Albedo Data for Bifacial PV Systems

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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 (Pictures, instruments and calibration history, soil and vegetation types, etc.)
- Site albedo statistics for each location (diurnal profiles, monthly and annual means, interannual variability)
- Analysis of the spectral mismatch for bifacial PV modules of the ground-reflected radiation for anticipated deployment surfaces (using both measured and modeled spectral albedo data).
- Comparisons of the measured albedos with available satellite-derived MODIS albedo products to validate the MODIS albedo products for estimating bifacial PV system performance.

The albedo data base will include data from the SURFRAD and Ameriflux measurement networks. *We are also 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.*

Background

For mono-facial PV systems, the ground-reflected radiation typically comprises only 1% to 2% of the total radiation received by the PV module. Consequently, a rudimentary understanding of the ground albedo is adequate for predicting their performance. However, for bifacial PV modules where their benefit is determined by the additional radiation reflected by the ground to their backside, a better understanding of albedo values and characteristics is needed by both the PV and financial communities to better estimate performance and to reduce risk.

The albedo of a surface is the fraction of the incident irradiance that it reflects. Albedo data are derived from measurements by two horizontal pyranometers, one facing the sky and the other inverted and facing the ground. The resulting albedo is the irradiance reflected by the ground and measured by the ground-facing pyranometer divided by the global horizontal irradiance (GHI) measured by the sky-facing pyranometer.

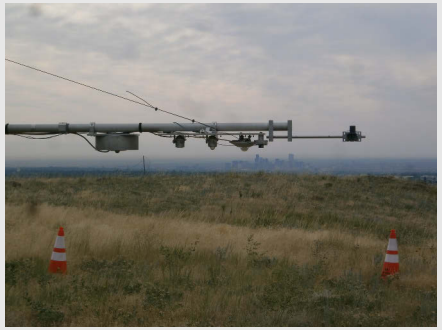


Fig 1. Albedo measurements at NREL's Solar Radiation Research Laboratory.

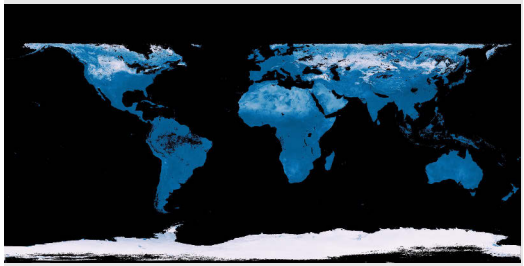


Fig 2. NASA's Earth Observations albedo map for December, 2016.

Albedo is an essential parameter for determining the earth's energy balance and climate change; consequently, NASA makes available albedo products using Moderate Resolution Imaging Spectroradiometer (MODIS) data from sensors onboard Terra and Aqua satellites. Ground reflection is measured from a changing satellite viewpoint over several days. Persistent cloudiness preventing the satellites from viewing the ground may result in "no data" (shown as black in Fig. 2 for parts of South America).

Albedo Characteristics

The albedo of a surface is not a constant. There is an angular dependence that typically increases the albedo as the sun's zenith angle increases. This imparts diurnal, seasonal, and latitude variations. Most surfaces do not reflect all wavelengths of light equally; consequently, as the spectral content of the radiation received by the ground surface varies throughout the day, variations in albedo may occur. Additionally, the spectral characteristics of the surface may also change with season, such as green grass becoming brown in the fall.

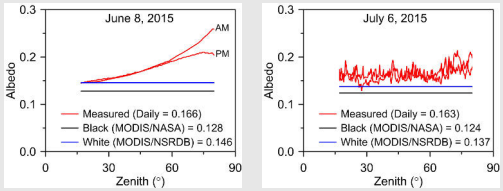


Fig 3. Albedo versus sun zenith angle for a sunny day (June 8) and a cloudy day (July 6). The cloudy day measurements show a smaller variation in albedo because the angular distribution of the radiation from the diffuse sky is more constant. The sunny day shows larger variations in measured albedo with maximum values occurring at larger sun zenith angles (near sunrise and sunset). Satellite derived daily albedo values are also shown. "Black-sky" is the derived albedo in the absence of a diffuse component and for solar noon. "White-sky" is the derived albedo in the absence of a direct component (cloudy skies).

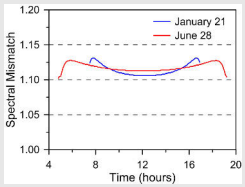


Fig 4. Albedo spectral mismatch for x-Si cells for clear skies and using SMARTS modeled ground-reflected spectral irradiance and spectral reflectance data for "Dry Long Grass". Mismatch values greater than one indicate PV module output is greater than indicated by albedo measured with broadband pyranometers.

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).

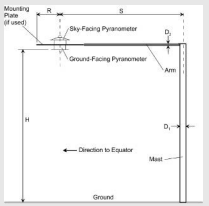
Albedometer data using either pyranometers or reference cells are sought. Additional meteorological data for quality assessment and general PV performance modeling would also be very useful if available. This includes parameters such as direct normal and diffuse horizontal irradiance, ambient dry bulb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

Metadata

Information about your albedo data and its collection will be needed (to the extent possible) for the following areas:

Location of Measurements
- City, state, country
- Latitude, longitude, elevation

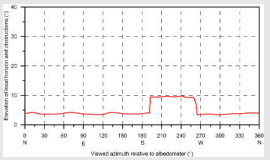
Ground Surface
- Vegetation and soil types



Albedometer Instruments
- Sky-facing, manufacturer and model
- Ground-facing, manufacturer and model

Albedometer Installation Dimensions
- Using reference dimensions to right

Shading Obstructions Viewed by Albedometer
- Sketched on diagram, if any



Maintenance
- Instrument cleaning and calibration frequency

Images
- Albedometer installation and the supporting structure
- Horizontal views from the albedometer for the four cardinal directions (N, E, S, and W).
- Ground surface. If the ground surface is vegetation, date-stamped images depicting seasonal changes.

Products

NREL will quality assess the albedo data and use a common data file format (hourly or less temporal resolution). Albedo summary statistics will be determined for each location (diurnal profiles, monthly and annual means, interannual variability). The albedo data files, the summary statistics, and the site metadata will be available from the DuraMAT website (https://www.duramat.org/).

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