SANDIA REPORT
SAND2025-06696
Printed June 2025

Sandia National Laboratories

A Data Set for Coincident Sky Images, Hemispherical Solar Irradiance, and Weather in Albuquerque, NM and Eugene, OR

Daniel M. Riley, Christopher A. Zapotocky, Brandon K. Byford

Prepared by
Sandia National Laboratories
Albuquerque, New Mexico
87185 and Livermore,
California 94550

Issued by Sandia National Laboratories, operated for the United States Department of Energy by National Technology & Engineering Solutions of Sandia, LLC.

Available to DOE and DOE contractors from
U.S. Department of Energy
Office of Scientific and Technical Information
P.O. Box 62
Oak Ridge, TN 37831

Telephone: (865) 576-8401
Facsimile: (865) 576-5728
E-Mail: reports@osti.gov
Online ordering: http://www.osti.gov/scitech

Available to the public from
U.S. Department of Commerce
National Technical Information Service
5301 Shawnee Rd
Alexandria, VA 22312

Telephone: (800) 553-6847
Facsimile: (703) 605-6900
E-Mail: orders@ntis.gov
Online order: https://classic.ntis.gov/help/order-methods/

ABSTRACT

This report describes the structure and content of an open dataset created for the purpose of correlating sky imagery, typical weather measurements, and hemispherical irradiance in an arc. The dataset includes the data for Albuquerque, NM (representing the desert southwest) and Eugene, OR (representing the pacific northwest).

ACKNOWLEDGEMENTS

The authors would like to acknowledge the efforts of the personnel at the University of Oregon Solar Radiation Monitoring Laboratory (SRML) for the use of their site, their support in maintaining the equipment in Eugene, and the use of their weather data as a part of this data set. Special thanks to Joshua Peterson and the late Frank Vignola.

The authors would also like to thank Jim Augustyn at Augustyn & Company for the use of the Multiplanar Irradiance System (MPIS) that was crucial for the development of the data set.

This material is based upon work supported by the U. S. Department of Energy's Office of Energy Efficiency and Renewable Energy (EERE) under the Solar Energy Technologies Office Award Number 38530.

CONTENTS

LIST OF FIGURES

LIST OF TABLES

ACRONYMS AND TERMS

Acronym/Term	Definition
CSV	Comma Separated Value
MPIS	Multi-Planar Irradiance Sensor
PSEL	Photovoltaic Systems Evaluation Laboratory
SNL	Sandia National Laboratories (in Albuquerque, NM)
SRML	Solar Radiation Monitoring Laboratory (at University of Oregon in Eugene, OR)

This page left blank

1. SUMMARY

1.1. Introduction

As part of a research project for single-axis solar trackers, Sandia National Laboratories collected data relevant to the weather and sky conditions for a site in the US desert southwest and the US pacific northwest. This report describes the collected data, and it is intended that the report be provided along with the data for future researcher use.

The data include sky images, weather and irradiance measurements, as well as irradiance profiles of hemispherical irradiance in an arc from east to west. The data spans approximately 2 years at each location.

1.2. About the sites

Two sites were selected for the diversity of climate which they represent. Albuquerque, New Mexico is a typically sunny location in the southwestern United States while Eugene, Oregon represents a cooler climate with more frequent rain and clouds typical of the United States Pacific Northwest.

1.2.1. Albuquerque, New Mexico

The Photovoltaic Systems Evaluation Laboratory (PSEL) at Sandia National Laboratories (SNL) sits on the southeast corner of the city of Albuquerque at a latitude/longitude of 35.0546, -106.5401. The site is relatively close to the Sandia mountains to the east and the Manzano mountains to the southeast. Weather data and sky images from PSEL were obtained from equipment atop a 5-meter-tall weather platform, while hemispherical irradiance profiles were obtained near ground level.

Data are present from May 1, 2020 through May 10, 2022 at the Albuquerque site.

1.2.2. Eugene, Oregon

The Solar Radiation Monitoring Laboratory (SRML) at the University of Oregon is located in the city of Eugene, Oregon. The instruments measured for this study were located on the northern section of the roof of Pacific Hall at latitude/longitude of 44.0467, -123.0742.

Data are present from March 14, 2023 through March 24, 2025 at the Eugene site.

1.3. Use of the data

The data included in this data set has been created by Sandia National Laboratories with funding from the U.S. Department of Energy's Office of Energy Efficiency and Renewable Energy (EERE) under the Solar Energy Technologies Office Award Number 38530. Users of the data shall acknowledge the source of the data in the following ways:

- An acknowledgement in any presentations, papers, or products generated using the data with language such as, "The authors would like to thank Sandia National Laboratories PSEL and the DOE EERE for the data presented herein."
- Referencing this report as

- D. M. Riley, C. A. Zapotocky, B. K. Byford. (2025). *A Data Set for Coincident Sky Images, Hemispherical Solar Irradiance, and Weather in Albuquerque, NM and Eugene, OR* (SAND 2025-06696). Sandia National Laboratories (SNL), Albuquerque, NM.

2. INSTRUMENTS AND MEASUREMENTS

This section describes the instruments and data output for each type of data contained within the dataset.

2.1. Sky Images

At each site, hemispherical (180° field of view) images of the sky were collected by an EKO Instruments ASI-16 once per minute between sunrise and sunset. The ASI-16 is an automatic all-sky imager from EKO instruments with a fisheye lens and a 5 megapixel sensor.

The camera installed at PSEL was an ASI-16 basic, which is just the camera; while the camera installed at SRML was the full ASI-16 which includes a ventilator and heating element.

The sky cameras at each site were oriented such that the downward direction in each sky image was pointed south. The alignment was checked by finding timestamped images near to local solar noon and ensuring that the image of the sun at local solar noon was centered in the image.

Each image is stamped with the serial number of the imager and the date and local standard time in the top left corner of the image. The image files themselves are labeled the time of image acquisition in UTC. The files are organized into file directories pertaining to the day of acquisition in UTC. Due to the position of the PSEL and SRML in time zones UTC-7 and UTC-8, respectively, the files from a single local day are split across two file directories.

The images presented as a part of the data set are the full set of images collected. Since the imagers were located outdoors, there are sometimes obstructions, artifacts, or other issues which may present difficulties in image analysis. These issues may be temporary or transient or they may be permanent; furthermore, some of the permanent obstructions may move and change shape within the images. Examples of these may include (but are not limited to):

- Nearby instruments or weather measurement equipment
- Humans performing routine cleaning or providing site tours
- Birds, spiders, insects
- Bird droppings
- Smoke or haze from nearby wildfires
- Lens flares
- Rain drops
- Dew or frost are unlikely, but may be present
- Utility poles or trees

Figure 1: ASI-16 Basic sky imager (center instrument) between two other solar radiation measurement sensors at the PSEL in Albuquerque, NM. The instrument on the left appears in the sky images in the top right portion of each image.

Figure 2: ASI-16 sky imager mounted at the SRML site in Eugene, OR.

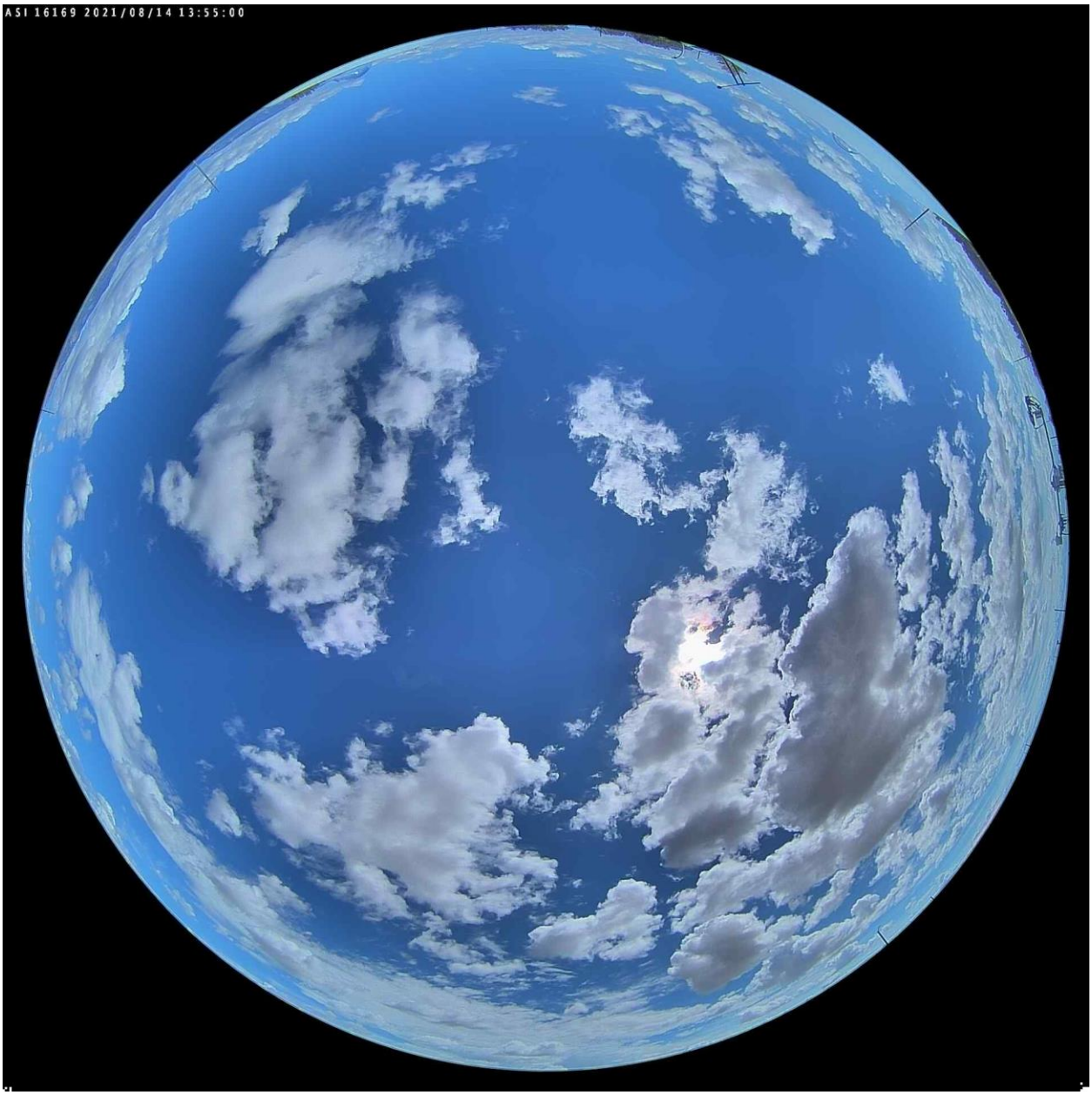

Figure 3: Sky image from the PSEL site on 2021-08-14 13:55. Note the weather tracker to the right side of the image, west of the camera. Also note the dome and radiation shield of the nearby spectroradiometer in the top right portion of the image, northwest of the camera.

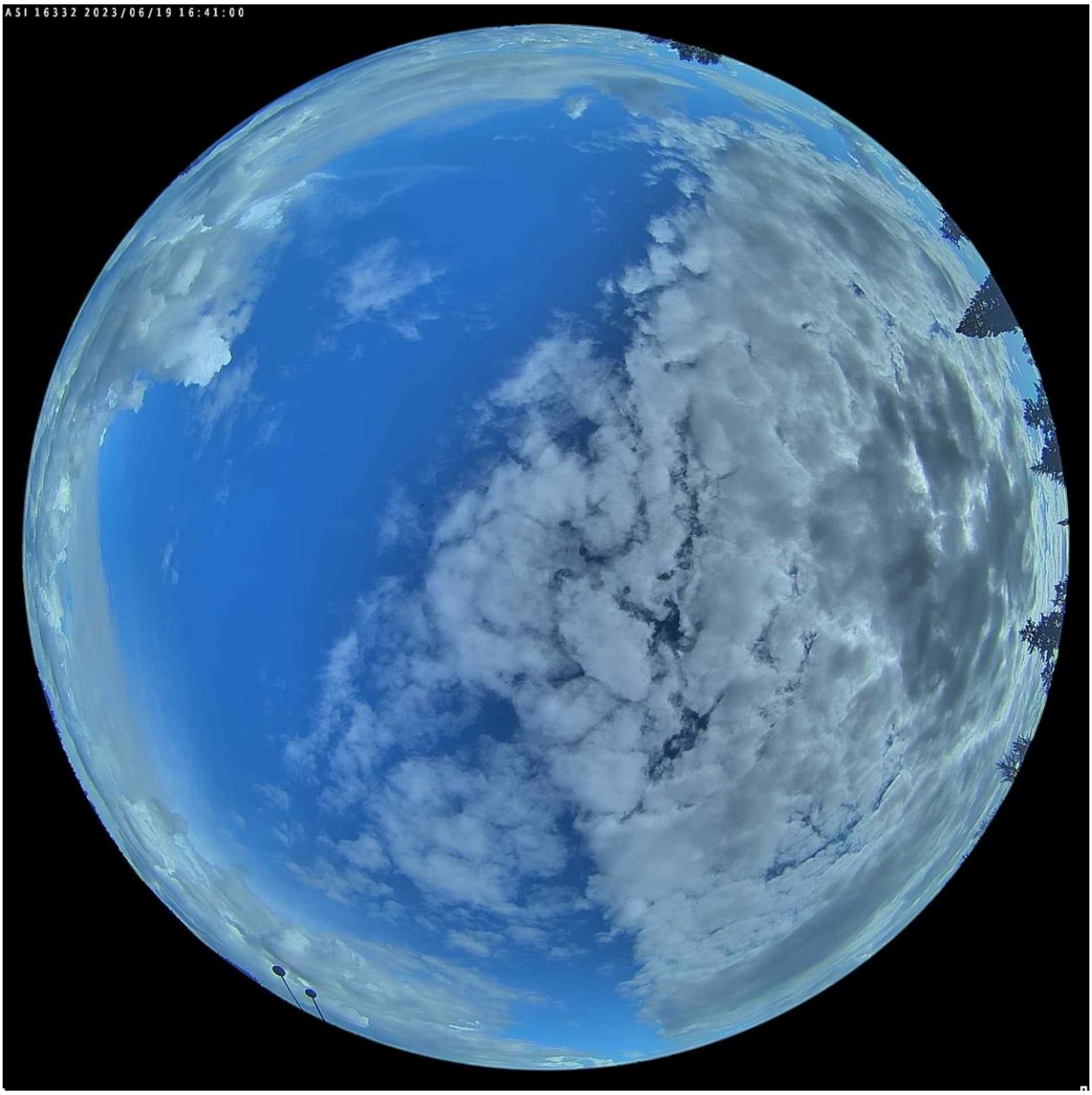

Figure 4: Sky image from the SRML site on 2023-06-19 16:41. Note the weather tracker components to the bottom left of the image (southeast of the camera) and the tall trees to the right and top of the image (west and north of the camera).

Figure 5: Sky image from the Eugene site where a nearby wildfire has created a thick haze which diminishes solar radiation.

2.2. Hemispherical Irradiance sweep

A custom multiplanar irradiance sensor (MPIS), created by Augustyn & Company, was installed at each location for a period of two years. The sensor measures the hemispherical irradiance using a fast-responding photodiode pyranometer; but sweeps the irradiance sensor in an arc to measure the hemispherical irradiance at each orientation along the arc. Thus, a profile of available hemispherical irradiance along the arc is generated. The instrument is oriented such that the arc begins with the sensor facing the horizon to the east, then sweeps the arc through the zenith, and finally ends the arc facing the horizon to the west. The instrument requires approximately 1 second to sweep the arc

and creates a measurement of the irradiance through the arc each minute at the beginning of the minute.

A custom multiplanar irradiance sensor (MPIS), created by Augustyn & Company, was installed at each location for a period of two years. The sensor measures the hemispherical irradiance using a fast-responding photodiode pyranometer; but sweeps the irradiance sensor in an arc to measure the hemispherical irradiance at each orientation along the arc. Thus, a profile of available hemispherical irradiance along the arc is generated. The instrument is oriented such that the arc begins with the sensor facing the horizon to the east, then sweeps the arc through the zenith, and finally ends the arc facing the horizon to the west. The instrument requires approximately 1 second to sweep the arc and creates a measurement of the arc each minute at the beginning of the minute.

The MPIS data are presented in a comma separated value (CSV) file format with the top header line containing the data labels. Each measurement includes a time stamp (TmStamp), a record number (RecNum) which is an internal record-keeping number for the data logger, and 360 values of a RunSweep variable (RunSweep_n). The RunSweep field names are correlated with a given tilt angle for the pyranometer as it sweeps through its arc. A subset of the RunSweep field names along with the pyranometer tilt angle is given in Table 1, with each subsequent field increasing the angle by 180/359 degrees. As shown, there is no direct measurement at horizontal.

Table 1: Description of data fields in MPIS data set

Label	Pyranometer Tilt Angle (degrees west from horizontal)
RunSweep_1	-90.0000
RunSweep_2	-89.4986
RunSweep_3	-88.9972
…	
RunSweep_178	-1.2535
RunSweep_179	-0.7521
RunSweep_180	-0.2507
RunSweep_181	0.2507
RunSweep_182	0.7521
…	
RunSweep_357	88.4958
RunSweep_358	88.9972
RunSweep_359	89.4986
RunSweep_360	90.0000

Figure 6: Multiplanar Irradiance Sensor (MPIS) by Augustyn & Company installed at PSEL. The sensor is in the middle of sweeping the pyranometer through its arc.

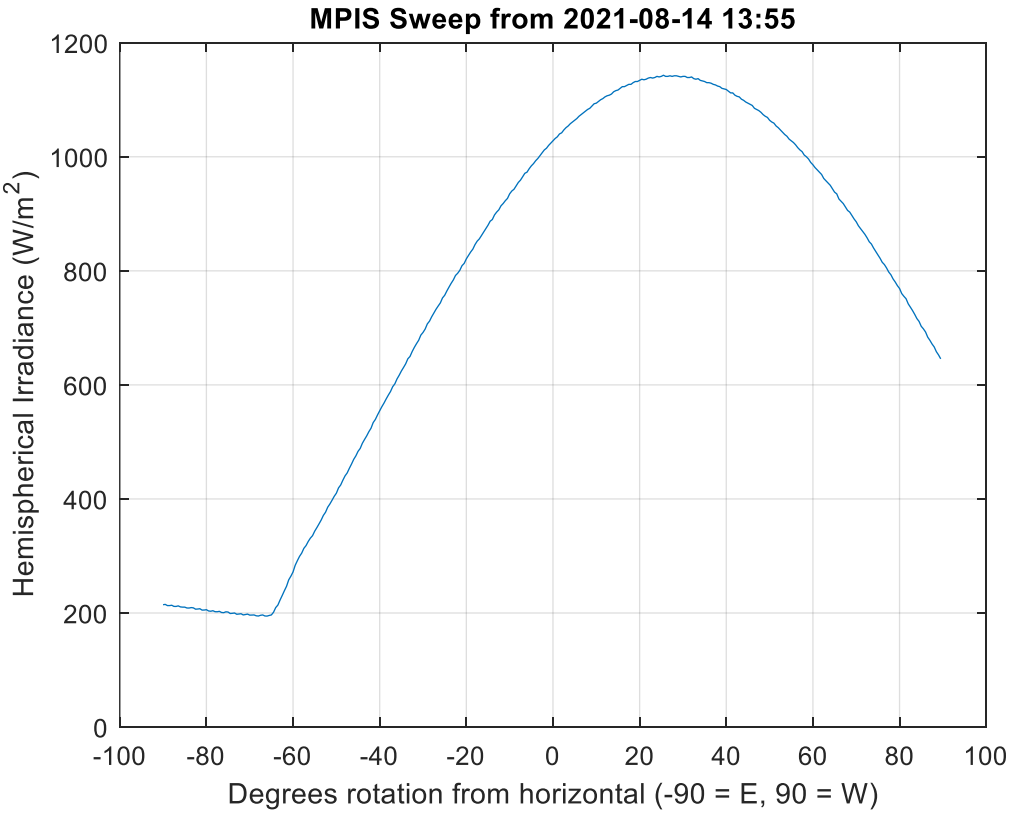

Figure 7: MPIS sweep data from 2021-08-14 13:55 at PSEL.

Figure 8: Head of the MPIS installed at SRML, sensor is at rest, waiting for the time to next sweep.

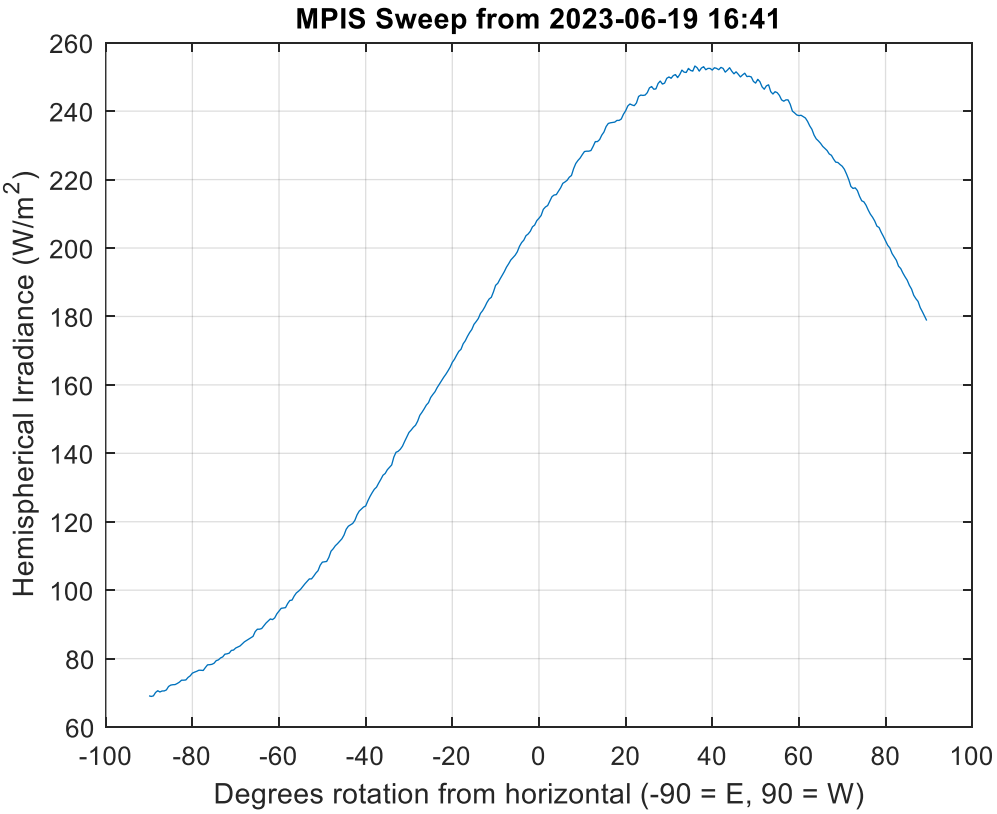

Figure 9: MPIS sweep data from 2023-06-19 16:41 at SRML.

2.3. Weather Data

Existing weather stations at the PSEL and SRML provide solar irradiance, ambient temperature, wind speed, and other relevant weather variables. These data are provided to allow for more in-depth analyses of solar irradiance conditions with collocated sky images and hemispherical irradiance profiles.

2.3.1. PSEL

The weather measurement system at PSEL measures various aspects of the solar radiation, precipitation, wind, and ambient temperature. The data are provided in a CSV file format with a single header line containing the data labels. The data fields are presented in Table 2.

Table 2: Description of data fields in the PSEL weather data set

Data label	Description
TmStamp	The time at the PSEL site in local standard time (UTC -7).
RecNum	A record number kept by the datalogger which resets when the logger is restarted or code is recompiled, unitless.
Global_Wm2_Avg	The mean global (hemispherical) horizontal irradiance in units of W/m^2 over the minute preceding the time stamp.
Direct_Wm2_Avg	The mean direct normal irradiance in units of W/m^2 over the minute preceding the time stamp.
Diffuse_Wm2_Avg	The mean diffuse horizontal irradiance in units of W/m^2 over the minute preceding the time stamp.
Pressure_mBar_Avg	The mean local atmospheric pressure in millibar over the minute preceding the time stamp.
WS_ms_Mean	The mean wind speed, measured at 10 meters above ground level, over the minute preceding the time stamp, in meters per second.
Wdir_Mean	The mean wind direction over the minute preceding the time stamp, in degrees east of north.
Wdir_Std	The standard deviation of the wind direction over the minute preceding the time stamp, in degrees east of north.
WS_ms_Std	The standard deviation of the wind speed over the minute preceding the time stamp, in degrees.

Data label	Description
WS_ms_3sec_Max	The maximum value of the 3-second running average of wind speed over the minute preceding the time stamp, in meters per second.
WD_deg_SMM	The wind direction that occurred during the maximum value of the 3-second running average of wind speed over the minute preceding the time stamp, in degrees east of north.
Temp_C_Avg	The mean ambient air temperature over the minute preceding the time stamp, in degrees C.
RH_pct_Avg	The mean relative humidity over the minute preceding the time stamp, in %.
Panel_Temp_C_Avg	The mean temperature of the datalogger panel over the minute preceding the time stamp, in degrees C.
Battery_V_Avg	The mean input voltage to the datalogger over the minute preceding the time stamp, in V.
ProcessTime_S_Max	The maximum amount of time the datalogger took to complete its measurements over the minute preceding the time stamp, in microseconds.
Global_mV_Avg	The mean measurement of the global horizontal pyranometer over the minute preceding the time stamp, in millivolts.
Rain_mm_Tot	The rainfall over the minute preceding the time stamp, in millimeters.
Rain_mm_Daily	The accumulated rainfall during the present day in millimeters.
Temp_CMP22_C_Avg	The mean temperature of the CMP 22 pyranometer serving as the global horizontal instrument over the minute preceding the time stamp, in degrees C.

Figure 10: A portion of the weather station at PSEL.

2.3.2. SRML

The weather measurement system at SRML also measures solar radiation and other relevant weather factors. Because the PSEL and SRML weather stations pre-dated the beginning of the other data sets, they are different from each other. Like the PSEL data set, the data are provided in a CSV file with a single header containing data labels. The data fields are presented in Table 3.

Table 3: Description of data fields in the PSEL weather data set

Data label	Description
TmStamp	The time at the SRML site in local standard time (UTC -8).
ghi_0	The mean global (hemispherical) horizontal irradiance in units of W/m^2 over the minute preceding the time stamp from instrument 0.
ghi_9	The mean global (hemispherical) horizontal irradiance in units of W/m^2 over the minute preceding the time stamp from instrument 9.

Data label	Description
dni_0	The mean direct normal irradiance in units of W/m^2 over the minute preceding the time stamp from instrument 0.
dni_1	The mean direct normal irradiance in units of W/m^2 over the minute preceding the time stamp from instrument 1 (an alternate instrument).
dhi_0	The mean diffuse horizontal irradiance in units of W/m^2 over the minute preceding the time stamp from instrument 0.
dhi_1	The mean diffuse horizontal irradiance in units of W/m^2 over the minute preceding the time stamp from instrument 1 (an alternate instrument).
bp_0	The mean local atmospheric pressure in millibar over the minute preceding the time stamp.
wind_direction_0	The mean wind direction over the last minute in degrees east of north over the minute preceding the time stamp.
wind_speed_0	The mean wind speed over the last minute in m/S over the minute preceding the time stamp.
temp_air_0	The mean ambient air temperature over the minute preceding the time stamp, in degrees C.
relative_humidity_0	The mean relative humidity over the minute preceding the time stamp, in %.

Figure 11: Irradiance tracker portion of the weather station at SRML

2.4. Combined Data Availability Flags

For ease of data integration, we have created a data set which easily describes the availability and, to some extent, the quality of the other three data sets. We call this data set the combined data availability flag. For each site, the full list of possible times is generated. Within the combined data availability flag, the availability of a particular data set is indicated with a Boolean 1 to indicate that a value of that particular data set is available at that time, or a 0 to indicate that a value of that particular data set is not available at that time. For each site there are 5 data sets described as shown in Table 4 and

Table 5.

Table 4. Description of headers provided in the combined availability data for the Albuquerque (PSEL) site

Header Name	Description
TmStamp	Time stamp for the time in question
abq_mpis_data_high	The MPIS data availability for the time stamp, a 1 indicates the MPIS data is available and no values are NAN
abq_mpis_data_low	The MPIS data availability for the time stamp, a 1 indicates the MPIS data is available (no check for NAN values)
abq_weather_data_high	The weather data availability for the time stamp, a 1 indicates the weather data are available and no values are NAN
abq_weather_data_low	The weather data availability for the time stamp, a 1 indicates the weather data are available (no check for NAN values)
abq_sky_date_time_format_mst	Sky image availability for the time stamp, a 1 indicates that a sky image is available.

Table 5: Description of headers provided in the combined availability data for the Eugene (SRML) site

Header Name	Description
TmStamp	Time stamp for the time in question
euo_mpis_data_high	The MPIS data availability for the time stamp, a 1 indicates the MPIS data is available and no values are NAN
euo _mpis_data_low	The MPIS data availability for the time stamp, a 1 indicates the MPIS data is available (no check for NAN values)
euo _weather_data_high	The weather data availability for the time stamp, a 1 indicates the weather data are available and no values are NAN
euo _weather_data_low	The weather data availability for the time stamp, a 1 indicates the weather data are available (no check for NAN values)
euo _sky_date_time_format_mst	Sky image availability for the time stamp, a 1 indicates that a sky image is available.

This page left blank

REFERENCES

[1] B. G. Pierce, J. L. Braid, J. S. Stein, J. Augustyn and D. Riley, "Solar Transposition Modeling via Deep Neural Networks With Sky Images," in IEEE Journal of Photovoltaics, vol. 12, no. 1, pp. 145-151, Jan. 2022, doi: 10.1109/JPHOTOV.2021.3120508.

[2] B. Byford and D. Riley. "Smarter Horizontal Single Axis Tracking Using Optimal Positioning Algorithms". *2024 IEEE 52nd Photovoltaic Specialists Conference (PVSC)*. IEEE, 2024.

This page left blank

DISTRIBUTION

Email—Internal

Name	Org.	Sandia Email Address
Technical Library	1911	sanddocs@sandia.gov

This page left blank

This page left blank

Sandia National Laboratories is a multimission laboratory managed and operated by National Technology & Engineering Solutions of Sandia LLC, a wholly owned subsidiary of Honeywell International Inc. for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-NA0003525.