8. Solar Radiation Measurements

There are three major spectral regions in which measurements of solar radiation are desired: UV (UV-A, around 386 nm; UV-B, around 306 nm), Solar (0.3–3.0 μm, also known as VISIBLE radiation) and IR (greater than 3 μm).

There are different ways in which to measure the incoming (UV and solar) radiation. You can measure global, direct or diffuse radiation. Diffuse radiation measurement instruments cover the whole hemisphere (180 degrees viewing angle) and are shaded from the sun. The detector is placed horizontally. Direct radiation meters are aimed directly at the sun, so the detector surface is at right angles with the incoming radiation. When measuring global radiation, the instrument receives both the diffuse and direct component on a horizontally placed detector.

The requirements for measuring solar radiation are largely dependant on the accuracy that is wanted.

For measuring global solar radiation, the standard instrument is a pyranometer. Its equivalent for the far infrared range is called a pyrgeometer. For the UV range the instruments are UV, UV-A or UV-B radiometers.

By 'shading' a pyranometer from the direct radiation (coming directly from the sun) one can measure the diffuse radiation (coming from the hemisphere, not directly from the sun).

For the measurement of direct radiation one can either use a calculation (global minus diffuse, corrected for the cosine of the zenith angle of the sun) or a measurement with a tube shaped detector that has to be aimed at the sun. The latter instrument is called a pyrheliometer. A measurement with a pyrheliometer is more accurate, but at the same time it demands more attention. There exists also a pyrheliometer version of the UV radiometer.

All the instruments mentioned are available in different accuracy classes, varying from reference instruments (+/- 0.5 %) to second class instruments (roughly +/- 10 %).

Three of the basic instruments, pyranometer, pyrheliometer and pyrgeometer are all based on a thermal detector. This detector has a flat spectral response. The differences are in a filter material and in field of view. For a pyranometer and pyrheliometer the filter material, which also protects the sensor against environmental influences, is glass, only letting solar radiation (0.3–3 μm) pass. For a pyrgeometer, the material used is coated silicon, only allowing far infrared radiation (3–50 μm) to pass.

A pyrheliometer has a limited field of view (5 degrees opening angle). The thermal detectors have a small voltage output, linearly proportional to the incoming radiation. Since 1993, pyranometers and pyrheliometers have been characterized according to the ISO standard number 9060. This ISO standard can act as a guideline in choosing the right detector specification. There is no ISO standard defined for pyrgeometers or UV radiometers.

The UV radiometers are different in both detector type and filter specifications. UV-B and UV-A radiometers have a narrow band sensitivity. For the UV-B radiometer, the central wavelength is at 306 nm because the optimum effect is reached when the human skin (Erythermal) spectrum and the solar spectrum are multiplied. The UV-A radiometer central wavelength, 386 nm, is chosen because this particular wavelength is also used in the WMO air pollution network.

Ventilation of radiation meters improves the accuracy and the reliablity of the measurements. It minimizes certain offsets and keeps the measuring instruments free from dew and frost.

The second trend is combining the tracking of pyrheliometers and the shading of pyranometers.

8.1 Radiation Detectors

Radiation quantities which have to be measured in solar energy research and application:

- Total (global) irradiance Total amount of solar irradiance on an upward-facing surface; sum of vertical component of direct normal solar irradiance and the diffuse sky irradiance. It is measured either with a pyranometer or more accurately by summing the direct and diffuse horizontal irradiance.
- Diffuse irradiance
  Radiation that reaches the ground that has been scattered by the atmospheric constituents. It is measured with a pyranometer that is continually shaded from the direct solar irradiance.
- Direct irradiance
  Solar radiation passing directly through the atmosphere from the sun without beeing scattered or absorbed by the atmosphere. Typically it is measured on a surface that is kept normal to the direction the center of the suns disc by a solar tracker.
- Spectral irradiance
  higher spectral resolution than broadband measurements. Typically in spectral bands of several to a few 10s of nanometers. The direct irradiance in certain narrowband channels is measured by sunphotometers. These observations can be used to derive the total transmittance of the atmosphere within the respective spectral band which can in turn be used to deduce aerosol optical depths.
- Sunshine hours (sunshine duration)
  duration of sunshine, only qualitative

Only broadband instruments will be treated in detail!

Different types of radiometric detectors:

calorimetric: radiant energy absorbed by an high-conductivity metal (black painted) is converted into heat that is measured;
temperature rise is measure of irradiation $\rightarrow$ absolute instrument possible

thermomechanic: different thermal expansion properties of two metal stripes when exposed to radiation lead to different distortions, which are measured
example: pyranographs (inaccurate!)

thermoelectric: two junctions of dissimmilar metal wires at different temperature lead to a voltage difference (electromotive force), it is $V \sim \Delta T$ (Seebeck-effect). Examples: Copper-Constantan, Manganin-Constantan
thermopile sensors, usually: increasing EMF by coupling several thermocouples in series (thermopile)
important: cold junctions must be at constant temperature $\rightarrow$ thermal contact with massive brass plate
Plot: thermopile configurations

photoelectric: mainly photovoltaic effect, usually silicon solar cell detector, usually temperature compensated.
advantage: cheap, fast response; disadvantage: spectral sensitivity
frequently used in PV-plant monitoring!

Plot: PV-spectral sensitivity