Atmospheric Radiation Measurement Program
Tropical Western Pacific

Nauru Site (ARCS-2) Instrument Book

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What is "Watt-Per-Square-Meter" (W/m^2)?

The watt-per-square-meter (W/M^2) is a measure of energy density or the amount of energy falling on a unit of area in a specific time period. Light bulbs come in different wattages – 50, 100, 150 watts (W). The higher the wattage the brighter they are and the more electricity they use. If all the energy (light and heat) that a 100-watt light bulb puts out were concentrated on a square area, 1 meter by 1 meter, then the energy density would be 100 watts per square meter. At noon on a clear day, the sun produces about 1000 W/m^2. That is like having 10 100-watt light bulbs producing energy in a square 1 meter on a side.

SKYRAD Instruments

SKYRAD Black & White (shaded) Precision Spectral Pyranometer (PSP)

The Black & White PSP measures the amount of solar radiation (sunshine) that falls on the sensor under the clear dome.

When the Black & White PSP is mounted on the solar tracker and shaded from the direct beam of the sun it measures only that part of the solar radiation that is scattered downward by clouds, other material in the air, and the air itself. The value is called the “diffuse” solar irradiance. On a clear day at Momote at noon it should measure about 100 watts per square meter. The diffuse component will increase when clouds are present.

The Black & White PSP is different from the unshaded PSP because it is lees affected by radiation cooling.

SKYRAD Shaded Precision Infrared Radiometer (PIR)

The PIR measures the amount of infrared (heat) energy that falls on a sensor under the shiny dome. This energy is the same heat energy you feel when standing next to a campfire or cook stove. The shiny dome reflects solar radiation but allows infrared radiation to pass through.

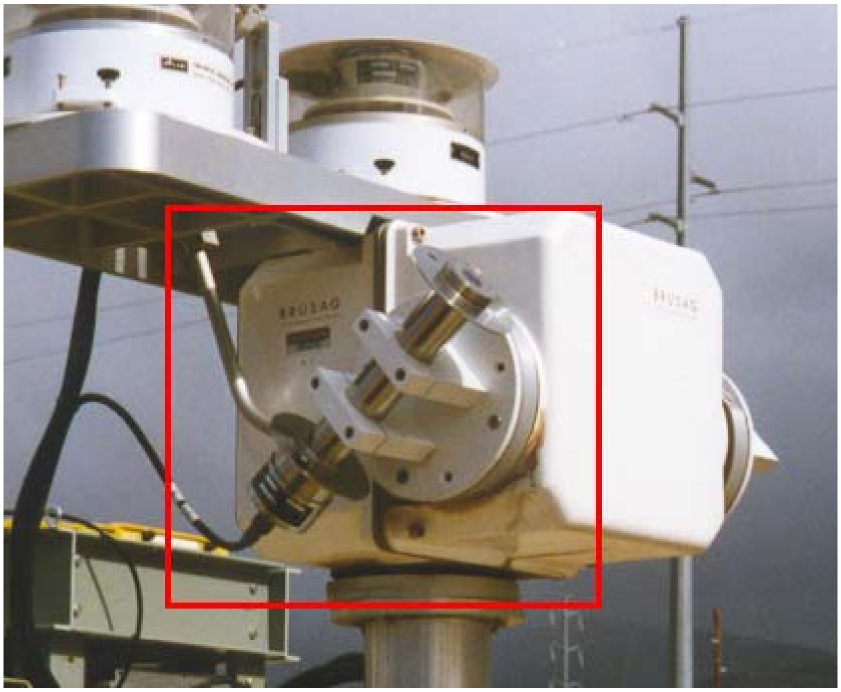
This PIR is mounted on the solar tracker and its sensor is shaded from the direct beam of the sun. The shading prevents heating of the dome and instrument by the direct sunlight; this heating could produce errors in the measurement. The value measured by this PIR should be very nearly the same as that measured by the unshaded PIR.

SKYRAD Unshaded Precision Spectral Pyranometer (PSP)

The PSP measures the amount of solar radiation (sunshine) that falls on the sensor under the clear dome.

When pointed upward and not shaded, the PSP measures the total amount of solar radiation coming directly from the sun plus that which is scattered downwards by clouds, other material in the air, and the air itself. This value it measures is called the “total” or “global” solar irradiance. On a clear day at Momote at noon, it should measure about 1100 watts per square meter. The value will be reduced when clouds are present.

Normal Incidence Pyrheliometer (NIP)



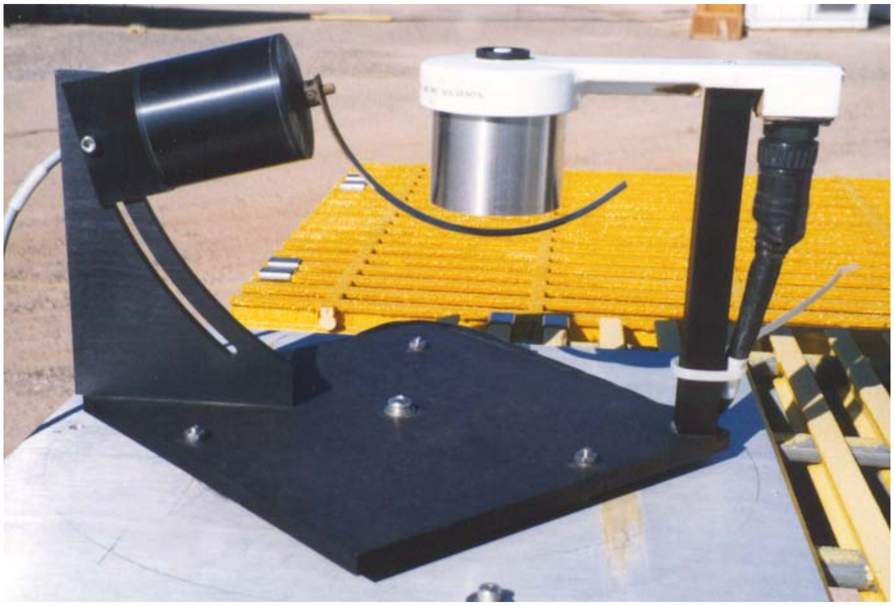
The NIP is like a narrow view telescope. It has a sensor at the viewing end that measures the amount of solar radiation that falls on it. The NIP is mounted on the solar tracker so that it is always pointing directly at the sun. The value that it measures is called the “direct” solar irradiance and on a clear day at noon at Momote it will have a value of about 1000 watts per square meter. This value will decrease when the sun is lower in the sky. When thick clouds are present (that is when the solar disk cannot be seen), the NIP should measure approximately zero.

Upward Pointing Infrared Thermometer (IRT)

The IRT measures the temperature of an object that it is pointing at by measuring the infrared radiation coming from the object. If you pointed it at a cooking fire it would tell you the temperature of the fire.

When the IRT is pointed upward, it measures the radiation temperature of the atmosphere or something called “sky temperature.” On a clear day at Momote, the sky temperature might be –20^{o}C. When there is a low cloud overhead the IRT measures the temperature of the bottom (or base) of the cloud. Low clouds might have a base temperature of +10^{o}C. When there are higher clouds, the IRT measures a combination of the radiation temperature of the atmosphere and the high cloud.

Multi-Filter Rotating Shadowband Radiometer (MFRSR)



The MFRSR uses measurements of the total and diffuse solar radiation to determine properties of the atmosphere. The MFRSR has a black shading arm that rotates over the sensor every 15 seconds. When the sensor is unshaded it measures total solar irradiance. When the shading arm blocks the sun from the sensor, the MFRSR measures the diffuse solar irradiance. The direct solar irradiance can be calculated by subtracting the diffuse value from the total value.

The MFRSR actually makes seven simultaneous measurements with seven detectors. One of these detectors measures all the sunlight coming in; this value is very similar to that obtained by the unshaded upward looking PSP. The other six measurements use the same kind of detector with different filters in front of them. These filters only allow certain portions of the sunlight to pass through them and on to the detector. As with the NIP, the amount of direct solar radiation depends on the height of the sun above the horizon and the cleanliness of the atmosphere. By measuring the direct solar irradiance at different sun angles, it is possible to calculate the amount of solar radiation at the top of the atmosphere and the amount that is removed by the atmosphere before it reaches the ground.

SKYRAD UVB Radiometer

The instrument mounted on the SKY stand, measures ultraviolet radiation. This component of radiation may cause skin cancer. The amount of this radiation that reaches the surface of the earth depends on the amount of ozone in the upper atmosphere.

GNDRAD Instruments

GNDRAD Precision Spectral Pyranometer (PSP)

The PSP measures the amount of solar radiation (sunshine) that falls on the sensor under the clear dome.

When the PSP is pointed downward, it measures the amount of solar radiation reflected from the surface below. The value it measures depends on the amount of sunshine hitting the surface and how well the underlying surface reflects the sunshine. On a clear day at Momote at noon, it should measure about 200 watts per square meter reflected from the grass below.

GNDRAD Precision Infrared Radiometer (PIR)

The PIR measures the amount of infrared (heat) energy that falls on a sensor under the shiny dome. This energy is the same heat energy you feel when standing next to a campfire or cook stove. The shiny dome reflects solar radiation but allows infrared radiation to pass through.

When the PIR is pointed downward it measures the upwelling infrared irradiance or heat energy given off by the surface below. When the grass is dry on a clear day at Momote at noon, the value the PIR measures is about 500 watts per square meter.

Downward Pointing Infrared Thermometer (IRT)

The IRT measures the temperature of an object that it is pointing at by measuring the infrared radiation coming from the object. If you pointed it at a cooking fire it would tell you the temperature of the fire.

When the IRT is pointed downward at the grass it measures the temperature of the grass. If you pointed it down on the airport runway, it would measure the temperature of the runway. This value is called the “surface temperature” and depends on the surface material, general weather conditions at the site, and the time of day.

Meteorological Tower (MET) Instruments

There are several instruments associated with the meteorological tower. These measure wind speed and direction, temperature, humidity, atmospheric pressure, and rainfall.

Propeller Van Wind Sensors

Two propeller vane wind sensors are mounted on the top of the meteorological tower. The propeller measures the wind speed. The direction of the wind is measured by the position of the vane. There are two propeller vanes so that data is not missed if one should fail.

Temperature and Humidity (T/RH) Sensors

The temperature and humidity sensors are mounted inside a tube to protect them from direct sunlight. The tube is attached to the meteorological tower near the bottom. A small fan at one end draws air into the tube and over the sensors.

Barometer

A barometer is housed inside the white cylinder at the base of the meteorological tower. A tube connects the barometer to the outside. Moisture is prevented from entering the barometer by a larger tube filled with water absorbing material. This cylinder also contains a special type of computer (called a datalogger) that collects from the instruments.

Optical Rain Gauge (ORG)

The ORG is mounted on a small pole near the meteorological tower. The ORG measures the rate of rainfall in millimeters per hour (mm/hr). The ORG sends a beam of light (which you cannot see) from one of its ends to a detector at the other end. When raindrops fall, they break the beam. The rain rate is measured by the ORG by measuring how often the beam is broken. The rain rate can be used to calculate the total amount of rain that has fallen in any given period.

Microwave Radiometer (MWR)

The MWR measures the total amount of water vapor and liquid water from the surface to the top of the atmosphere. Water vapor is just the water molecules in the air; you can't see them. Liquid water is the water droplets in the clouds. The value the MWR reports for the water vapor is what you would get if you could get all the water vapor above a rain gage to condense as liquid water in the gage. Typical values for water vapor in the tropics range from 4-6 centimeters. Although clouds look like they contain a lot of water, the liquid water values the MWR measures are usually a few tenths of a millimeter. The MWR does not detect ice. Clouds higher than 5 kilometers are usually composed of ice particles rather than water drops and the MWR will not detect them.

Ceilometer

The Ceilometer is located near the back of the instrument van. The Ceilometer measures the distance from the ground to the bottom of a cloud directly overhead. This distance is called “cloud base height.” The Ceilometer can measure cloud bases up to about 8 kilometers above the surface. The Ceilometer sends out a pulse (flash) of light and measures how long it takes for it to come back to the Ceilometer after being reflected off the bottom of a cloud.

How the Ceilometer Works

Suppose you drove a car or truck at 40 kilometers per hour from Momote to Lorengau and back to Momote without stopping. If it took you an hour to make the round trip, then you could calculate how far it is from Momote to Lorengau. We know that the distance traveled is the speed multiplied by the time it takes.

Distance for Momote to Lorengau and back to Momote – (40 m/hr) x (1 hr) = 40 km.

But this is twice the distance, so the distance from Momote to Lorengau is half that or 20 km.

We know how fast light travels so we can do the same thing to figure out the heights of clouds. Light travels at 186,000 miles per second. It takes very good detectors and electronics to measure such a high speed.

Micro Pulsed Lidar (MPL)

The MPL works just like the Ceilometer but can see clouds that are much higher. The MPL can detect cirrus clouds in the tropics, which can be as high as 16-17 kilometers above the ground.

Millimeter Wave Cloud Radar (MMCR)

The MMCR is a zenith-pointing radar that operates at a frequency of 35 GHz. The main purpose of this radar is to determine cloud boundaries (e.g., cloud bottoms and tops). This radar will also report radar reflectivity (dBZ) of the atmosphere up to 20 km. The radar has a doppler capability that allows the measurement of cloud constituent vertical velocities.

Balloon-Borne Sounding System (BBSS)

The Balloon-Borne Sounding System (BBSS) provides in situ measurements (vertical profiles) of both the thermodynamic state of the atmosphere and the wind speed and direction.

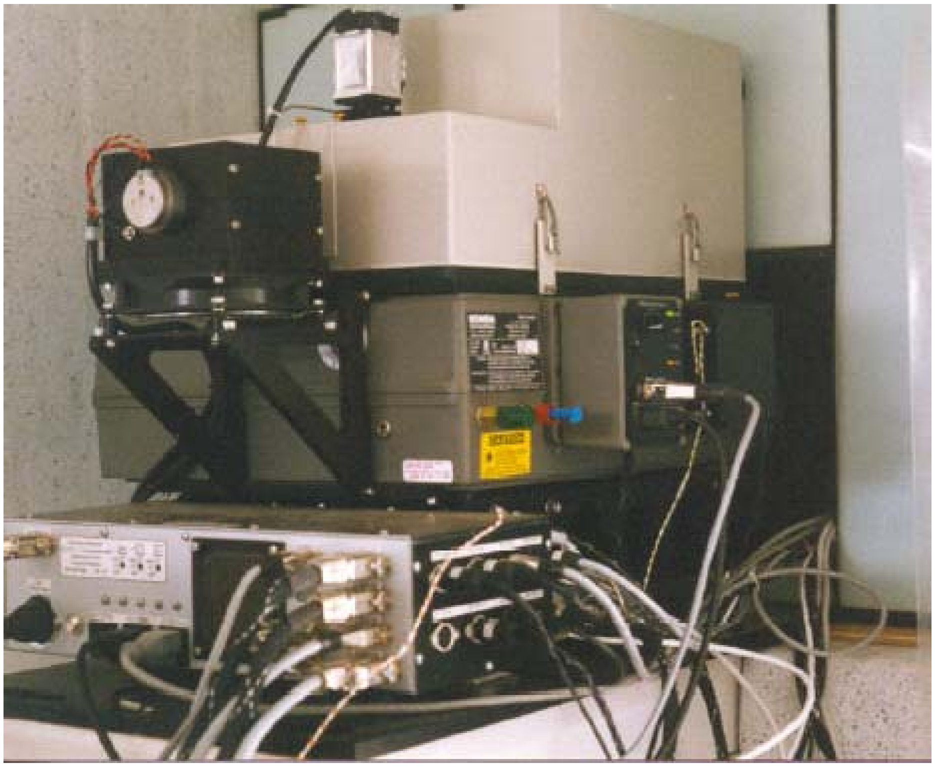
Whole Sky Imager (WSI)

The Whole Sky Imager (WSI) is an automated imager used for assessing and documenting cloud fields and cloud field dynamics. The WSI is a ground-based electronic imaging system that monitors the upper hemisphere. It captures sky images. We can then assess the presence, distribution, shape, and radiance of clouds over the entire sky using automated cloud decision algorithms and related processing.

Total Sky Imager (TSI)

The Total Sky Imager (TSI) provides time series of hemispheric sky images during daylight hours, and retrievals of fractional sky cover for periods when the solar elevation is greater than 5 to 10 degrees.

Atmospheric Emitted Radiance Interferometer (AERI)



The AERI measures a spectrum of heat radiation of the sky directly above the instrument. A spectrum is a distribution of energy across a range of wavelengths. Because the AERI measures a spectrum of heat radiation, its data produces profiles of temperature and water vapor of the atmosphere above the instrument. Scientists also use the AERI data to improve models of how heat radiation behaves in the earth's atmosphere.

CIMEL Sunphotometer

The CIMEL Sunphotometer is a multi-channel, automatic sun-and-sky scanning radiometer that measures the direct solar irradiance and sky radiance at the Earth's surface. Measurements are taken at pre-determined discrete wavelengths in the visible and near-IR parts of the spectrum to determine atmospheric transmission and scattering properties. This instrument is weather-proof and requires little maintenance during periods of adverse weather conditions. It takes measurements only during daylight hours (sun above horizon).