Solar Resource and Meteorological Assessment Project (SOLRMAP)
Solar and Meteorological Station Options:
Configurations and Specifications

December 12, 2008 (revised)
Steve Wilcox and Tom Stoffel
National Renewable Energy Laboratory

Purpose

This document provides guidance for standard measurement system configurations to produce solar resource information consistent with accuracy requirements for site-specific resource assessment and/or installed power system performance validation. The measured data will also be used for improving satellite-based modeling of solar radiation and for validation of solar resource forecasting methods. The configurations listed present a range of instrument accuracies from which to choose for the fundamental measurements as well as information necessary for data validation.

In support of the Solar Technologies Program, NREL will provide expert advice and assistance on configuring, installing and operating commercially available equipment for a solar radiation measurement station. Additionally, NREL will provide expert data analysis, including data quality assessment, archive the data and provide access to the historical and nearly real-time data via the internet through the Measurement & Instrumentation Data Center (http://www.nrel.gov/midc).

Background

Accurate site-specific measurements of solar radiation resources are important for the design of solar energy conversion systems and for assessing installed system performance. Measuring the electrical output of a solar power plant is a fairly straightforward effort and can be accomplished with high accuracy. However, evaluating the efficiency of renewable energy conversion requires knowledge of the solar energy incoming to the plant as measured with commercially available radiometers with varying accuracies.

Estimates of historical (1991 – 2005) hourly solar irradiance from satellite-based cloud imagery and surface cloud observations have been used to produce the National Solar Radiation Database Update (NSRDB) [http://rredc.nrel.gov/solar/old_data/nsrdb/1991-2005/]. A limited amount of accurate measurements of solar irradiance were used to validate these models. Measurements from additional locations are needed to develop improved models and address research needs for developing solar radiation forecast methods.

High quality instruments are available from various manufacturers. Price estimates from three manufacturers are included here for instruments with which we have experience. This list does not constitute an endorsement, nor does it preclude the selection and use of equipment from other manufacturers. However, equipment not listed here may be incompatible with the NREL calibration procedures or data acquisition and distribution infrastructure. The prices listed here are approximate and based on manufacturer’s price lists. Firm and final pricing is available by quote from the manufacturers.
Equipment

Two basic instrument packages are described below for making site-specific solar resource measurements or for instrumenting a solar energy conversion power plant to support operational needs for system performance and/or solar resource forecasting. The two configurations offer a range of measurement uncertainty and maintenance requirements. Each configuration provides sub-hourly data for the direct normal irradiance (DNI), diffuse (DIFF) irradiance, and the global horizontal (GH) irradiance, as well as ambient air temperature (TEMP), wind speed (WS) and direction (WD), and relative humidity (RH). Additional instrumentation can be added as required for site-specific applications, e.g., plane-of-array (POA) irradiance, barometric pressure (BP), and/or precipitation (PRECIP). The estimates below do not include infrastructure costs, such as underlying support surfaces or structures, electrical power, telephone/internet connectivity, etc.

Both configurations require a location for the instruments that provides good daily solar access throughout the year. This should be an area with a clear horizon without any obstructions that might shade the instruments or introduce reflected solar radiation (for instance, a building roof is often a good location). But the location should also have safe and secure access, which is required for regular equipment inspections.

Equipment spares are recommended to provide replacement due to failure and/or calibration, especially for the radiometers. Please consult with the manufacturer or NREL to determine the optimum types and quantity of equipment spares.

A total sky imager can supplement the data recorded from either recommended configuration. This all-weather instrument provides sky images and cloud amounts important for interpreting the coincident solar radiation and meteorological data. (See http://www.yesinc.com/products/cloud.html or http://www.nrel.gov/midc/srrl_bms/)

Configuration 1 – Silicon Photodiode Radiometers – Lower Cost / Lower Maintenance / Higher Measurement Uncertainty Potential

This lower-cost option provides solar measurements adequate for many applications and also requires a lesser amount of maintenance. The Rotating Shadowband Radiometer (RSR) system design is based on the fast response (10 µsec) of the silicon photodiode detector used in the pyranometer. The RSR system includes a data logger that provides additional input channels for optional sensors. The base configuration includes measurements for temperature, humidity, wind speed, and wind direction. The communications interface is a telephone modem (optional internet connectivity is highly desirable to allow for more frequent data access and display). This system is self-powered via photovoltaic panels and is desirable for use in areas without reliable grid electrical power. Instrumentation, measurement parameters, equipment purchase price, installation labor, and estimated measurement uncertainties for Configuration 1 are summarized in Table 1. Typical RSR installations are shown in Figure 1.

Figure 1. RSR installations at NREL (Left) and at Pueblo, Colorado (Right).
<table>
<thead>
<tr>
<th>Instrument</th>
<th>Data Parameter(s)</th>
<th>Purchase Price</th>
<th>Installation (Person-Hrs)</th>
<th>Bias (mean deviation)</th>
<th>Random (std deviation)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rotating Shadowband Radiometer System (Irradiance, Inc Model RSR2)</td>
<td>Measured GH and DIFF irradiances. Computed DNI. Includes secondary sensor, CR800 data logger with air temperature and gill shield.</td>
<td>$9,100</td>
<td>4</td>
<td>-3.5 to -7.5% DNI</td>
<td>16 to 19%†</td>
</tr>
<tr>
<td>Mounting Method</td>
<td>Simple pipe for flat surface (e.g. concrete pile)</td>
<td>$95</td>
<td>4</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Choose Power Supply (as needed)</td>
<td>10-watt module, charge controller and battery for high insolation (&gt;3 kWh/m²/2 day average during minimum month)</td>
<td>$500</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td></td>
<td>20-watt module, charge controller and battery (&gt;2 kWh/m²/2/day minimum)</td>
<td>$700</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Temperature and Relative Humidity</td>
<td>Campbell CS 215</td>
<td>$535</td>
<td>1</td>
<td>±0.2° temp ±2% RH</td>
<td>Not evaluated</td>
</tr>
<tr>
<td>Barometric Pressure</td>
<td>CS106</td>
<td>$885</td>
<td>1</td>
<td>±1 mbar</td>
<td>Not evaluated</td>
</tr>
<tr>
<td>Wind</td>
<td>03001-L RM Young WS/WD set with supporting 10 ft mast</td>
<td>$1050</td>
<td>2</td>
<td>±5° WD ±1.5% WS</td>
<td>Not evaluated</td>
</tr>
<tr>
<td>Communications</td>
<td>Telephone wired modem</td>
<td>$550</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Licor LI-200 pyranometer (optional)</td>
<td>POA for fixed tilt collector</td>
<td>$270</td>
<td>2</td>
<td>+2.8 to -2.0%</td>
<td>3 to 8%</td>
</tr>
<tr>
<td>Texas Electronics Tipping Bucket (Campbell p/n TE525-20)</td>
<td>PRECIP</td>
<td>$615</td>
<td>3</td>
<td>± 0.01”</td>
<td>Not evaluated</td>
</tr>
<tr>
<td>Communications Upgrades</td>
<td>Ethernet (hard wired)</td>
<td>$640</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td></td>
<td>Ethernet (cellular gprs/edge)</td>
<td>$1125</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Data logger upgrade to Campbell CR-1000</td>
<td>Required for meteorological instruments and optional solar instruments</td>
<td>$700</td>
<td>N/A</td>
<td>N.A.</td>
<td>N/A</td>
</tr>
<tr>
<td>Total</td>
<td>Minimal configuration</td>
<td>$12,620</td>
<td>12</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>With all options</td>
<td>$15,555</td>
<td>17</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* Estimated measurement uncertainty for sub-hourly data intervals over a wide range of zenith angles, based on annual instrument calibrations traceable to national and international measurement standards and other NREL evaluations. Assumes proper equipment installation and regular maintenance at two to three times per week. Radiometer uncertainty ranges account for spectral irradiance variations due to changes in atmospheric conditions. Uncertainties for daily, monthly, or annual means may be less. Radiometer uncertainties do not include data logging uncertainties.

† High random error may be exaggerated due to slower response of reference thermopile instruments (10 µsec vs. 1 sec)
Configuration 2 – Thermopile Radiometers – Higher Cost / Higher Maintenance / Lower Measurement Uncertainty Potential

This option, while of greater cost for both equipment acquisition and on-going maintenance, provides the lowest uncertainty measurements of global, direct beam, and diffuse solar irradiance. This configuration is recommended for operators requiring the best possible solar resource measurements for assessing power plant performance.

While a specific application may not require all three of the recommended solar components, one critical advantage of this option is the ability to maintain much tighter controls on data quality assessment through redundant measurements. That is, data quality tests include checks of internal consistency based upon:

\[
GH = DNI \cdot \cos(Z) + DIFF
\]

where, \( Z \) = solar zenith angle for the time of measurement.

Thus, removing one or more of the solar components that do not directly support a particular application will result in a much higher post-measurement uncertainty.

This system requires reliable electrical power or an adequate uninterruptible power supply such that electricity can be maintained without interruption for many weeks. A stand-alone PV system rated for at least 600 Watts with battery storage has been used successfully for this purpose. A site specific analysis should be done if PV power is required.

Maintenance for this option is more critical than Configuration 1. Daily instrument cleaning and tracker alignment checks are necessary to maintain the lower measurement uncertainty potential for this option. Routine preventative maintenance can be accomplished in about 15 minutes per visit. Corrective maintenance (e.g., solar tracker failure) can require several hours. Without a commitment to this ongoing maintenance schedule, much of the advantage afforded by higher instrumentation cost will be lost. Instrumentation, measurement parameters, equipment purchase price, installation labor, and estimated measurement uncertainties for Configuration 2 are summarized in Table 2. The system installation used for the DOE Atmospheric Radiation Measurement Program is shown in Figure 2 (see also http://www.arm.gov/about).

Maintenance

Proper operations and maintenance of the measurement system is critical for the production of accurate solar resource data.

Measuring solar radiation requires clean optics to prevent attenuation of the solar signal that reaches the instrument sensor and accurate solar tracking for proper alignment of instruments with the solar disk. Site operators will be responsible for maintaining the instrumentation as required by the application.

Studies have shown that the instrumentation in Configuration 1 is less prone to soiling from environmental conditions than that specified in Configuration 2 (see http://www.nrel.gov/docs/fy99osti/25374.pdf, section 8.3). The recommended interval for cleaning instruments in Configuration 1 is two to three times a week, depending on weather conditions, whereas daily maintenance is required for Configuration 2 to fully exploit the reduced uncertainty of the instruments. NREL has developed real-time data quality control test methods that can be used to alert
the station operator of suspected equipment problems. On-site maintenance needs for either configuration are summarized in Table 3. A permanent record of maintenance activities is a critical tool for evaluating the quality of the measured data (see http://www.nrel.gov/midc/apps/maint.pl?BMS).

**Data processing/analysis**

NREL may provide expert analysis and quality checks for all data. Data may be acquired in near-real time (depending on internet connectivity at the station location) and analyzed for quality. NREL may provide easy internet access to sanctioned data sets in a standard format. Data may appear on an NREL web site, similar to this (data from the Nevada Power Clark Station):
http://www.nrel.gov/midc/npcs/

Special access limitations can be provided for proprietary data sets. To help maintain the greatest potential for the site operator’s investment, NREL may also fund data analysis, distribution costs and provide expertise as required to understand and interpret the data.

![Figure 2. Unshaded pyranometer (Left) for GH measurement, shaded pyranometer and pyrgeometer (on solar tracker horizontal platform) for DIFF and downwelling longwave (infrared – for atmospheric science study), and pyrheliometer (on sided of solar tracker) for DNI measurements at the DOE/ARM Southern Great Plains station near Lamont, Oklahoma.](image-url)
Table 2. Equipment Configuration 2 – Higher Cost / Higher Maintenance / Lower Measurement Uncertainty Potential

<table>
<thead>
<tr>
<th>Instrument</th>
<th>Data Parameter(s) / comments</th>
<th>Purchase Price</th>
<th>Installation (Person-Hrs)</th>
<th>Bias (mean deviation)</th>
<th>Random (std deviation)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Baseline Configuration</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pyrheliometer</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Eppley Model NIP</td>
<td>DNI</td>
<td>$2,350&lt;sup&gt;1&lt;/sup&gt;</td>
<td>2</td>
<td>±0.46 to -0.53%</td>
<td>0.4 to 0.6%</td>
</tr>
<tr>
<td>Kipp &amp; Zonen Model CH1</td>
<td></td>
<td>$3,500&lt;sup&gt;2&lt;/sup&gt;</td>
<td>2</td>
<td>+0.23 to +0.1%</td>
<td>0.4 to 0.5%</td>
</tr>
<tr>
<td>Ventilated Pyranometer</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Eppley Model PSP w/VEN ventilator</td>
<td>GH</td>
<td>$3,200&lt;sup&gt;1&lt;/sup&gt;</td>
<td>6</td>
<td>+1.6 to -11.3%</td>
<td>2 to 8%</td>
</tr>
<tr>
<td>Kipp &amp; Zonen Model CM22 w/CV-2 Ventilator and CVP-2 Power supply</td>
<td></td>
<td>$9,016&lt;sup&gt;2&lt;/sup&gt;</td>
<td>6</td>
<td>-0.6 to +0.4%</td>
<td>2 to 3%</td>
</tr>
<tr>
<td>Ventilated Pyranometer</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Eppley Model 8-48 w/VEN ventilator</td>
<td>DIFF</td>
<td>$2,475&lt;sup&gt;1&lt;/sup&gt;</td>
<td>6</td>
<td>±5% of reading or 10 W/m&lt;sup&gt;2&lt;/sup&gt;</td>
<td>±3W/m&lt;sup&gt;2&lt;/sup&gt;</td>
</tr>
<tr>
<td>Kipp &amp; Zonen Model CM22 w/CV-2 ventilator and CVP-2 Power supply</td>
<td></td>
<td>$9,016&lt;sup&gt;2&lt;/sup&gt;</td>
<td>6</td>
<td>±2% of reading or 5 W/m&lt;sup&gt;2&lt;/sup&gt;</td>
<td>±3W/m&lt;sup&gt;2&lt;/sup&gt;</td>
</tr>
<tr>
<td>Automatic Solar Tracker</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Eppley SMT-3</td>
<td></td>
<td>$18,975&lt;sup&gt;1†&lt;/sup&gt;</td>
<td>4</td>
<td>&lt;0.1° (1/50 5°FOV)</td>
<td>±0.02° (1/250 5°FOV)</td>
</tr>
<tr>
<td>Kipp &amp; Zonen Model 2AP-GD</td>
<td></td>
<td>$29,350&lt;sup&gt;2&lt;/sup&gt;</td>
<td>4</td>
<td>&lt;0.05° (1/100 5°FOV)</td>
<td>±0.01° (1/500 5°FOV)</td>
</tr>
<tr>
<td>Meteorological Tower Campbell Scientific</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CM10 10 ft steel tripod tower</td>
<td></td>
<td>$450</td>
<td>4</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>ENC12/14 Enclosure for logger</td>
<td></td>
<td>$205</td>
<td></td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td><strong>Meteorological Instruments</strong></td>
<td>Campbell Scientific, Inc. Model CR1000</td>
<td>Programmable control and data acquisition system. Includes extended temperature range and 4MB memory</td>
<td>$1,640</td>
<td>6</td>
<td>(OFFSET) $22\mu V$ (~2-3 Wm(^{-2}) at 7 $\mu V/W$)</td>
</tr>
<tr>
<td>--------------------------------</td>
<td>----------------------------------------</td>
<td>-------------------------------------------------</td>
<td>-------</td>
<td>---</td>
<td>-----------------------------------</td>
</tr>
<tr>
<td><strong>Data Logger</strong></td>
<td>Campbell Scientific, Inc. Model COMM220</td>
<td>(Access data logger recordings by land line)</td>
<td>$400</td>
<td>2</td>
<td>N/A</td>
</tr>
<tr>
<td><strong>Telephone Modem</strong></td>
<td>Campbell Scientific, Inc. Model CR1000</td>
<td>(Access data logger recordings by land line)</td>
<td>$400</td>
<td>2</td>
<td>N/A</td>
</tr>
<tr>
<td><strong>Miscellaneous</strong></td>
<td>Cabling, connectors, conduit, hardware, etc.</td>
<td></td>
<td>$400</td>
<td>3</td>
<td>N/A</td>
</tr>
<tr>
<td><strong>Network Link Interface</strong></td>
<td>Campbell Scientific, Inc. Model NL100</td>
<td>(Access data logger recordings by internet connection to NREL/MIDC)</td>
<td>$500</td>
<td>2</td>
<td>N/A</td>
</tr>
<tr>
<td><strong>Ventilated Pyranometer</strong></td>
<td>Eppley Model PSP w/ VEN ventilator</td>
<td>POA for tracking flat plate collector</td>
<td>$3,200(^1)</td>
<td>2</td>
<td>±1.6% ‡</td>
</tr>
<tr>
<td></td>
<td>Kipp &amp; Zonen Model CM22 w/CV-2 Ventilator and CVP-2 Power supply</td>
<td></td>
<td>$9,016(^2)</td>
<td>2</td>
<td>±0.6% ‡</td>
</tr>
<tr>
<td><strong>Optional Upgrades</strong></td>
<td>Eppley Model PSP w/ VEN ventilator</td>
<td>POA for fixed tilt collector</td>
<td>$3,200(^1)</td>
<td>2</td>
<td>+1.6 to -11.3%</td>
</tr>
<tr>
<td></td>
<td>Kipp &amp; Zonen Model CM22 w/CV-2 Ventilator and CVP-2 Power supply</td>
<td></td>
<td>$9,016(^2)</td>
<td>2</td>
<td>+0.6 to +0.4%</td>
</tr>
<tr>
<td><strong>Barometer</strong></td>
<td>Vaisala CS106</td>
<td>BP</td>
<td>$590</td>
<td>1</td>
<td>±1 mbar</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td><strong>Base system</strong></td>
<td>$31,265(^1)</td>
<td>45</td>
<td>N/A</td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>With all options</strong></td>
<td>$38,355(^1)</td>
<td>52</td>
<td>N/A</td>
</tr>
</tbody>
</table>

\(^1\) Eppley Configuration
\(^2\) Kipp & Zonen Configuration

†SmartTracker estimate includes $800 allowance for tripod or mounting fixture, not supplied by Eppley

* Estimated measurement uncertainty for sub-hourly data intervals over a wide range of zenith angles based on annual instrument calibrations traceable to national and international measurement standards and other NREL evaluations. Assumes proper equipment installation and regular daily maintenance. Uncertainties for daily, monthly, or annual means may be less. Radiometer uncertainties do not include data logging uncertainties.

‡ Uncertainties for tracking plane of array radiometers assume a limited range of solar incident angles.
Table 3. Maintenance Items

<table>
<thead>
<tr>
<th>Item</th>
<th>Comments</th>
<th>Approximate Time*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cleaning and inspection</td>
<td>Radiometer optics require cleaning using distilled water and a clean, lint-free cloth. Minimal training and expertise are necessary, but a commitment to quality and thoroughness is required.</td>
<td>5-10 minutes</td>
</tr>
</tbody>
</table>
| Tracker alignment check     | **Configuration 1:** Confirm shading band rotation is occurring on time (2/minute).  
                            | **Configuration 2:** The tracker is software controlled and does not require regular maintenance. Proper operation can be quickly ascertained visually through the use of the built-in alignment target. | 2 minutes         |
| On-site troubleshooting     | Assistance may be required for on-site troubleshooting by NREL for identified equipment problems as they occur. This may involve an instrument swap for difficult failures. | Highly variable – average of 1-2 hours per month. |
| Annual calibration swaps    | Remove/replace radiometers during recalibration at NREL.                 | Four hours per year |
| Weather Observation         | During maintenance, the operator can record cloud amount and other weather conditions relevant to interpreting the measured data. | 5 minutes         |

* Time estimates exclude travel to/from the equipment location.

Data Uses

Developers can use the data for site resource analysis and to support site evaluations in conjunction with other large-scale solar resource databases. Plant operators can use the data sets for analysis of plant operations and conversion efficiencies. NREL will use the data for on-going research, including refinement of the long term solar resource and its variability at the site, advancing model development for direct normal irradiance using satellite imagery, and for validating solar resource forecasting methods currently under development.

Educational Cooperatives

Where feasible and compliant with the needs or restrictions of power plant operators, NREL will encourage collaboration with nearby education institutions to involve students in measurement station operations. Students could be engaged to perform station maintenance (visiting the site to clean instruments and check operations in lieu of plant personnel) and to use the data for collaborative research involving the power plant operator and NREL.
Radiometer Manufacturers & Distributors

Analytical Spectral Devices, Inc.
5335 Sterling Drive, Suite A
Boulder, CO  80301
Telephone: (303) 444-6522
Telefax: (303) 444-6852
http://www.asdi.com
Spectral Irradiance Measurements

Brusag
Chapfiewesenstrasse 14
CH-8712 Stäfa
Switzerland
Telephone: +41 1 926 74 74
Telefax: +41 1 926 73 34
Automatic Solar Trackers

Campbell Scientific, Inc.
815 West 1800 North
Logan, Utah USA 84321-1784
Telephone: 435.753.2342 (Info)
Telephone: 435.750.9681 (Orders)
Telefax: 435.750.9540
Email: info@campbellsci.com
http://www.campbellsci.com
Data Logger Systems & Weather Stations

Casella London Limited
Regent House
Britannia Walk
London N1 7ND
Telephone: 01-253-8581
Telex: 26 16 41
Radiometers

Davis Instruments, Corp.
3465 Diablo Ave.
Hayward, CA 94545, USA
Telephone: (510) 732 9229
Telefax: (510) 670 0589
http://www.davisnet.com
Weather Stations

DAYSTAR
3250 Majestic Ridge
Las Cruces, NM 88011
Telephone: (505) 522-4943
http://www.raydec.com/daystar
Radiometers

Delta-T Devices Ltd
130 Low Road, Burwell
Cambridge, CB25 0EJ
UK
Radiometers, Weather Stations and Data Loggers
U.S. Distributor:
Gary L. Woods, Sales Manager
garywoods@dynamax.com
www.dynamax.com
800-896-7108 - Toll Free
281-564-5100
281-564-5200 - Fax

EKO Instruments Trading Co., LTD.
21-8
Hatagaya 1-chome
Shibuyaku, Tokyo 151
Japan
Telephone: 81-3-3469-4511
Telefax: 81-3-3469-4593
Telex: J25364 EKOTRA
http://www.eko.co.jp/eko/english/03/a.html
Radiometers, Trackers, Data Loggers
U.S. Distributor:
SC-International, Inc.
346 W. Pine Valley Drive
Phoenix, AZ 85023
Telephone: (602) 993-7877
Telefax: (602) 789-6616

The Eppley Laboratory, Inc.
12 Sheffield Avenue
Newport, RI 02840
Telephone: (401) 847-1020
Telefax: (401) 847-1031
http://www.eppleylab.com/
Radiometers, Trackers, Data Loggers

(Continues)
Hukseflux Thermal Sensors B.V.
Elektronicaeweg 25
2628 XG Delft
The Netherlands
Telephone: +31-15-2142669
Fax: +31-152574949

Radiometers
Hukseflux U.S. Sales Representative
Robert Dolce
HuksefluxUSA
P.O. Box 850
Manorville, NY 11949
631-251-6963
E-mail: rdolce@HuksefluxUSA.com

Irradiance, Inc.
41 Laurel Drive
Lincoln, MA 01773 USA
Phone/Fax (781) 259-1134
http://www.irradiance.com/rsr.html

Rotating Shadowband Radiometer (RSR)

Kipp & Zonen, Delft BV
P.O. Box 507
2600 AM Delft Holland
Mercuriusweg 1
2624 BC Delft Holland
Telephone: 015-561 000
Telfax: 015-620351
Telex: 38137
http://www.kippzonen.com

Radiometers, Trackers, Data Loggers
US Sales Representative for K&Z:
Joan Flamino
Kipp & Zonen
125 Wilbur Place
Bohemia, NY 11716
(631)589-2065 ext 25
(631)589-2068 fax

LI-COR, Inc.
4421 Superior Street
Lincoln, NE 68504
Telephone: (402) 467-3576
(800) 447-3576
Telefax: (402) 467-2819
http://licor.com/

Radiometers, Data Loggers, Weather Stations

Matrix, Inc.
537 S. 31st St.
Mesa, AZ 85204
Telephone: (480) 832-1380

Radiometers

Medtherm Corporation
P.O. Box 412
Huntsville, AL 35804
Telephone: (256) 837-2000
Telefax: (256) 837-2001
http://www.medtherm.com

Cavity Radiometers

Middleton Solar
factory 20, 155 Hyde Street
Yarraville, Victoria 3013 Australia
+61-3-9396 1890
+61-3-9689 2384 (Fax)

Radiometers

Ocean Optics, Inc.
830 Douglas Ave.
Dunedin, FL 34698 USA
Telephone: 727.733.2447
Telefax 727.733.3962
http://www.oceanoptics.com

Spectroradiometers
European Sales Office:
Geograaf 24
6921 EW DUIVEN
The Netherlands
+31 (0) 26 319 0500
Fax +31 (0) 26 319 05 05

PH. Schenk GmbH & Co KG
Jedleseer Strasse 59
A-1210 Wien, Austria
Telephone: (+43/1) 271 51 31-0
Telefax: (+43/1) 271 12 28 12
E-Mail: office@schenk.co.at
http://www.schenk.co.at/schenk

Radiometers

Solar Light Company
721 Oak Lane
Philadelphia, PA 19126-3342
Telephone: (215) 927-4206
http://www.solar.com/

Radiometers

Yankee Environmental Systems, Inc.
Montaque Industrial Park
101 Industrial Road
P.O. Box 746
Turners Falls, MA 01376
Telephone: (413) 863-0200
Telefax: (413) 863-0255
http://www.yesinc.com/

Radiometers, Data Systems, Sky Imagers