Solar Radiation Monitoring **for Climate Change**

An introduction to The Baseline Surface Radiation Network of The World Climate Research Programme

Kipp & Zonen - Davos

Solar, atmospheric and terrestrial radiation (the radiation budget) drives almost every dynamic process on the Earth's surface and above, from ocean current circulation to weather, climate and life itself. Small changes can have large and long-lasting effects that are difficult to predict, so accurate determination of the radiation budget at the surface of the Earth is fundamental to understanding the Earth's climate system and climate change issues such as Global Warming and Global Dimming.

Unfortunately, global estimates of the surface radiation budget cannot be inferred reliably from satellite observations because the instruments change characteristics with time and cannot be calibrated in-situ. High accuracy, long-term, surface-based measurements at a variety of sites are required for calibration and validation (ground-truthing) of satellite data.

The Baseline Surface Radiation Network

The World Climate Research Programme (WCRP), jointly sponsored by the World Meteorological Organization (WMO), the International Council of Scientific Unions (ICSU) and the Intergovernmental Oceanographic Commission (IOC) of UNESCO, initiated the Baseline Surface Radiation Network (BSRN) to meet these demands. The goal is to provide data for calibrating satellite-based estimates of the surface radiation budget and radiation transfer through the atmosphere, and to monitor regional trends at the Earth's surface.

The network is global, with stations in the Arctic, forests, plains, high mountains, rain-forest, desert, and tropical islands. The BSRN website, www.ethz.ch, lists station locations. Sites have been specifically selected for determination of local climate trends and to provide accurate ground-truth for satellite observations.

The BSRN Operations Manual provides guidelines and requirements for all aspects of a solar radiation monitoring station, including; instruments, ancillary equipment, location, installation, operation, maintenance, calibration, data collection, quality control and data management. The instrumentation and operational procedures can be used as effective guidelines to upgrade equipment and methods of observation to the state-of-the-art with commercially available products. Traceability is to the World Radiation Centre in Davos, Switzerland.

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BSRN is associated with the WMO Global Atmosphere Watch (GAW), the Atmospheric Radiation Measurement (ARM) Program, the Global Energy and Water Cycle Experiment (GEWEX) and the Global Climate Observing System (GCOS).

Radiation at the Earth's surface is split into short-wave radiation in the wavelength range 300 to 4,000 nm (4 μm) and long-wave radiation range from 4.5 to > 40 μm. Measurements are usually made using thermopile type radiometers with a flat spectral response in the required wavelength range.

Kipp & Zonen's 2AP Solar Tracking System operating in Russia

The basic radiation measurements required

Direct Solar Irradiance - Short-wave radiation directly from the sun is measured by a Pyrheliometer with a 5˚ view that is pointed accurately at the centre of the sun by an automatic Sun Tracker.

Diffuse Solar Radiation - Radiation from the sun is scattered by aerosols in the atmosphere or reflected by clouds. This short-wave diffuse radiation is measured by a Pyranometer with a hemispherical view, mounted on the sun tracker and with a mechanism to shade the pyranometer from the direct solar irradiance.

Global Solar Radiation - This is measured by an un-shaded Pyranometer with a hemispherical view. The Direct Solar Irradiance plus the Diffuse Solar Radiation should equal the Global Solar Radiation.

Down-welling Infrared Radiation - Radiation from the sun is absorbed by clouds, aerosols and molecules in the atmosphere which warm up and radiate long-wave energy (infrared). This is measured by a Pyrgeometer with a hemispherical view, mounted on the sun tracker and shaded.

An 'expanded' station makes two additional radiation measurements

Reflected Solar Radiation - A Pyranometer looking downwards over a representative surface, such as grass, measures the reflected short-wave radiation. From this measurement and the Global Solar Radiation the Albedo can be calculated.

Upward Infrared Radiation - The surface for the Reflected Solar Radiation also emits long-wave radiation, which is measured by a Pyrgeometer looking downwards.

The signal output of each radiometer is normally acquired by a high accuracy multi-channel data logger that is programmed with the sensitivity of each radiometer, so that data can be stored correctly in units of W/m^2. The radiometers and data logger must be very stable under a wide range of environmental conditions. Together with local meteorological data these measurements enable accurate calculation of the radiation budget (energy balance).

Instrumentation improves and the initial performance targets for BSRN have been revised twice, as shown below:

The 1997 targets are the minimum standard for a good quality solar radiation monitoring system for research into weather, climate or solar energy. The 2004 targets are achievable with the best currently available commercial instruments. ■

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BSRN Target Measurement Uncertainty

Quantity	1991	1997 Target	2004 Target
Basic BSRN Station			
Direct Solar Irradiance		1% or 2 W/m^2	0.5% or 1.5 W/m^2
Diffuse Solar Radiation	10 W/m^2	4% or 5 W/m^2	2% or 3 W/m^2
Global Solar Radiation	15 W/m^2	2% or 5 W/m^2	2% or 5 W/m^2
Down-welling Infrared Radiation	30 W/m^2	5% or 10 W/m^2	2% or 3 W/m^2
Expanded BSRN Station			
Reflected Solar Radiation	15 W/m^2	5%	3%
Up-welling Infrared Radiation	30 W/m^2	5% or 10 W/m^2	2% or 3 W/m^2