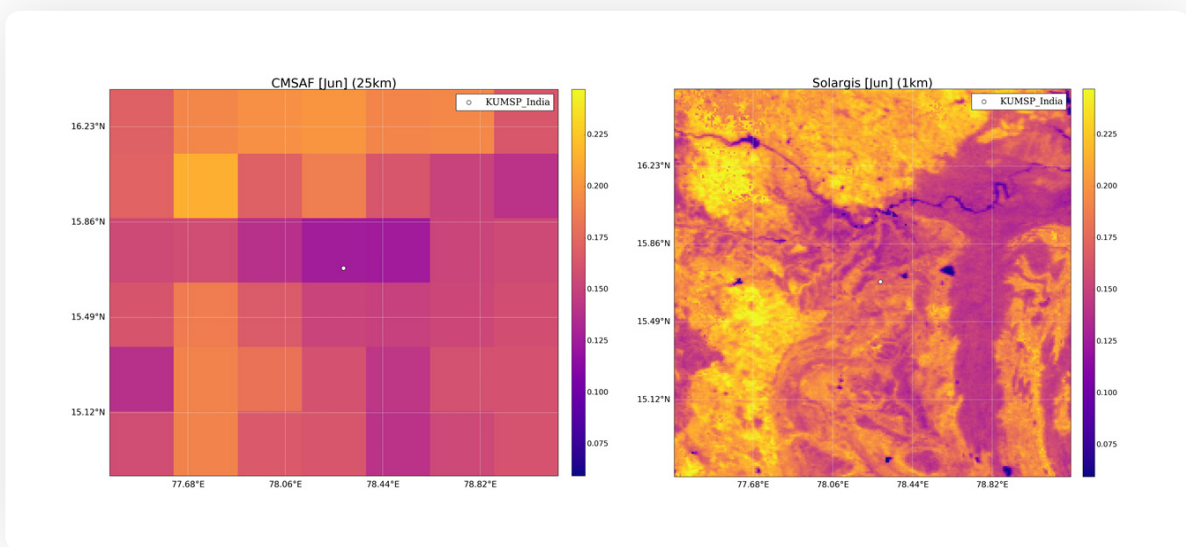




Albedo for bifacial PV projects — Part I

How to identify albedo data sources for bankable energy simulations



Whitepaper

Solargis research 2021

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Overview

The importance of having accurate albedo data

Surface albedo has been traditionally assumed as a constant value in solar energy applications, essentially due to practical constraints and its secondary order of importance with respect to other variables that impact on the solar energy production.

However, the increased adoption of bifacial PV technology has put the spotlight on the importance of obtaining reliable and accurate values for this spatially and temporally variable parameter.

A complete characterization of albedo allows developers and investors to reduce risk during development phase of bifacial PV projects

As a result, having a complete characterization of albedo helps remove uncertainties around energy simulations for bifacial PV plants and makes it possible for developers and investors to reduce risk and provide bankable energy yield assessments.

Benban PV power plant, a Bifacial PV pioneer project under operation

This project developed by Scatec Solar and financed by EBRD and located in upper Egypt was one of the first of this size using bifacial technology. According to the EBRD, market share of bifacial modules is expected to grow rapidly driven by falling prices and the availability of advanced infrastructure.



Fig. 1: Benban site in Aswan, Egypt.

Choosing the optimal technology for a PV project

Important decisions about PV system design optimisation, such as “tracking vs fixed”, or “more vs less densely packed modules” are now coupled with the “mono vs bifacial” dilemma.

As a result, a full set of weather data, ground albedo included, is essential to determine the most suitable technology for a location of interest and to assess the economic feasibility of the solar projects.

Bifacial vs other technology gains in Shanghai

We have simulated the energy yield for several combinations of technologies and two ground coverage ratios (GCR), for the same PV capacity installed. Assuming that monofacial+fixed+more densely packed field is the reference (=100), we have ranked the results in the table.

For the calculations we have used SAM simulator with the following details:

- Capacity: ~215 kWp, 696 modules Sunpower 310Wp, DC/AC ratio 1.20
- System configuration: 1-axis tracker with +/-45 rotation limits, backtracking; fixed at 25°.
- Bifacially factor 85% (high efficiency good quality); height above ground 1 m

Technology	Track mode	GCR	Energy production
Monofacial	Fixed	0.45	100.0
Monofacial	Fixed	0.33	100.9
Bifacial	Fixed	0.45	108.1
Bifacial	Fixed	0.33	109.8
Monofacial	Tracking	0.45	117.7
Monofacial	Tracking	0.33	119.0
Bifacial	Tracking	0.45	124.6
Bifacial	Tracking	0.33	126.8

Tab. 1. Energy produced by a sample PV system located in a sample site in Shanghai, China, considering a constant albedo of 0.2.

Role of albedo in energy simulations

Albedo for solar energy applications

By definition, albedo is a primary parameter that determines the total solar energy reflected by Earth's surface (RHI). Photovoltaic (PV) technology is able to harness the reflected irradiance as an additional source of solar energy to produce electricity. In particular, bifacial PV modules are specially devised to exploit the irradiance reflected back from the ground.

Accurate estimation of reflected irradiance is essential for solar energy applications

Albedo is a dimensionless magnitude, and its physical possible values range from 0 to 1 (sometimes expressed in percentage), corresponding its theoretical extreme values to a perfect absorber and perfect reflector respectively.

Albedo is a spectral parameter, i.e. it is wavelength dependent. However, due to practical reasons it is treated in a general way as a broadband variable in this document.

What is albedo?

Albedo (from the Latin "albus", which means "white") is the ratio of the total upward reflected irradiance to the total downward irradiance received by a surface.

Using a common language for solar applications, this can be mathematically expressed by the following basic equation:

$$\rho = \frac{RHI}{GHI} \quad \text{where,}$$

RHI is the total reflected irradiance scattered back by the ground surface reaching the horizontal surface.

GHI is the global (or total) solar irradiance reaching the horizontal surface.

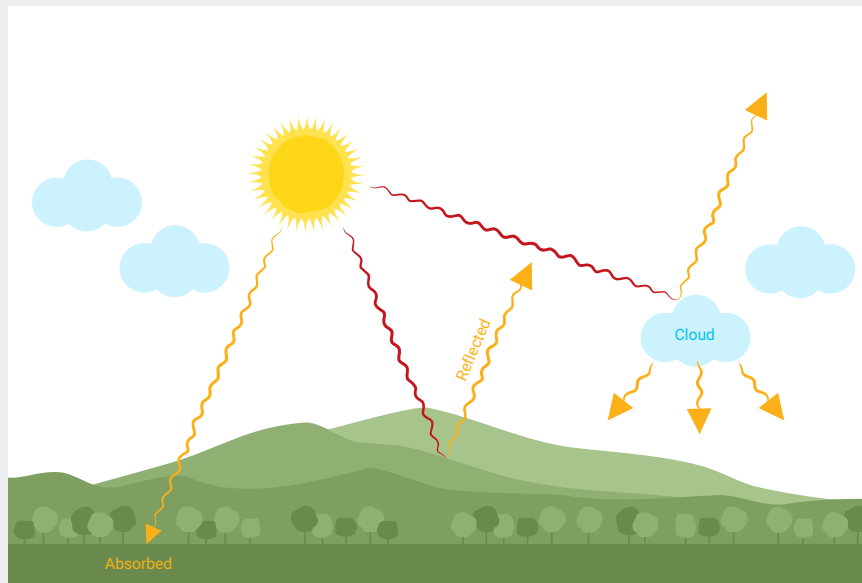


Fig. 2. Reflected and absorbed solar irradiance. Image: Solargis

Effect on monofacial modules

Historically, albedo has been routinely assumed as a constant in the solar industry (default value $\rho=0.2$ in PVsyst, or $\rho=0.12$ as previously used by Solargis), because of its second order of relevance compared to other parameters, such as GHI (global horizontal irradiance) or air temperature, and the difficulty of obtaining reliable long-term values, worldwide. However, this assumption leads to non-negligible deviations in the estimated GTI (global tilted irradiance).

GTI calculated at an optimum fixed angle, with site-specific albedo instead of 0.12 default value, show differences in annual PV energy production that can range from values generally around 1% to 2% up to 8% in the extreme cases, according to a comparison done by Solargis globally.

When using “traditional” 0.2 means overestimation of albedo, as it can be for many common surfaces, there are differences that are typically negligible for GHI (backscattering effect), slightly appreciable for GTI, and substantial for RHI (directly proportional to the difference between the albedo values). Situations for the opposite situation (the underestimation of albedo when using the 0.2 constant) are also possible, e.g. in desert zones like the Arabian Peninsula where the albedo can easily reach values over 0.3.

GTI calculated using actual albedo values instead of the standard constant value of 0.12 show differences in annual PV energy higher by 1% to 2% up to 8%, in the extreme cases.

Using actual albedo value instead of 0.2

The example shows a difference in GTI, GHI, and RHI caused by a change in the value of the surface albedo during a clear-sky day. A decrease of the albedo from a reference value (0.2) to the actual albedo for that location estimated using Solargis albedo data (0.134), is considered.

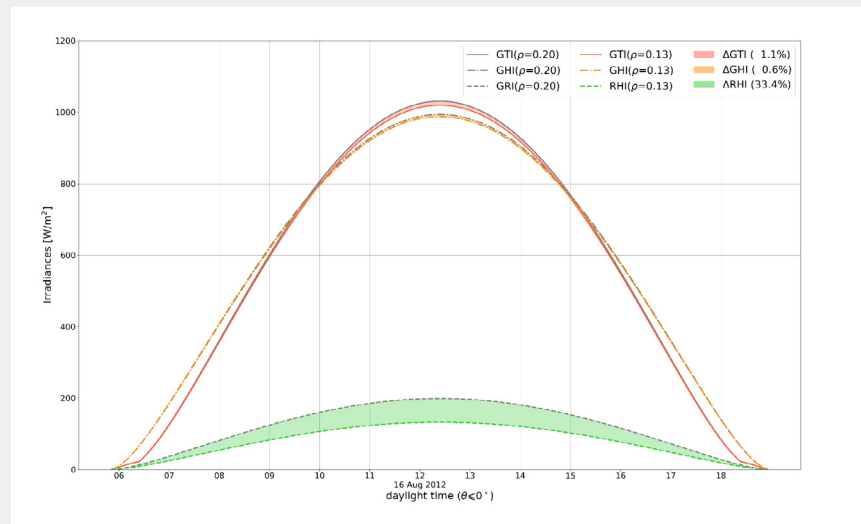


Fig. 3. Clear-sky values of GTI, GHI, and RHI for two different albedo values at Walnut Gulch Kendall Grasslands in the USA. Fixed mounted PV modules at an inclination angle of 25°.

Effect on bifacial modules

The rear side of bifacial PV modules is purposely designed to collect the reflected horizontal irradiance (RHI). As a consequence, the energy production of bifacial photovoltaic modules is significantly more sensitive to variations in the albedo, and to uncertainty in its estimation, than those based on monofacial technology.

There is still a lack of knowledge to accurately predict the performance gains of bifacial PV. More realistic studies reproducing real conditions for large facilities suggest that expected gains are in the range 5–15% [12] and 6–17% [13], depending on the surface albedo and the configuration of a PV power plant.

Results are in good accordance with the study conducted by Solargis using the software NREL-SAM, where the gains change as a function of albedo for different configurations and technologies, as shown in the chart below.

Considering a site in Shanghai, China, after running a set of simulations for different system types and albedo values, we confirm the importance of having accurate albedo. Considering only the most common range of albedo values (values around 0.2; usually between 0.1 and 0.3), an error of 0.1 in the albedo value results in a difference from 2% to 4% in the total PV energy output.

Studies reproducing conditions for large facilities suggest that expected gains are in the range of 5% to 17%, depending on the albedo of the surface and a configuration of a PV power plant.

Bifacial gains for different PV configurations

Although a wide range of albedo values is shown for completeness, the vast majority of cases on land are actually constrained to the albedo value range between 0.1 and 0.3.

Albedo value	GCR 0.33 + fixed	GCR 0.45 + fixed	GCR 0.33 + tracking	GCR 0.45 + tracking
0	1%	1%	2%	2%
0.1	5%	5%	5%	4%
0.2	9%	8%	7%	6%
0.3	13%	11%	8%	8%
0.4	16%	15%	10%	9%
0.5	19%	18%	12%	11%

Tab. 2. Bifacial gain as a function of albedo for Shanghai, China.

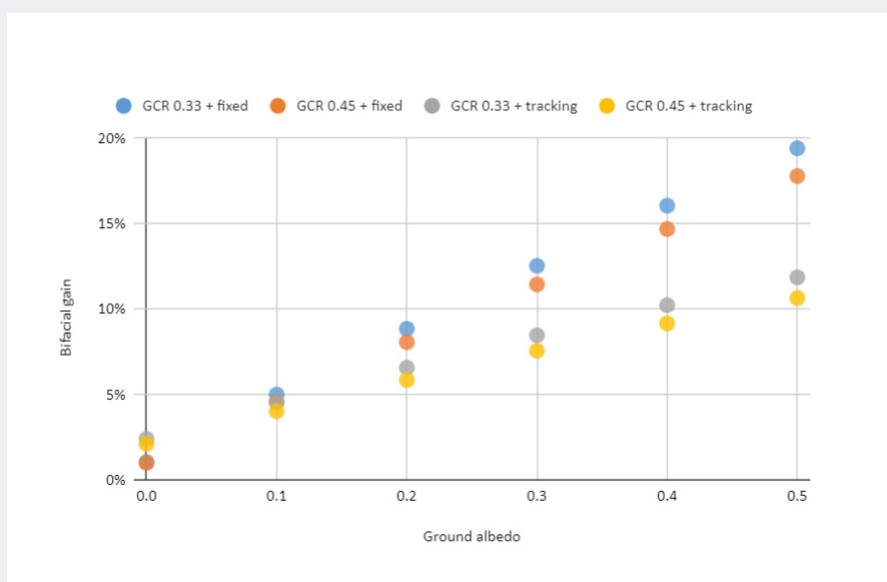


Fig. 4. Annual gains as a function of albedo for different PV installations.

Challenges for energy simulation models

It is clear that accurate knowledge of the ground albedo (in practice, the most representative value of it for the ground surface below the PV modules and surrounding terrain) is of key importance to reliably analyze the production of the PV power plants and to reduce the uncertainty, particularly for bifacial PV. Albedo is therefore a mandatory input for the most popular PV modeling tools.

However, accurately predicting the actual performance gains of bifacial PV technology is still a challenge. Several factors should be considered: PV module degradation, soiling losses, and cleaning schedules, maintenance of ground material, spectral and shading effects, structural design, backtracking optimization, etc.

Popular PV simulation tools include some of these elements to perform bifacial simulations. Yet, there are still some limitations in the applied models, and their validation is still in progress [15]. Notwithstanding, the active research on this topic is producing new methods and models to better characterize the reflected irradiance received by the rear side of the bifacial modules, such as those based on ray-tracing [11].

Accounting for reflected irradiance on front and rear sides

Together with direct and diffuse, reflected irradiance is one of the components of the primary source of energy received by the photovoltaic modules.

The total irradiance received is the result of the addition of the projections of all three components (direct, diffuse and reflected) to the surface of the PV modules, considering both front and rear planes in the case of bifacial PV technology.

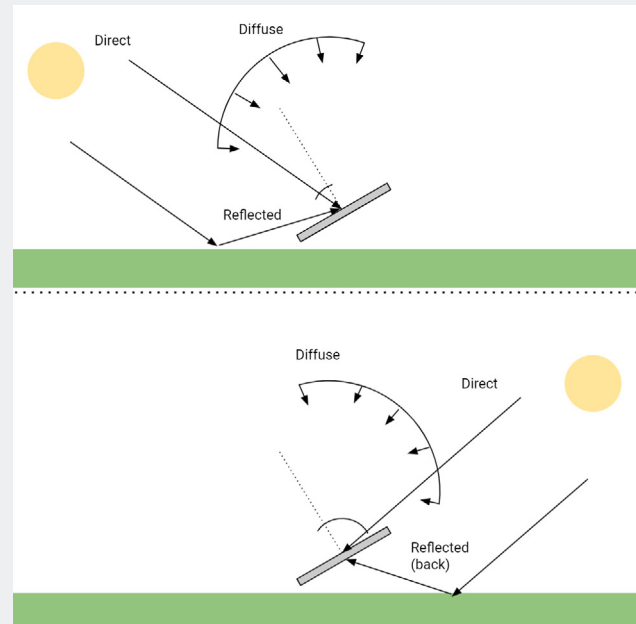


Fig. 5. Components of solar irradiance on a tilted plane.

Understanding variability of albedo

Albedo values in nature

In nature, most of the land surface not covered by ice or snow have an albedo in the range of 0.10–0.35. In contrast, water bodies usually have a low albedo, typically around 0.05. On the opposite side, regions covered with fresh snow or clean ice have a very high albedo, which may exceed 0.85.

However, it cannot make complete sense to describe albedo with a single value without understanding its variability. Thus, when a particular type of surface is said to have a typical albedo value, it is always an average value, which is representative only to a limited extent.

Global map of albedo (yearly average)

The map illustrates the high albedo values provided by desert regions and regions covered by snow and ice, in most parts of the year. Water bodies show the opposite since most of the solar radiation is absorbed in that case.

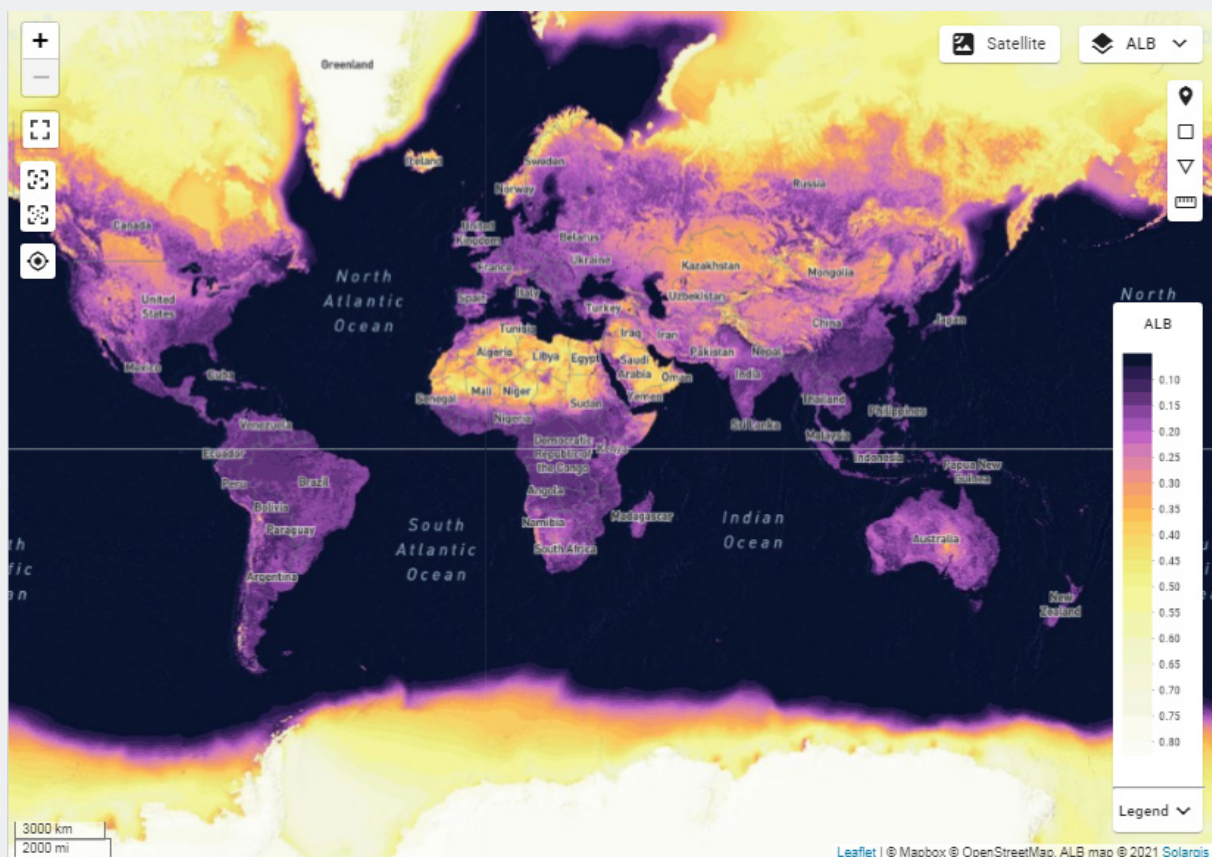


Fig. 6. Yearly average of ground albedo at 1-km grid resolution (Solargis database)

The coupled features of albedo

Albedo is a complex phenomenon: it is not merely a true constant surface property, but rather a characteristic of the coupled surface-atmosphere system. In particular, surface albedo is a function of the inherent surface characteristics, atmospheric parameters, and illuminating conditions [2].

In general, albedo presents a high variability, both in a geographical extent (at scales of only a few meters) and time (at scales from minutes to daily, seasonal, and even inter-annual) [3, 4]. The next figures show examples of the spatial and temporal variability of the ground albedo for the same location.

Albedo has high variability in geographical extent (at scales from only a few meters) and time (from minutes to daily, seasonal, and even inter-annual)

In general, besides the deterministic and stochastic changes in the illumination conditions (sun path, aerosols, clouds), any action—natural or anthropogenic—or circumstance that causes a change of the surface properties results in a variation of albedo. Thus, for instance, changes in the precipitation regime affect the amount of available water, and hence the life cycle of vegetation. Other environmental elements influencing the surface albedo are humidity, wind, snow aging (melting and soiling), etc.

Illuminating conditions

As shown in the graph for a sample site, albedo does not only depend on the type of surface, but also on the illuminating conditions. Diurnal curves reveal a clear dependence of the albedo values on solar position for clear-sky conditions, while it is approximately constant under cloudy conditions.

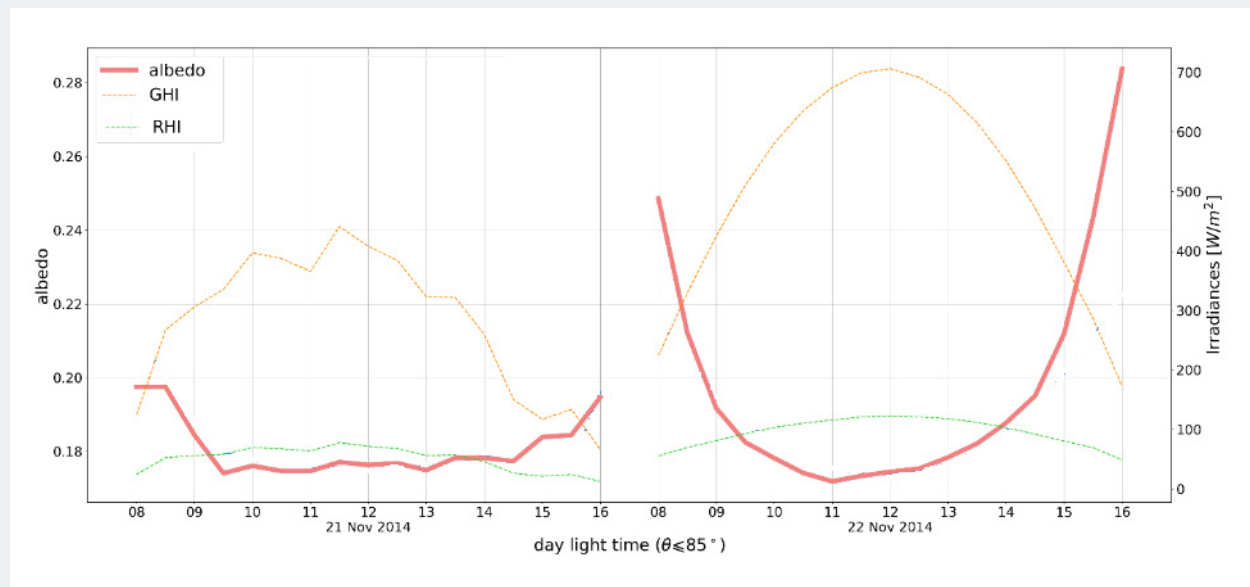


Fig. 7. Diurnal variation of albedo along with GHI and RHI in a cloudy day (top-left) and clear-sky day (top-right) recorded at the meteorological station located in Walnut Gulch Kendall Grasslands, USA.

Seasonal and interannual variability

Time series of daily values clearly show daily, seasonal, and inter-annual variability patterns. Besides the illuminating conditions, ground albedo is influenced by factors that shape the ground surface conditions: use of land, precipitation, seasonal vegetation and humidity cycles, etc.

This is even more relevant for areas that are used for agricultural activities, where seasonal variability is expected to be influenced by the different phenological stages of crops, i.e. seed, germination, growth, harvest.

Understanding the full variability of albedo is consequently of importance when running PV simulations based on averaged values.

Annual variability for a site in arid area

The data covers a period of 20 years between 2000 and 2020. The range of values registered for the site is seen from 0.133 (year 2003) and 0.153 (year 2020). The average value over the entire period is 0.144.

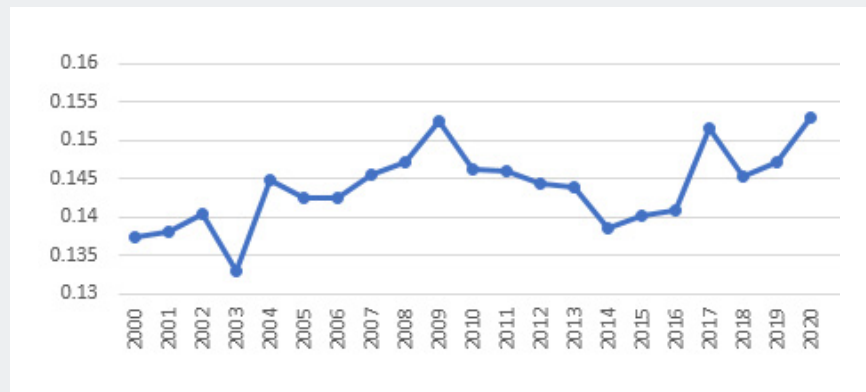


Fig. 8: Annual values of albedo in Tabernas, Spain. Data source: Solargis

Monthly variability for a sample site in arid area

The chart shows monthly statistics and percentiles to show the variability recorded for the site.

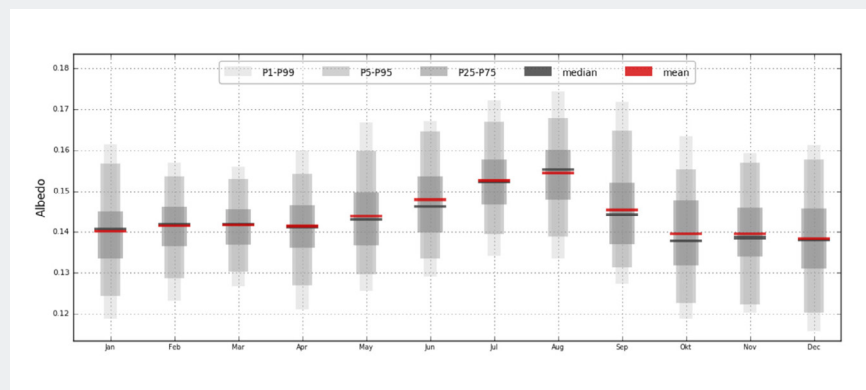


Fig. 9: Monthly values of albedo with representation of statistics in Tabernas, Spain. Data source: Solargis

Sources of albedo data

Ground observations

Surface albedo can be measured by means of a ground-based instrument called albedometer. It consists of two pyranometers arranged in an opposite direction, parallel to the horizontal surface, and measuring synchronously GHI and RHI respectively.

Albedometers are accurate instruments if properly installed, rigorously operated and maintained

Measuring albedo on-site is usually considered the most accurate method, on the condition that the instruments are properly installed, and under rigorous operation and maintenance (O&M). As with all radiometric instruments, the albedometers are also subject to the same quality standards on which the reliability and uncertainty of the measurements depend.

However, the area seen by the instrument's field of view (FOV) is limited, when assessing the representativeness of the measurements associated with large areas to be occupied by a PV power plant.

How does an albedometer work?

One of the pyranometers measures GHI and the other RHI. So albedo is directly obtained using the equation:

$$\rho = \frac{RHI}{GHI} \quad \text{where,}$$

RHI is the total reflected irradiance scattered back by the ground surface reaching the horizontal surface.

GHI is the global (or total) solar irradiance reaching the horizontal surface.



Fig. 10: Hukseflux SRA11 albedometer.

Satellite observations

First, it should be noted that providing accurate global data with high spatial resolution entails an enormous scientific and technological challenge. The spatial and temporal variability of ground albedo makes achieving this goal unfeasible by means of ground observations exclusively.

Measuring full variability of the ground surface albedo is not feasible without satellite observations

Fortunately, nowadays albedo is also routinely estimated on the basis of the surface reflectance measured by instruments aboard satellite platforms. Probably the most popular example of this kind of data is a suite of MODIS data products, which include the most advanced and extensively validated collection of albedo data.

In particular, these products are the foundation of some of the albedo databases being used by the solar industry. Notwithstanding, other satellite-based and reanalysis databases of albedo are also available.

MODIS instruments

The Moderate Resolution Imaging Spectroradiometer (MODIS) is an instrument aboard the Terra and Aqua satellites.

The orbits of the satellites around the Earth are so that Terra crosses over the equator from north to south in the morning, meanwhile, in opposition Aqua does it from south to north in the afternoon.

The instrument data cover the Earth's surface every 1 to 2 days. It makes measurements in 36 spectral bands. MODIS products are provided in a set of projected grids with different spatial resolutions.

At present, the highest spatial resolution achieved in a mature operational product based on satellite estimates is produced by the MODIS team at a pixel size of approximately 0.5 km [7].

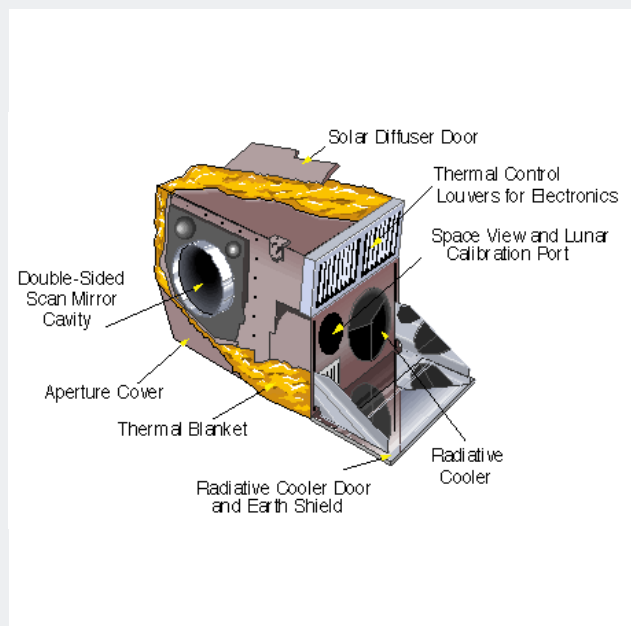


Fig. 11: Image of satellite with MODIS instrument.

Reanalysis data

Meteorological reanalysis databases include comprehensive sets of parameters based on the inputs from ground observation networks and satellite data, generated using NWP (Numerical Weather Prediction) models. Some include the surface albedo, e.g. ECMWF ERA-5 and NASA MERRA-2 projects.

The advantage of this technology of calculating albedo is that it provides data globally, for any surface, without gaps. On the other hand, the spatial resolution that is achieved is much lower compared to other methods.

How reanalysis works

Reanalysis makes use of ground observations, satellite and model data that are used to construct the global state of the atmosphere over long periods of time (several decades) in history. The data inputs are used as initial and boundary conditions for the NWP model runs to complete the time intervals between initial atmospheric states. The result is a comprehensive set of meteorological variables covering the world with relatively high temporal resolution (typically hourly) and low spatial resolution (typically tens of kilometers).

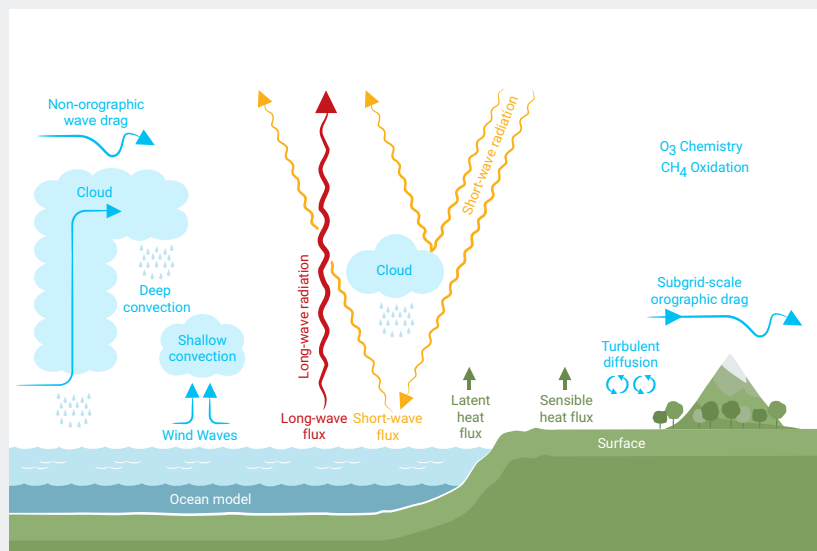


Fig. 12. Diagram showing atmospheric physical processes formulated in NWP models.
Image: Solargis

Comparison of albedo databases

Selection of albedo data sources

Solargis performed intercomparison of several data sources [3], including satellite-based and computed by the reanalysis models. The data sources providing albedo data globally have been included in this intercomparison study.

Two types of datasets have been included in the study: monthly averages (used by most PV energy simulators) and time series data (used for variability analysis).

This list of sources does not include all of the available albedo data sources; the study has been restricted to those, which to the best of our knowledge, are more likely to be used by solar industry professionals and researchers and are made with inputs of proven quality.

Long-term monthly averages used in this study come from averaging the time series data (representing years 2011–2015) except for:

- Mines ParisTech, which provides only the monthly averaged product, calculated for a period of 2004–2011.
- Solargis monthly averages, based on a more extended period 2006–2015 with a specific methodology designed to fill the data gaps (the monthly averaged data product is different from the Solargis time series data product).

Source	Type	TIME SERIES		LONG TERM AVERAGES	
		Temporal resol.	Spatial resol.	Temporal resol.	Spatial resol.
CMSAF	Satellite (CLARA-A2-SAL)	5 days	25 km	Monthly averages	25 km
GLASS	Satellite (AVHRR)	8 days	5.6 km	Monthly averages	5.6 km
NREL — NSRDB	Satellite (MODIS)	1 day	4 km	Monthly averages	4 km
Mines ParisTech	Satellite (MODIS)	—	—	Monthly averages	5.6 km
Solargis	Satellite (MODIS + Solargis)	1 day	0.5km	Monthly averages	1 km
ERA-5	Reanalysis (ECMWF)	1 hour	≈ 30 km	Monthly averages	≈ 30 km
MERRA-2	Reanalysis (NASA)	1 hour	≈ 50 km	Monthly averages	≈ 50 km

Tab. 3: Sources of albedo included in the intercomparison study.

Reference stations for comparison of measured and modeled albedo

The use of the ground and satellite-based assessments for comparison and validation requires that the spatial representativeness of the areas covered is equivalent. This occurs only in circumstances of large homogeneous surfaces.

Validation of satellite-based databases by ground measurements requires that the spatial representativeness of both types of observation is similar.

Assessment of the representativeness of data source includes two considerations:

- Area covered by a data source, which is given by a spatial resolution (in case of satellite-based sources) and field of view (for albedometers).
- Homogeneity of the area covered by each data source.

Name	Country	Source	Latitude [°]	Longitude [°]	Elevation [m a.s.l.]
Bondville	USA	SURFRAD	40.05192	-88.37309	213
Desert Rock	USA	SURFRAD	36.62373	-116.01947	1007
Table Mountain	USA	SURFRAD	40.12498	-105.2368	1689
Fort Peck	USA	SURFRAD	48.30783	-105.1017	634
Walnut G. K. G.	USA	AmeriFlux	31.7365	-109.9419	1531
Willow Creek	USA	AmeriFlux	45.8059	-90.0799	520
Morgan M. S. F.	USA	AmeriFlux	39.3232	-86.4131	275
Metolius M. P. P.	USA	AmeriFlux	44.4523	-121.5574	1253

Tab. 3: List of stations used for the validation of albedo data sources. Only Bondville station is not considered a sufficiently homogeneous location. We have included it for the sake of completeness to reflect situations of non-homogeneous project sites.

Map of stations



Fig. 13: Geographical location of the radiometric stations used in the evaluation of the albedo data products.

Qualification of albedo measurements for validation of modeled data

Prior to the comparison with satellite-based solar resource data, the ground-measured albedo needs to be quality controlled to remove erroneous values that sensors may have recorded.

Quality has been controlled for all GHI, RHI and albedo time series and they include both automatic and visual tests. Automatic procedures help to identify missing values, time shifts and allow comparisons against sun position and physical limits.

Ground albedo measurements are quality controlled to remove erroneous values that sensors may have recorded

Visual inspections on the other hand are applied to identify inconsistencies of more complex nature such as shading, regular data error patterns, irregular anomalies such as reflections and comparison with measurements from different instruments (if available).

Assessment of the representativeness of data source includes two considerations:

- Area covered by a data source, which is given by a spatial resolution (in case of satellite-based sources) and field of view (for albedometers).
- Homogeneity of the area covered by each data source.

Representation of all sources for a sample site

The chart below represents a time series of observations and several sources of albedo during a period of 5 years. High values (jumps) in the data are due to snow, which shows seasonal snow events for this site. Sources not having daily data resolution are represented with dots.

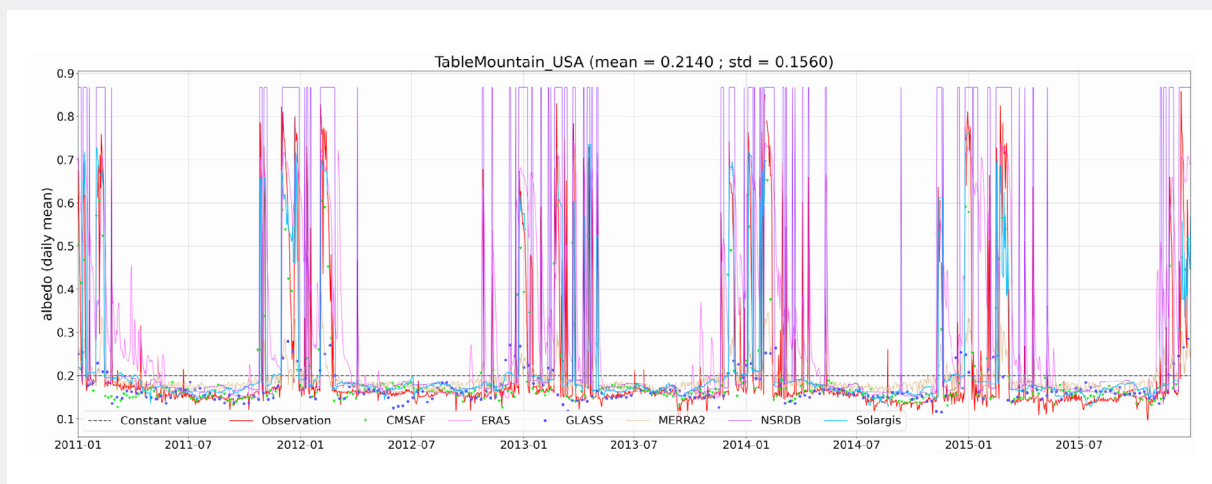


Fig. 14: Time-series of daily values (5-years period [2011, 2015]) of different sources and ground observations at Table Mountain station.

Results from comparison of albedo data sources

Deviation scores

The values of the mean bias deviation (MBD), mean absolute deviation (MAD) and root mean square deviation (RMSD), are calculated for each data source.

Satellite-based products show lower deviations but the magnitude of these deviations differs from one location to another.

In general, MODIS-based sources tend to slightly underestimate the albedo (negative bias), except for NSRDB, which has a higher bias, probably due to the problem of considering a constant value of 0.8669 for snow albedo [14].

Source		CMSAF	GLASS	NREL NSRDB	Mines ParisTech	Solargis	ERA-5	MERRA-2
MONTHLY AVERAGES								
Spatial resolution		25 km	5.6 km	4 km	5.6 km	1km	≈30 km	≈50 km
Validation statistics	MBD	-0.01	-0.02	0.07	-0.02	-0.01	0.01	0.08
	MAD	0.03	0.04	0.09	0.03	0.02	0.04	0.05
	RMSD	0.05	0.06	0.16	0.05	0.04	0.06	0.07
TIME SERIES								
Spatial resolution		25 km	5.6 km	4 km	—	0.5 km	≈30 km	≈50 km
Validation statistics	MBD	-0.01	-0.02	0.07	—	-0.02	0.01	0.00
	MAD	0.04	0.05	0.10	—	0.03	0.05	0.05
	RMSD	0.07	0.09	0.22	—	0.06	0.09	0.10

Tab. 5: Validation statistics calculated for all sources included in the comparison.

Indicators

Reference indicators are commonly used for providing references for both systematic deviations and spread of random discrepancies between the compared datasets, where x_m is the data from the model and x_g is the data from ground measurement, calculated for N data points.

MBD represents systematic deviation between the modelled and measured values (positive bias indicates overestimation, and negative bias shows underestimation of the model)

$$\Sigma (x_m - x_g) / N$$

MAD represents the average of total deviations considered in absolute terms

$$\Sigma |x_m - x_g| / N$$

RMSD represents the spread of deviations given by random discrepancies between the measured and modelled data

$$\sqrt{\Sigma (x_m - x_g)^2 / N}$$

Summary of statistics for all sites – Monthly averages

The dots are colored to distinguish the months of the seasons in the northern hemisphere (winter corresponds to December, January and February). The presence of snow is a challenge for albedo data sources. It introduces larger deviations that can be seen in all the cases (blue dots representing winter season are more scattered).

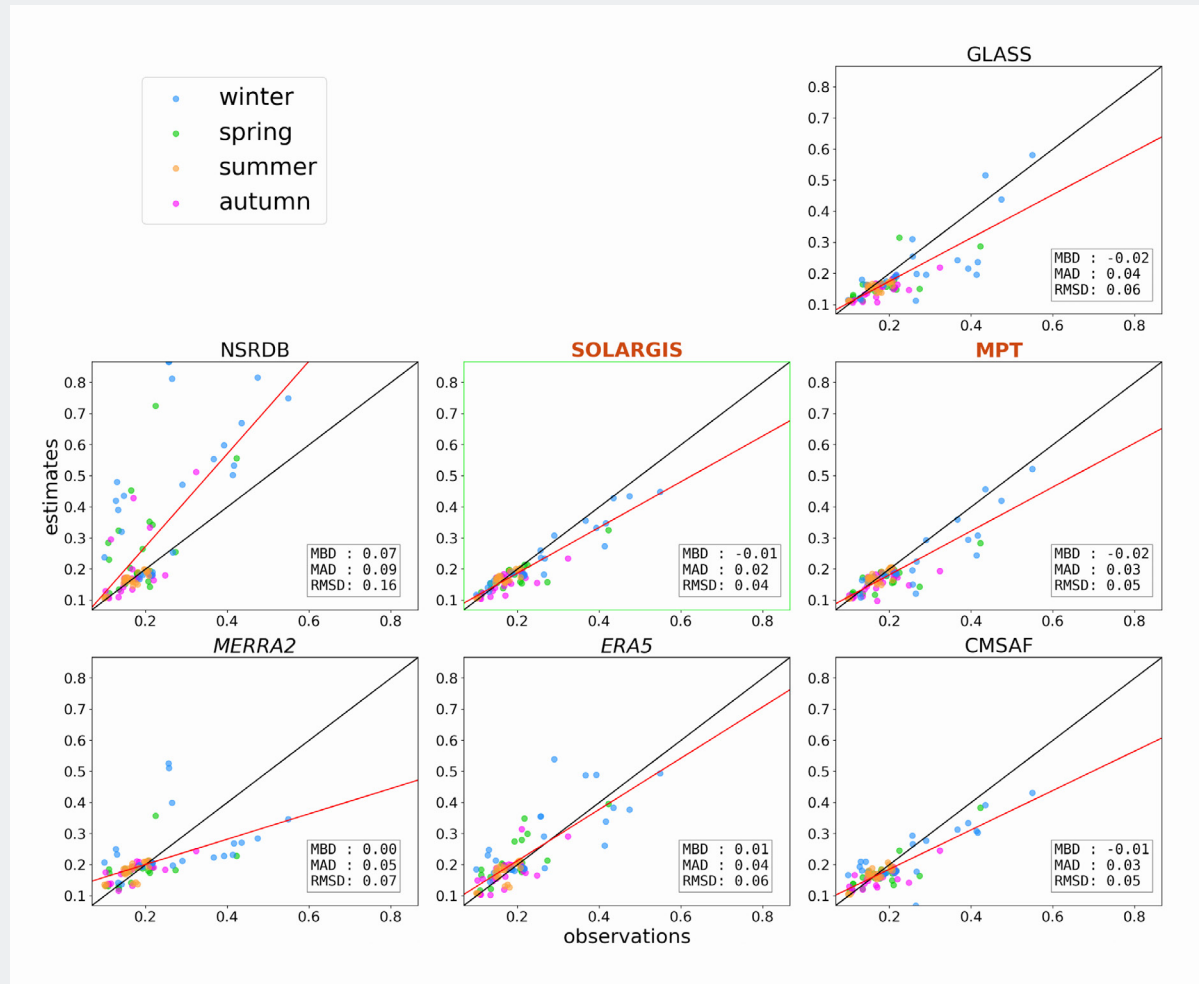


Fig.15: Scatterplots of the long-term monthly averages from different data sources against the ground observations for all locations.

Summary of statistics for all sites – Daily time series

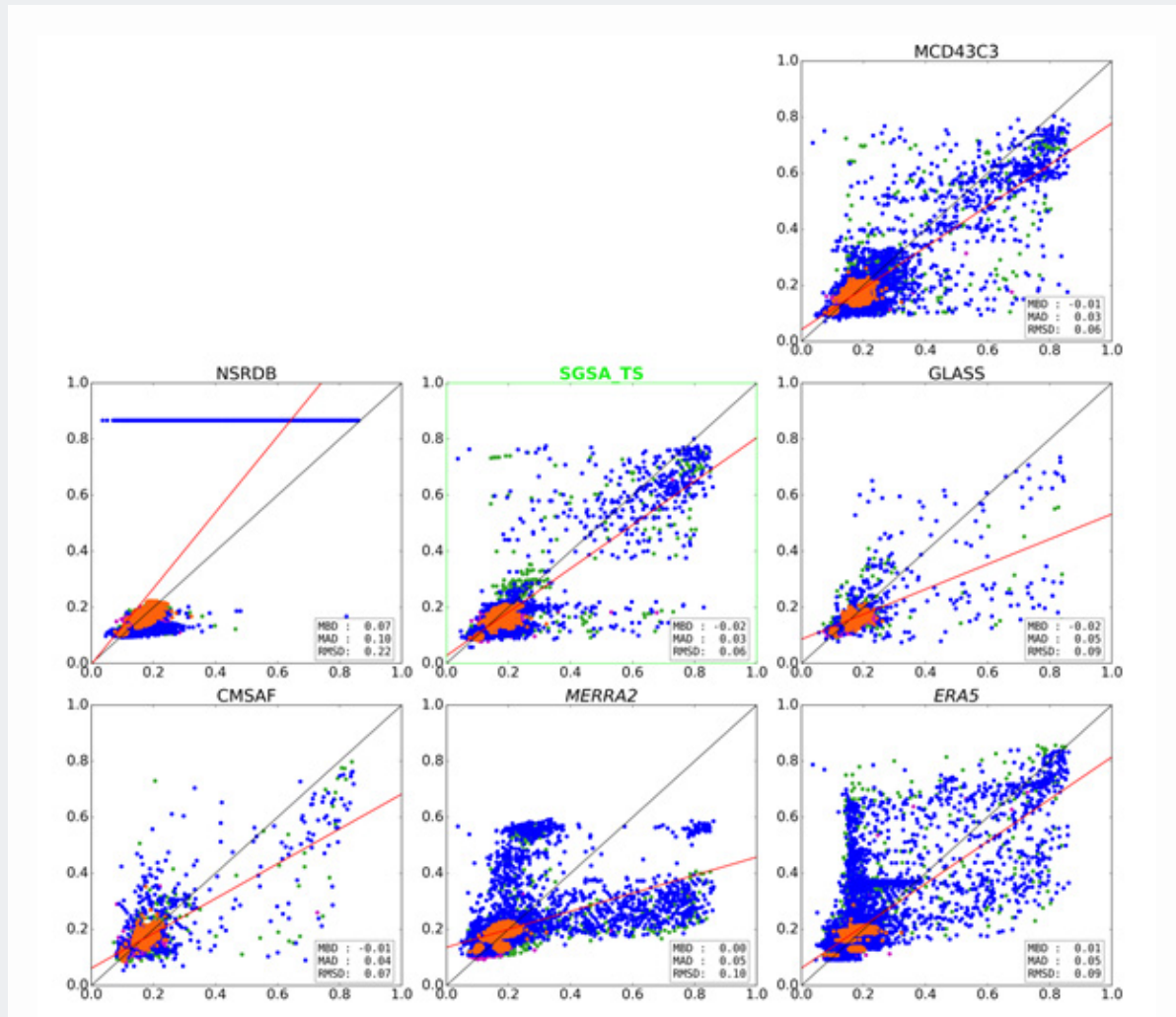


Fig.16: Scatterplots of daily values from different data sources against the ground observations for all locations.

Spatial resolution

Albedo data coming from sources with lower spatial resolutions is representative only for surfaces that are homogeneous across the pixel area. That may explain the poorer results of the data sources with coarse spatial resolution.

Source	Resolution
CMSAF	25 km
GLASS	5.6 km
NREL NSRDB	4 km
Mines ParisTech	5.6 km
Solargis (time series)	0.5 km
Solargis (monthly averages)	1 km
ERA-5	≈ 30 km
MERRA-2	≈ 50 km

Tab. 6: Spatial resolution of data sources used in this study.

Spatial resolution of two databases, KUMSP, India

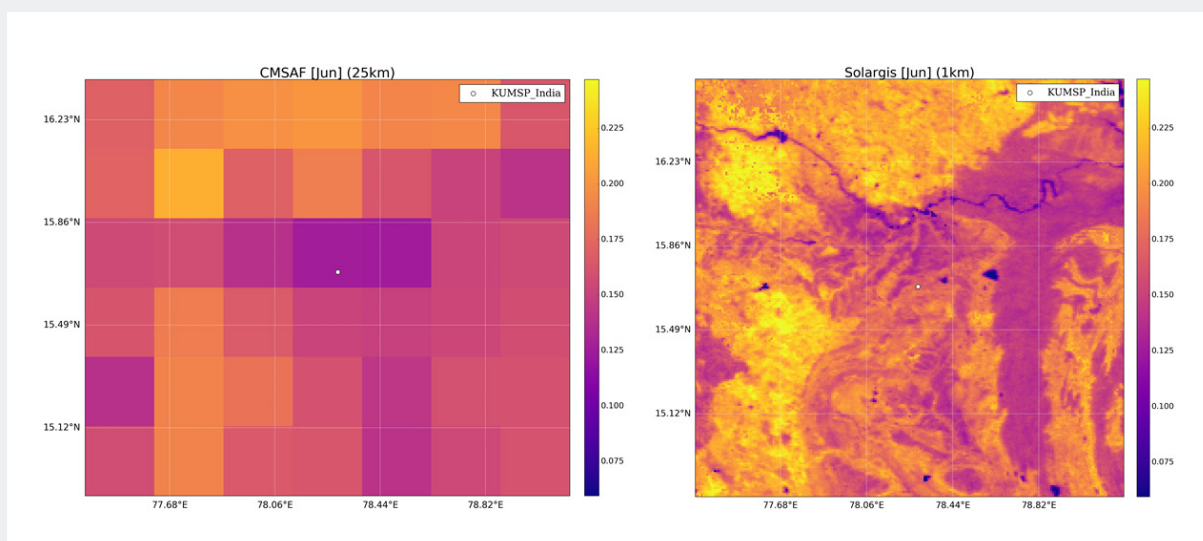


Fig. 17: Effect of spatial resolution showing albedo long-term monthly averages: CMSAF (left) and Solargis long-term average database (right).

Gaps in the data

Gaps are inevitable from satellite sources when there are persistent clouds, or when there are misdetections. Therefore they are reflected in the historical time series products. As a result, temporal and spatial gaps are usual in the time series by MODIS.

The size of the gap is related to the spatial resolution of the dataset, while the length of the gap depends on the persistence of cloudy conditions.

However, calculation of monthly averages allows for the construction of a gap-free dataset by combining a selection of MODIS products that are already gap-filled, with others providing information for snow conditions.

Source	Gaps	Size
CMSAF	Yes	25 km
GLASS	Yes	5.6 km
NREL NSRDB	Yes	4 km
Mines ParisTech	Yes	5.6 km
Solargis (time series)	Yes	0.5 km
Solargis (monthly averages)	No	1km
ERA-5	No	≈ 30 km
MERRA-2	No	≈ 50 km

Tab.7: Summary of presence of gaps in the data for the sources included in the study.

Missing data

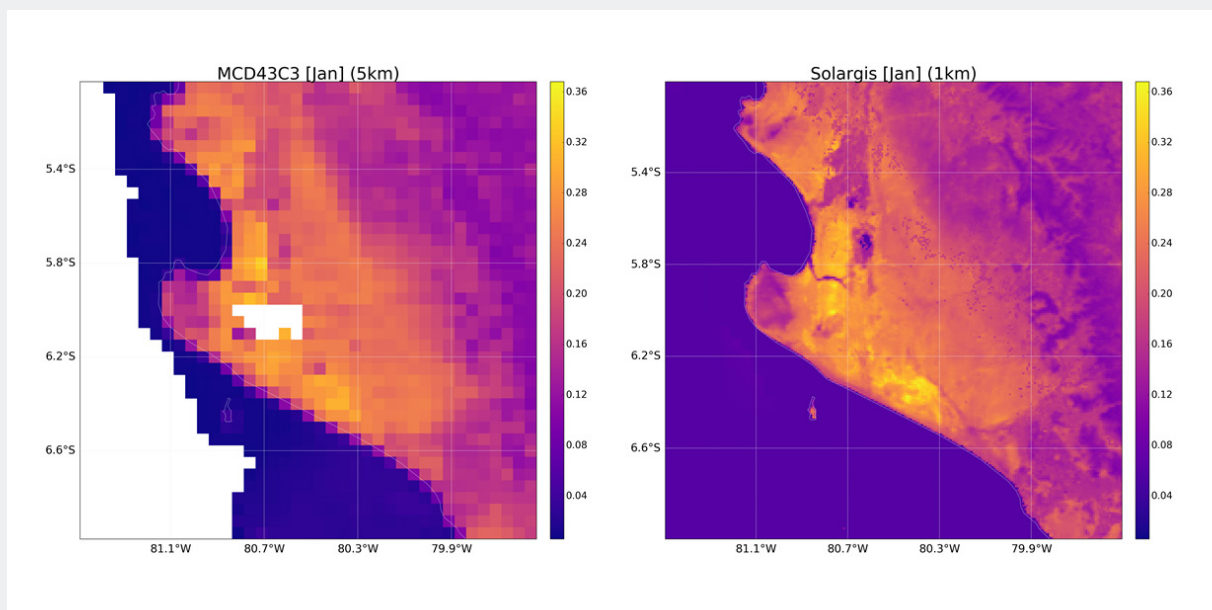


Fig.18: Presence of gaps in sources of albedo data: MODIS product MCD43C3 (left, 5.6 km resolution) and Solargis' long-term monthly averages (right, 1 km resolution) in Sechura Desert (Peru).

Effect of snow

Locations with regular snow events show visibly higher statistical scores, particularly bias. Snow conditions represent a major challenge for the estimation of albedo and they should be treated carefully.

Snow conditions represent a major challenge for the estimation of albedo and they should be treated carefully

In general, snow ages quite fast and snowfalls are accompanied by persistent cloudiness that does not allow the satellite to "see" the surface. It is therefore very usual to see gaps in the data when there are snow events.

The effect of snow for satellite-based products suggests that correction (site-adaptation) of snow values should be moved apart for the standard correction and treated separately.

Snow map

Snow introduces larger albedo values, and when averaging over time, it is important to bear in mind, at the site, that snow albedo values can be very high compared to the values without snow. For example, the average value for the month of January, in a place with an average albedo without snow equal to 0.25, the monthly average value will increase to 0.35, if there are 5 days with fresh snow with an albedo 0.85. Snow introduces larger values of uncertainty too. In the map below the presence of snow is represented by the number of snow days, which is an indication of the presence of snow for each site.

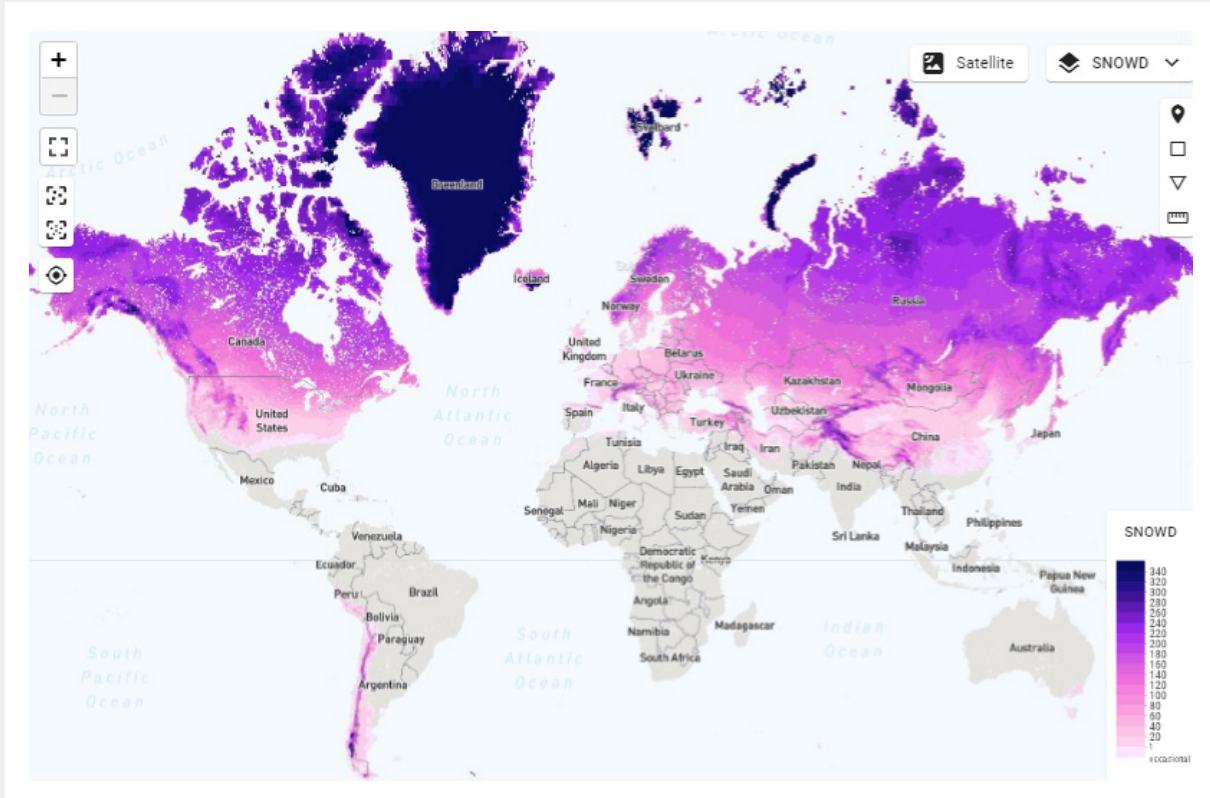


Fig.19. Map showing the number of snow days per year. Source: Solargis

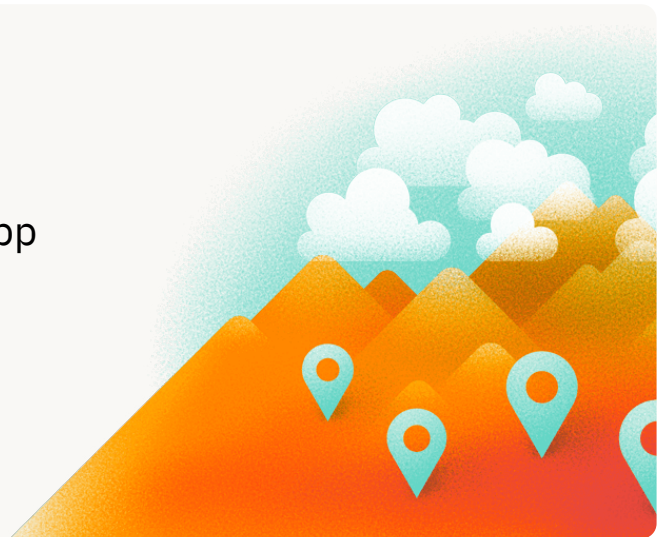
Conclusion

The results obtained in this study are consistent with other scientific publications evaluating MODIS albedo products (e.g. [2, 8]).

- Accurate estimation of reflected irradiance is essential for solar energy applications. A relatively small difference in albedo value results in markable variations when estimating bifacial gain of solar PV plants.
- Although most of the simulators work with long-term average monthly values as inputs, additional data, such as daily time series, are required for the characterization of variability of ground albedo and evaluation of different scenarios.
- Validation of available data sources using high-quality albedo ground measurements shows significant differences in their accuracy. Solargis shows the most accurate values for ground stations at 8 sites in the US, in different geographies and land cover types.
- The difference in spatial resolutions, gaps in the data and special evaluation of snow conditions are key factors to explain differences in albedo provided by different sources.

Get **free monthly** average albedo data for 1 project by signing up for **14-day trial** to Solargis Prospect app

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Further reading

- [1] [Albedo white paper Part II](#)
- [2] [Albedo methodology section in Solargis web site](#)
- [3] [Albedo data accessible from Prospect app](#)

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