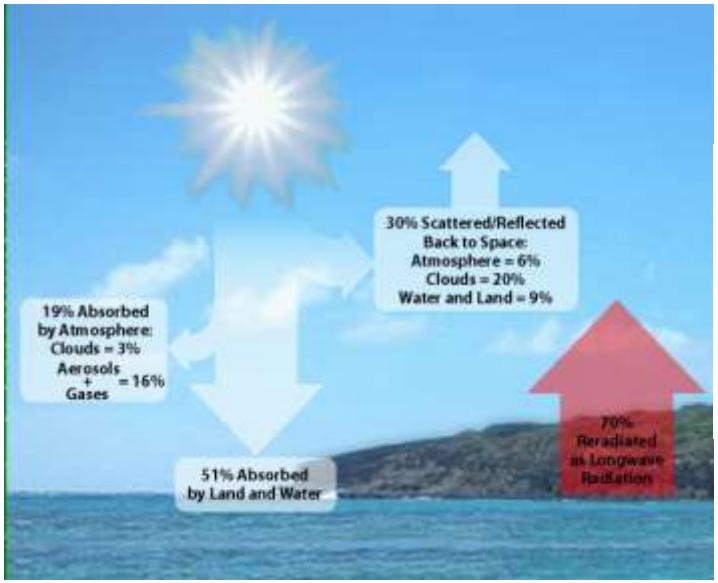
Topics for this presentation

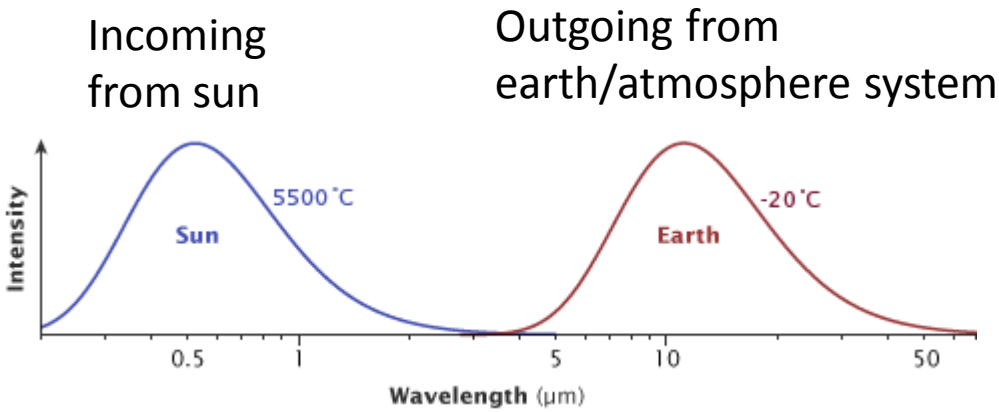
- What is a pyranometer?
- Using pyranometer data to understand climate and weather
- Using insolation data to characterize clouds
- Building your own pyranometer
- Collecting insolation data
- Other uses for pyranometers

What is a pyranometer?

- Pyranometers measure radiation reaching Earth's surface from the sun, in units of W/m^2.
- Research-grade instruments use thermopile detectors (US$5,000-$10,000).
- Pyranometers for routine monitoring use silicon photodetectors (commercial instruments in the range US$200-$500)
- Students can build their own very reliable silicon-based pyranometers for less than US$20 (more about that later!)

Pyranometers and Earth's radiative balance



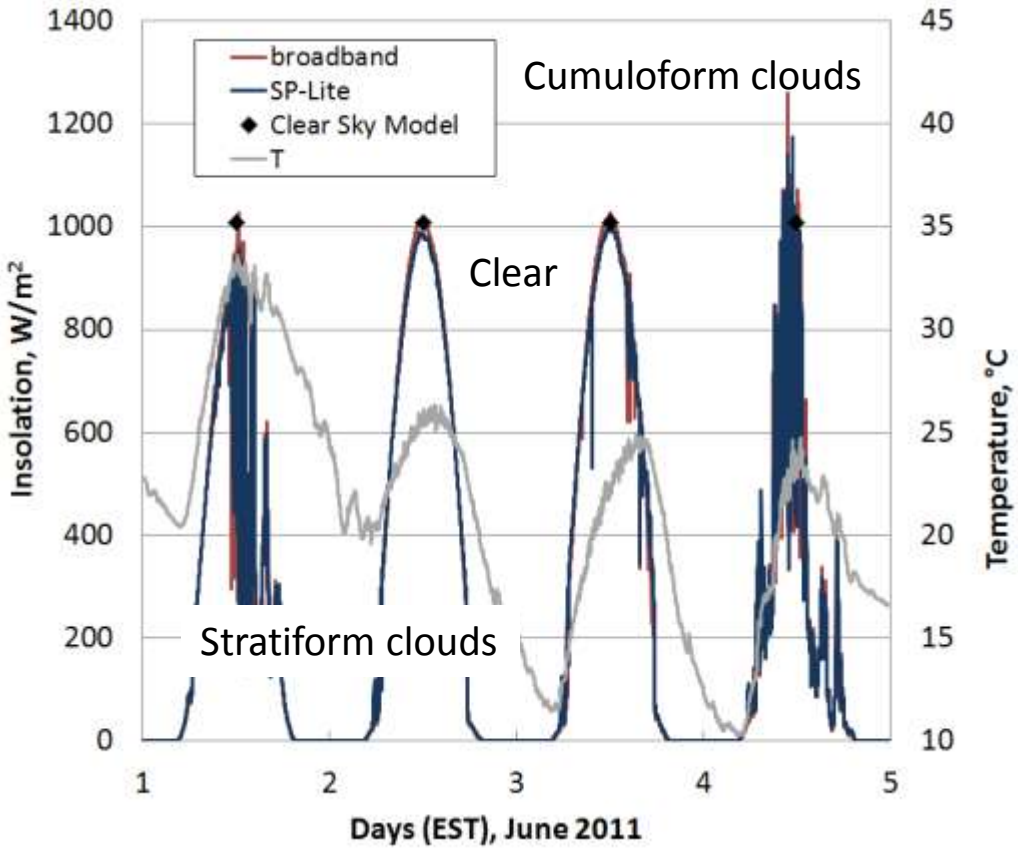


- Solar radiation reaching Earth is reflected (30%) or absorbed (70%) by the atmosphere or surface.
- The absorbed radiation is then re-radiated in the form of longwave (thermal) radiation.
- Solar energy is the driving force for creating and maintaining Earth's weather and climate.

Insolation data provide a window into weather and seasonal changes

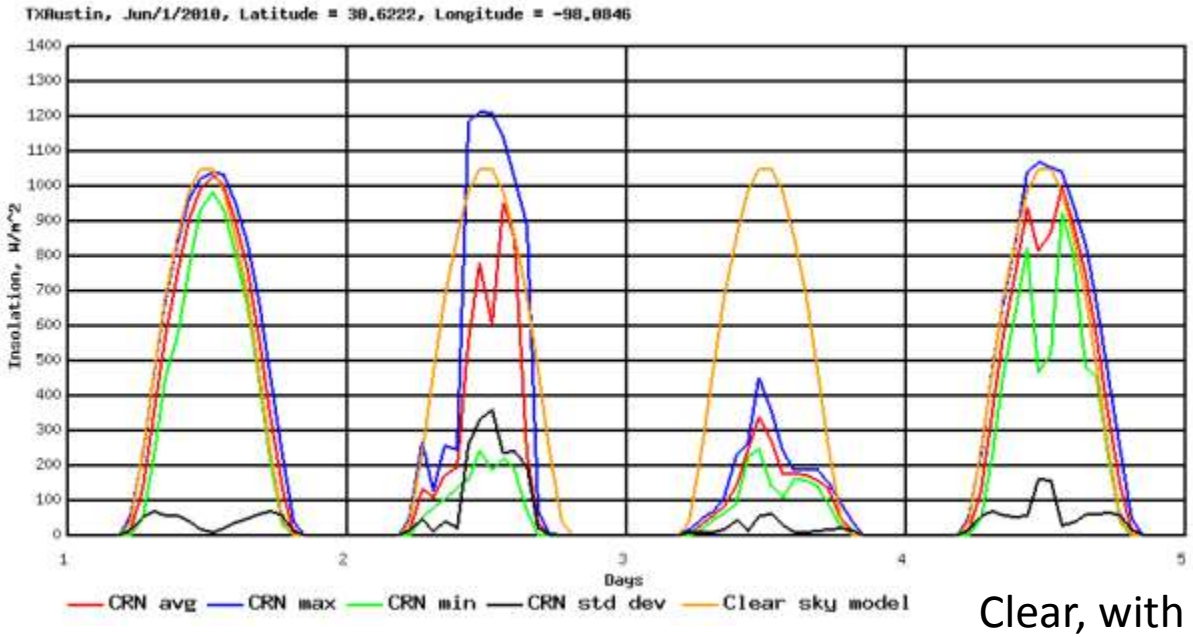
Partly cloudy skies produce distinctive insolation patterns, depending on cloud type and amount.

one-minute samples,
Worcester, PA USA
40°N, 75°W



Insolation data, NOAA Climate Reference Network (CRN)

One-hour averaged insolation at ~125 sites around the U.S. – mean, max, min, “standard deviation” (a measure of range during the hour, not a “statistical” standard deviation)



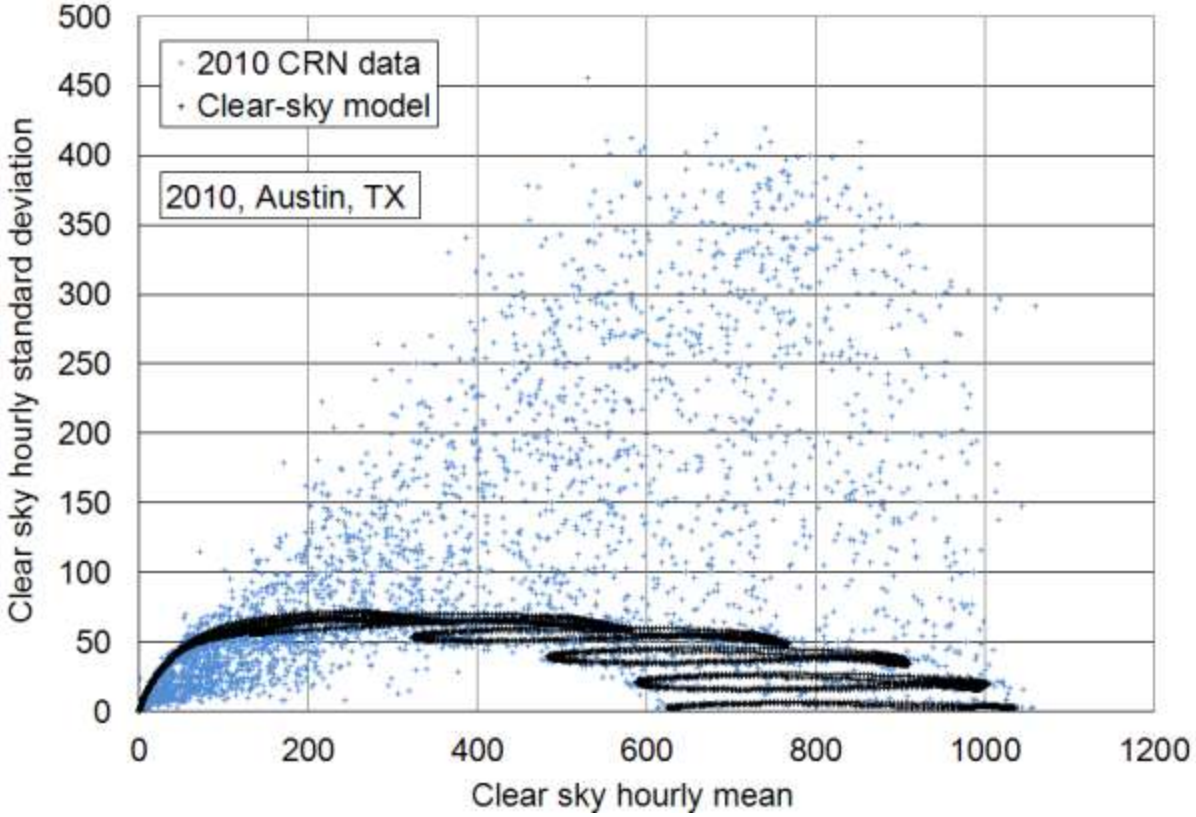
Clear

Overcast

Clear, with stratus around mid-day

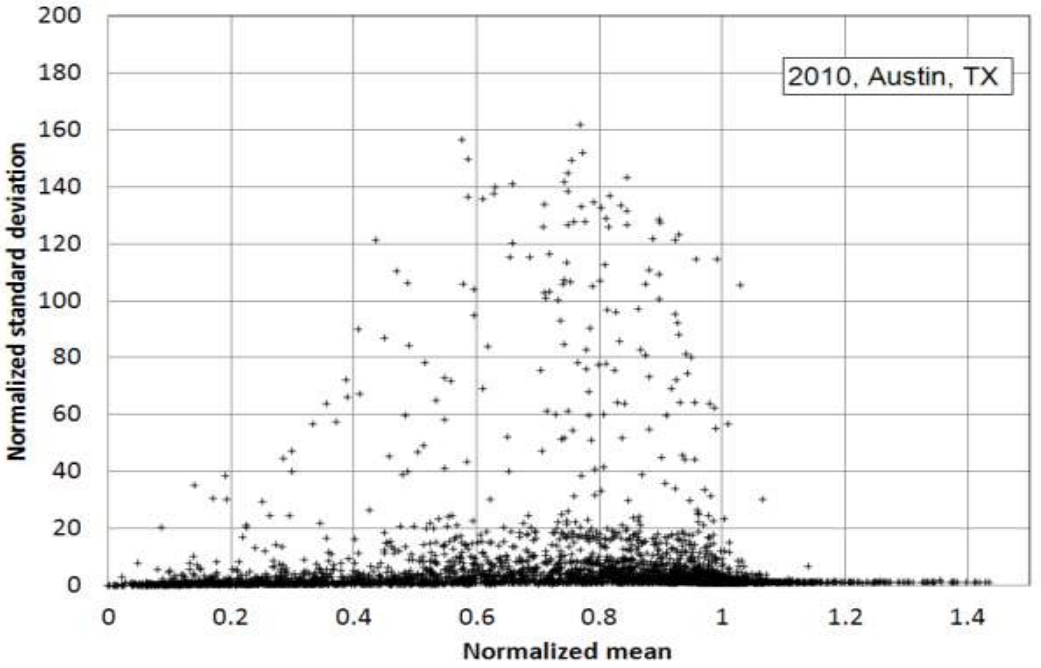
Overcast in the morning,
Scattered cumulus around mid-day,
overcast again in late afternoon

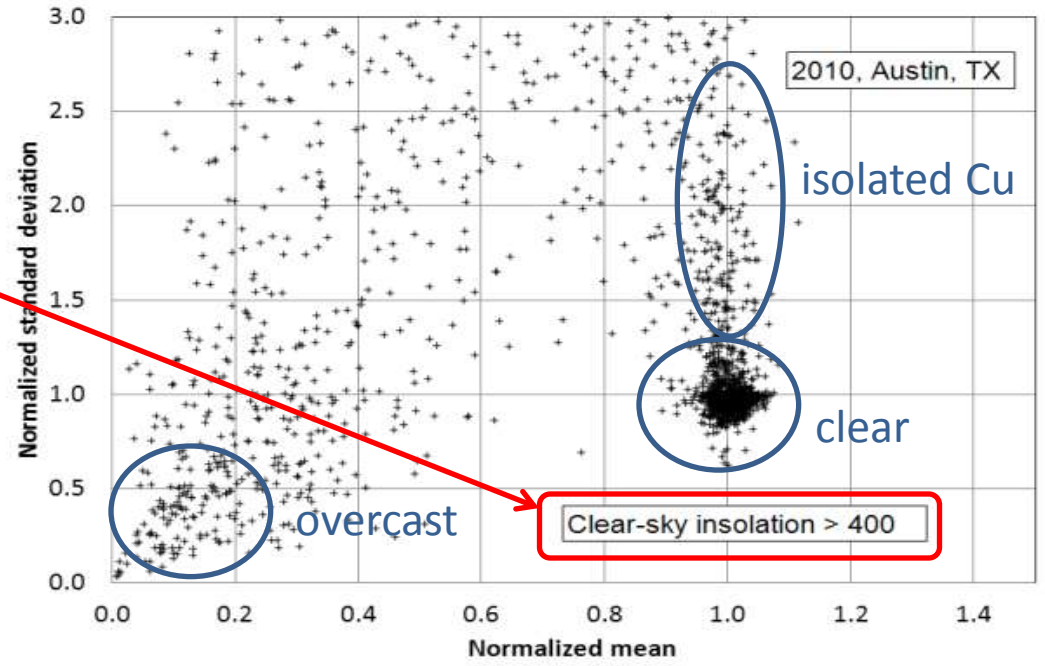
The range and variability of insolation compared to a clear-sky model provides a window into cloud patterns



“Normalized” insolation data (observed/clear sky) provide a way to quantify cloud characteristics

Examining subsets of the data provides insights into cloud characteristics.

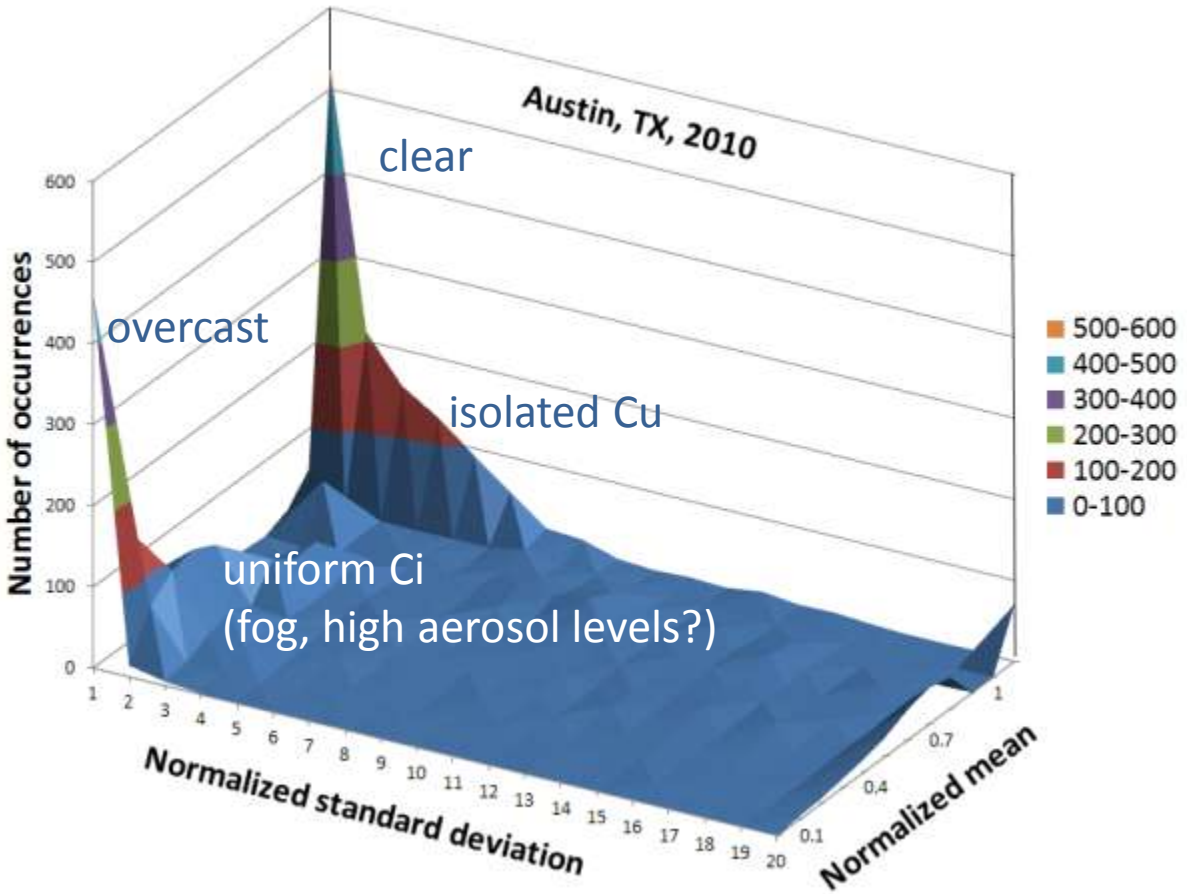




Mid-morning to mid-afternoon

Contour plots characterize cloud characteristics at a particular site. Will these patterns change over time as a result of climate change?

All 2010 data (seasonal data are also of interest)



Build your own pyranometer

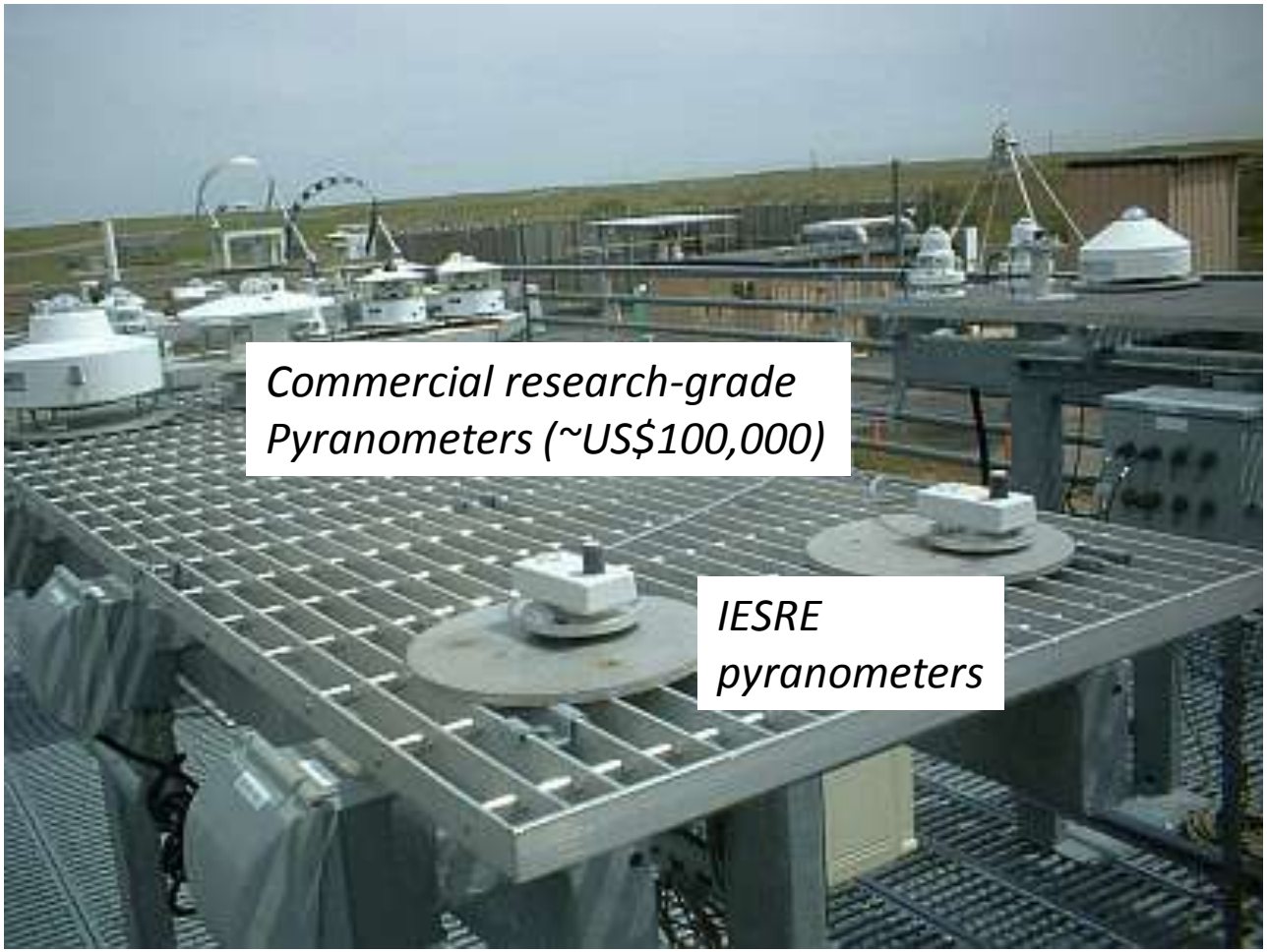
A pyranometer requires just a few parts:

* a silicon photodetector and housing
* a “bullseye” level (bubble level)
* a resistor to produce an output voltage proportional to incoming solar radiation
* a case to hold the detector assembly
* a cable to connect to a data logger

The *Institute for Earth Science Research and Education* has sold hundreds of pyranometers in kit form (US$20) and assembled and calibrated. Kit-built pyranometers must be calibrated against a reliable standard or by using a clear-sky model over time. Once calibrated properly, these instruments will produce reliable data for years. The least expensive commercial silicon-based pyranometer costs about US$200.

(See http://www.instesre.org/construction/pyranometer/pyranometer.htm

Calibrating *IESRE* pyranometers at the National Renewable Energy Laboratory, Golden, CO



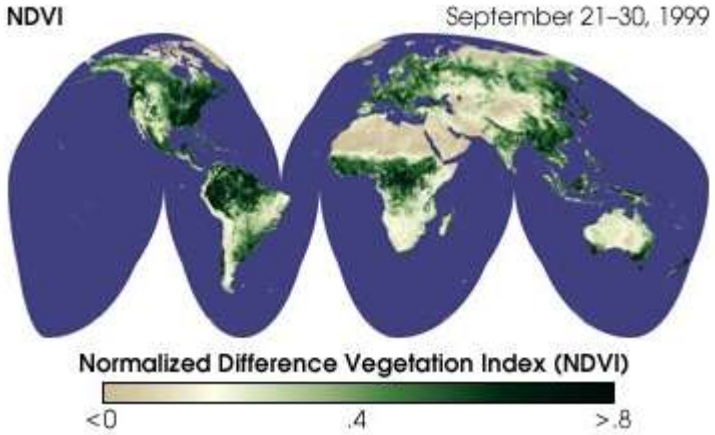
Establishing a site for collecting insolation data

- Find a location where there is an unobstructed view of the horizon and where instruments are easy to access and will be safe from vandalism. (A flat school rooftop may be a good site for this measurement.)
- Construct a platform where a pyranometer can be mounted horizontally. If possible, it is a good idea to have two pyranometers to protect against data gaps.
- Connect the pyranometer(s) to a data logger in a nearby location that is also easily accessible. The data logger must be protected from moisture! It may be possible to use long cables that will reach through a window into a classroom.
- Collect data at one-minute intervals. Download your data once a week and send the files to a central collection site.
- Analyze your data to make sure that equipment is working properly. (Use a clear-sky model as a reference against which to compare your data.)
- You may wish to collect other meteorological data as well as sky photographs. (Use a convex mirror if you have one, to get images of the entire sky.)

What else can you do with a pyranometer?

- You can monitor the performance of solar photovoltaic and solar thermal systems.
- With two pyranometers – one pointing up and one pointing down – you can measure surface reflectivity.

- With a second detector – a physically identical near-IR version of the broadband silicon photodiode – you can generate data related to the Normalized Difference Vegetation Index (NDVI).



These measurements do not require an absolute radiometric calibration – only a relative calibration between pairs of detectors.

In conclusion…

- Pyranometry is an ideal student measurement.
- Once a monitoring site is established, data are easy to collect.
- Understanding insolation data helps students understand weather, seasons, and climate.
- Reliable insolation data have considerable scientific value.
- Insolation data are critical for understanding and implementing renewable solar energy.