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Introduction

At the September 2018 Bifacial PV Workshop in Lakewood, CO, a better understanding of albedo values and characteristics was identified as a key need by both the PV and financial communities to better estimate performance and to reduce risk of bifacial PV systems. To meet this need, the U.S. Department of Energy (DOE) has initiated work with the National Renewable Energy Laboratory (NREL) to provide the following:

- A multi-year database of measured and quality assessed albedo values with temporal resolution of one hour or less for numerous locations and types of ground surfaces.
- Site metadata for each location
- Site albedo statistics for each location
- Analysis of the spectral mismatch for bifacial PV modules of the ground-reflected radiation for anticipated deployment surfaces
- Comparisons of the measured albedos with available satellite-derived MODIS albedo products.

The albedo data base will include data from the SURFRAD and Ameriflux measurement networks and data contributed by the PV industry. This poster describes results from the first stage of the project when using data from the SURFRAD measurement network.

Background

Albedo measurements are made with two horizontal pyranometers, one facing the sky and the other facing the ground. The albedo is the irradiance measured by the ground-facing pyranometer divided by the irradiance measured by the sky-facing pyranometer. The conventional name for the sky-facing measurement is the global horizontal irradiance (GHI). For consistency, we refer to the ground-facing measurement as the ground-reflected irradiance (GRI). Elsewhere, the GHI and GRI may be referred to as the downwelling and upwelling (reflected) irradiances, or the incoming and outgoing (reflected) irradiances.

Besides GHI and GRI, other meteorological data useful for determining the performance of PV systems are included in the albedo data sets, if available. This includes the direct normal irradiance (DNI), the diffuse horizontal irradiance (DHI), the dry bulb temperature (Tdry), the relative humidity (RH), the wind speed (Wspd), the wind direction (Wdir), and the atmospheric pressure (Pres).

SURFRAD Network

The Surface Radiation budget (SURFRAD) network consists of seven stations and is operated by the National Oceanic and Atmospheric Administration (NOAA) to provide continuous and high-quality surface radiation budget measurements to support climate research, weather forecasting, satellite, and educational communities.

Location	Data Years	Ground Surface	Overall Albedo
Bondville, IL	24	Native grasses	0.247
Boulder, CO	23	Sandy with exposed rocks, sparse grass, desert shrubs and small cactus	0.199
Desert Rock, NV	20	Fine rock and scattered creosote bush	0.211
Fort Peck, MT	23	Native grasses	0.247
Goodwin Creek, MS	24	Pasture grass and sparse deciduous trees	0.200
Penn State Univ, PA	20	¼ grass and ¾ crops	0.252
Sioux Falls, SD	15	Native grasses	0.238

Albedo Products

Both time-series data and summary statistics are provided. Time series data are provided at the original temporal resolution (3-minutes for SURFRAD data prior to 2009, and 1-minute after) and for an hourly resolution, which was derived from the original data. Quality assessment flags are assigned to data to indicate if they are within expected limits.

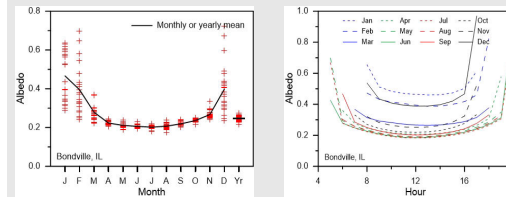
The hourly data were used to determine statistics for monthly and annual albedos, including means, medians, minimums, maximums, and sample standard deviations.

Albedo Statistics for Sioux Falls, SD

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
2004	0.409	0.704	0.210	0.211	0.202	0.195	0.198	0.204	0.182	0.201	0.206	0.219	0.238
2005	0.532	0.259	0.336	0.179	0.177	0.190	0.197	0.185	0.187	0.206	0.284	0.624	0.233
2006	0.415	0.261	0.393	0.205	0.190	0.194	0.191	0.175	0.174	0.201	0.223	0.237	0.219
2007	0.353	0.451	0.396	0.225	0.195	0.195	0.196	0.179	0.196	0.202	0.226	0.638	0.249
2008	0.735	0.760	0.490	0.254	0.193	0.191	0.197	0.190	0.186	0.192	0.280	0.439	0.292
2009	0.584	0.290	0.231	0.252	0.202	0.191	0.192	0.182	0.175	0.173	0.205	0.570	0.234
2010	0.796	0.846	0.369	0.208	0.206	0.194	0.197	0.191	0.186	0.202	0.228	0.452	0.283
2011	0.746	0.678	0.362	0.207	0.189	0.177	0.187	0.193	0.189	0.210	0.242	0.255	0.261
2012	0.284	0.294	0.226	0.196	0.187	0.193	0.190	0.172	0.181	0.210	0.218	0.475	0.211
2013	0.456	0.374	0.226	0.281	0.177	0.164	0.179	0.177	0.168	0.174	0.293	0.645	0.229
2014	0.588	0.584	0.327	0.200	0.184	0.160	0.175	0.167	0.173	0.183	0.293	0.322	0.242
2015	0.384	0.296	0.206	0.189	0.171	0.172	0.181	0.179	0.169	0.183	0.247	0.408	0.205
2016	0.652	0.463	0.277	0.181	0.174	0.182	0.187	0.176	0.167	0.173	0.267	0.375	0.229
2017	0.448	0.261	0.282	0.186	0.199	0.191	0.190	0.173	0.165	0.171	0.195	0.383	0.212
2018	0.444	0.430	0.301	0.332	0.187	0.185	0.196	0.183	0.174	0.182	0.196	0.315	0.259
Minimum	0.294	0.259	0.206	0.179	0.171	0.160	0.175	0.167	0.165	0.171	0.195	0.219	0.205
Maximum	0.796	0.846	0.490	0.332	0.208	0.195	0.198	0.204	0.196	0.210	0.293	0.645	0.292
Mean	0.521	0.463	0.309	0.220	0.188	0.185	0.190	0.182	0.178	0.191	0.236	0.424	0.238
Median	0.448	0.430	0.301	0.207	0.187	0.191	0.190	0.179	0.175	0.192	0.228	0.408	0.234
Std. Dev.	0.157	0.202	0.093	0.043	0.011	0.011	0.007	0.01	0.009	0.014	0.032	0.144	0.025

Bondville, Illinois

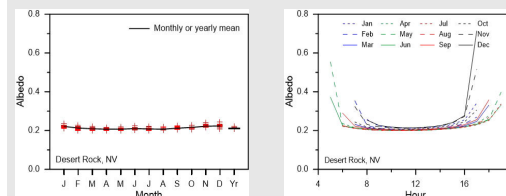
Latitude, Longitude: 40.05° N, 88.37° W
Data Files: Hourly and 1- or 3-minute
Data Elements: GHI, DNI, DHI, GRI, Tdry, RH, Wspd, Wdir, and Pres
Ground Surface: Native Grasses
Overall Albedo: 0.247



Bondville monthly and yearly albedos (left) and hourly albedos (right)

Desert Rock, Nevada

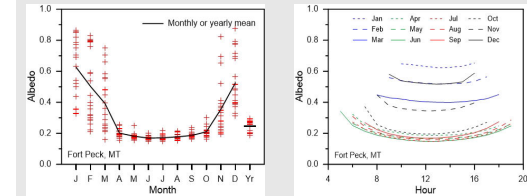
Latitude, Longitude: 36.62° N, 116.02° W
Data Files: Hourly and 1- or 3-minute
Data Elements: GHI, DNI, DHI, GRI, Tdry, RH, Wspd, Wdir, and Pres
Ground Surface: Fine rock and scattered creosote bush
Overall Albedo: 0.211



Desert Rock monthly and yearly albedos (left) and hourly albedos (right)

Fort Peck, Montana

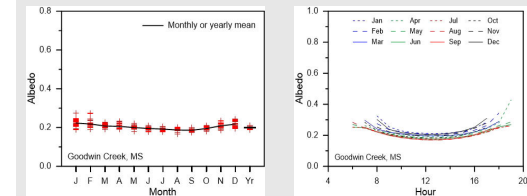
Latitude, Longitude: 48.31° N, 105.10° W
Data Files: Hourly and 1- or 3-minute
Data Elements: GHI, DNI, DHI, GRI, Tdry, RH, Wspd, Wdir, and Pres
Ground Surface: Native Grasses
Overall Albedo: 0.247



Fort Peck monthly and yearly albedos (left) and hourly albedos (right)

Goodwin Creek, Mississippi

Latitude, Longitude: 34.25° N, 89.87° W
Data Files: Hourly and 1- or 3-minute
Data Elements: GHI, DNI, DHI, GRI, Tdry, RH, Wspd, Wdir, and Pres
Ground Surface: Pasture grass and sparse deciduous trees
Overall Albedo: 0.200



Goodwin Creek monthly and yearly albedos (left) and hourly albedos (right)

How to Participate

We are asking the PV industry to provide their albedo measurements and take part in a cooperative effort to create an expansive and accurate data base of albedo values. If you have albedo data to contribute or for more information, please contact Bill Marion (bill.marion@nrel.gov or 303-384-6793).

Albedometer data using either pyranometers or reference cells are sought. Additional meteorological data for quality assessment and general PV performance modeling would also be very useful if available. This includes parameters such as direct normal and diffuse horizontal irradiance, ambient dry bulb temperature, relative humidity, wind speed and direction, snowfall, and rainfall (wet soils have lower albedo).

Data Availability

The albedo data files for the SURFRAD network and their summary statistics and site metadata will be available from the DuraMAT website (<https://www.duramat.org>) beginning in June 2019. Albedo data files and summary statistics for the Ameriflux network and for data contributed by the PV industry will be added as available.