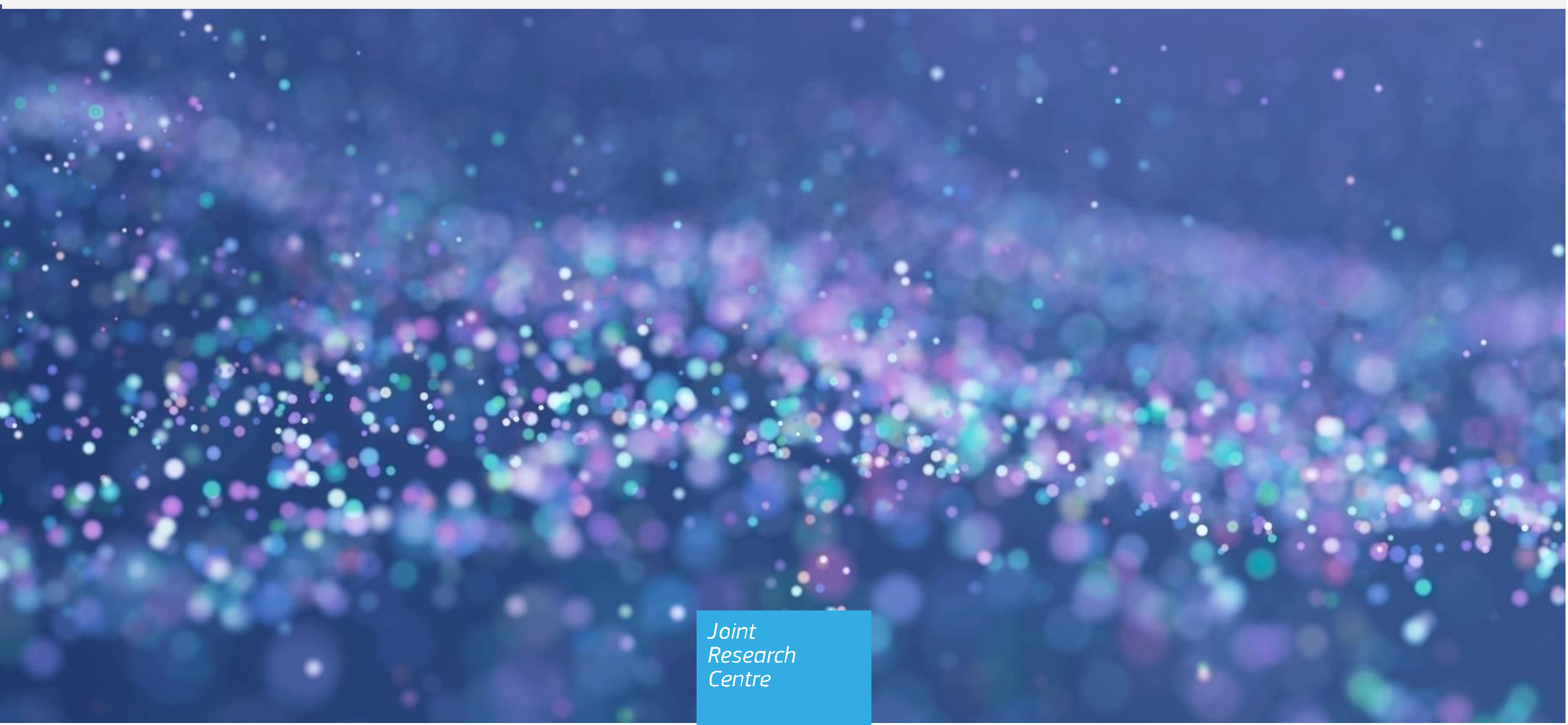
Ref. Ares(2024)6795318 - 26/09/2024

European Commission

PVGIS 5.3 Dataset Update

Gounari, O., Martinez, A., Taylor, N., Alexandris, N.

2024



Joint Research Centre

Contact information
Name: Ana Martinez
Email: jrc-pvgis@ec.europa.eu

EU Science Hub
https://joint-research-centre.ec.europa.eu
JRC139355

Ispra: European Commission, 2024

How to cite this report: European Commission, Joint Research Centre, Gounari, O., Martinez, A., Taylor, N. and Alexandris, N., *PVGIS 5.3 Dataset Update*, European Commission, Ispra, 2024, JRC139355.

Table of Contents

Abstract

The Joint Research Centre's PVGIS (Photovoltaic Geographical Information System) has provided solar radiation data for over 20 years. PVGIS relies on meteorological datasets from satellite observations and reanalysis data which require periodic updates to capture climate change effects. This report summarizes the fixes implemented in PVGIS 5.2.1, the data processing pipeline for PVGIS 5.3 datasets and the validation of the new datasets PVGIS 5.3 datasets have been temporal extended to 2023, covering now the solar irradiation data of 19 years. Additionally, have been spatial extended to include a 25km coastal zone to support the assessment of floating photovoltaic units.

This paper focuses on the validation of the updated data by comparing it with the previous version of PVGIS, as well as with ground measurements from 16 Baseline Surface Radiation Network (BSRN) stations. Validation is carried out for three time periods: the years 2005–2020, common between PVGIS 5.2.1 and PVGIS 5.3 datasets, all available years for each version, and the most recent 16-years period for each PVGIS version. Three methods are used for validation, including analysis of the difference in annual averages between PVGIS versions 5.2.1 and 5.3 using maps for irradiance, PV energy yield, and temperature variables for the three time periods. Additionally, a time series comparison between the two PVGIS versions and BSRN stations ground measurements is conducted for irradiance and temperature variables, evaluated using metrics such as MDB, rMDB, RMSD, rRMSD, MAE, and R^2 for the periods 2005–2020 and 2005–2023. The trend of time series for the two PVGIS versions and the BSRN stations for irradiance and temperature variables over the period 2005–2023 is studied. The observed variations support the replacement of the existing datasets with the newly generated ones.

Acknowledgements

The authors would like to thank the Satellite Application Facility on Climate Monitoring (CMSAF), European Centre for Medium-Range Weather Forecast (ECMWF) and Baseline Surface Radiation Network (BSRN) for making all their datasets publicly available, and Deutscher Wetterdienst (DWD) for their technical support in the development of the new updated datasets.

Thanks also to our colleagues Sandor Szabo, Alexandros Falangas, Alessandro Pirovano, Cristian Domicoli and the JRC Big Data Analysis Platform (BDAP) for their support, ideas and encouragement.

1 Introduction

The Joint Research Centre's Photovoltaic Geographical Information System PVGIS, has provided information on solar radiation and photovoltaic potential for over 20 years [1]. PVGIS relies on meteorological databases from satellite observations, in particular Surface Solar Radiation Climate Data Record (SARAH) by European Organisation of Meteorological Satellites (EUMETSAT) Satellite Application Facility on Climate Monitoring (CMSAF). It also uses European Centre for Medium-Range Weather Forecasts (ECMWF) Re-Analysis ERA5 and ERA5-Land datasets to provide world-wide coverage of climatic data for variables such as irradiance, temperature, wind speed, wind direction and others. All these need to be periodically to include data from recent years to capture, for example, climate change effects. Such updates require a corresponding validation against ground measurements and comparisons with previous PVGIS versions [2].

The present report is a summary of the PVGIS 5.3 dataset update, along with some fixes that were implemented for PVGIS 5.2.1.

The PVGIS 5.2.1 fixes relate to a minor software modification to remove the temperature downscaling function introduced in the past when using lower resolution environmental data, and the addition of some missing/corrupted data that enables the extraction of global maps without gaps and the use of SARAH-2 data in regions that were not available before.

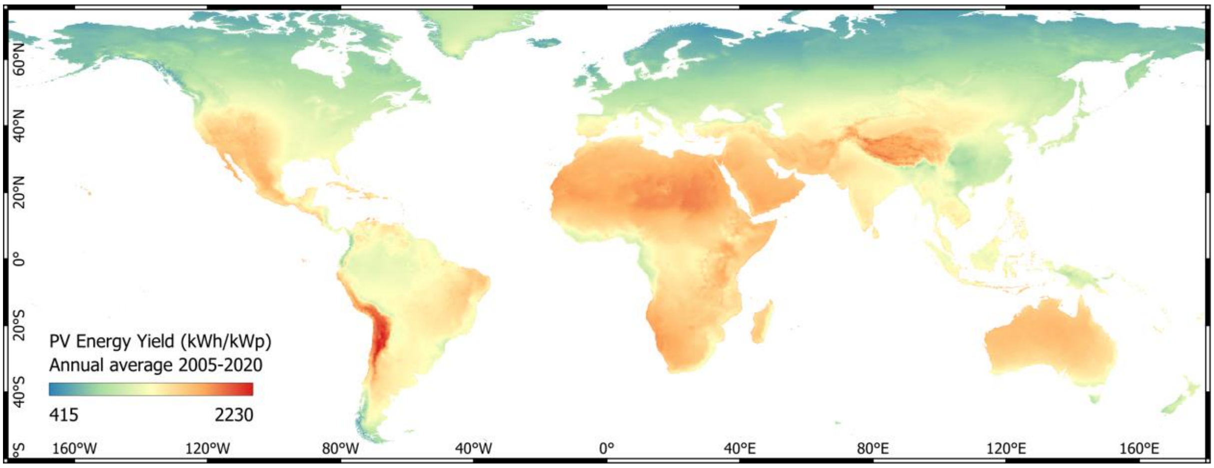
The PVGIS 5.3 dataset update aims to enhance the overall spatial and the temporal extent. This new dataset is developed for the PVGIS needs, combining the latest release of Surface Solar Radiation Climate Data Record (SARAH-3) with fifth generation European ReAnalysis ERA5 and ERA5-Land datasets. The new datasets are complete up to year 2023, starting from 2005. To stay relevant with the emerging potential to deploy floating PV technology in coastal waters, the ERA5 data availability is extended to cover 25 km from the shoreline. SARAH-3 is used to replace SARAH-2 for surface incoming direct (SID) and shortwave (SIS) radiation. ERA5-Land replaces the ERA5 values for the regions that ERA5-Land has available data and for all the PVGIS variables except SID and SIS that ERA5 data are used.

This report presents the validation of the new datasets through a comparison of the annual average maps for temperature, PV energy yield and irradiance between PVGIS 5.2.1 and PVGIS 5.3. Additionally, a comparison of temperature, global horizontal irradiance and global inclined irradiance values from PVGIS 5.2.1 and PVGIS 5.3 with measurements from Baseline Surface Radiation Network (BSRN) ground stations is conducted to quantify the differences in the key variables resulting from the use of the different datasets. The trends of global horizontal irradiance and temperature for BSRN, PVGIS 5.2.1 an PVGIS 5.3 are also examined.

2 PVGIS 5.2.1

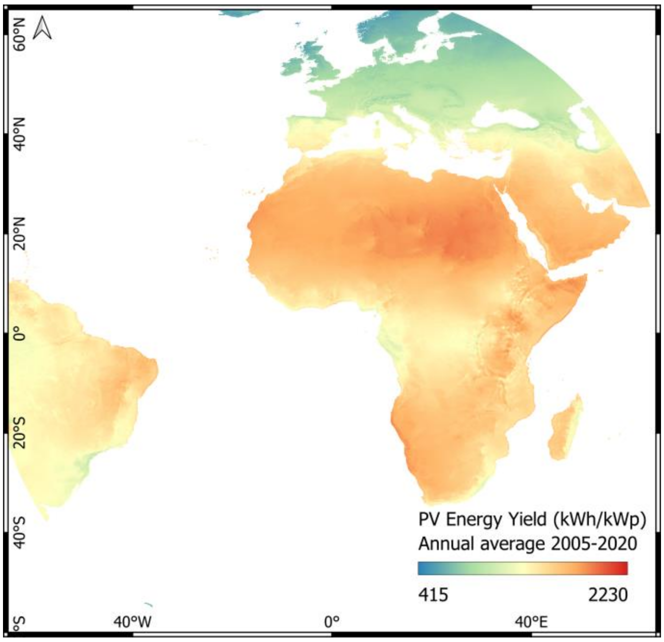
This section presents the fixes implemented in PVGIS 5.2.1, applied in July 2023 (see also the Release Notes). Following the fixes described in this section2, it is now possible to generate maps for land regions between latitude 60°S to 75°N and longitude 180°W to 180°E using PVGIS 5.2.1. Figure 1 and Figure 2 show two example maps showing the annual average PV energy yield (kWh/kWp) with spectral corrections, covering all the available years period from 2005 to 2020. The PV yield values for the map in Figure 1 are calculated using ERA5 irradiance data with a pixel resolution of 0.1°, while the map in Figure 2 is generated using SARAH-2 irradiance data with a higher pixel resolution of 0.05°. For both maps, the PV panel slope was set to 0° (horizontal panel) with a fixed mounting type.

Figure 1. Annual PV Energy Yield 2005-2020, PVGIS 5.2.1 with ERA5 irradiance dataset.



Source: Produced for the current report.

Figure 2. Annual PV Energy Yield 2005-2020, PVGIS 5.2.1 with SARAH-2 irradiance dataset.



Source: Produced for the current report.

2.1 Temperature Downscaling in Software

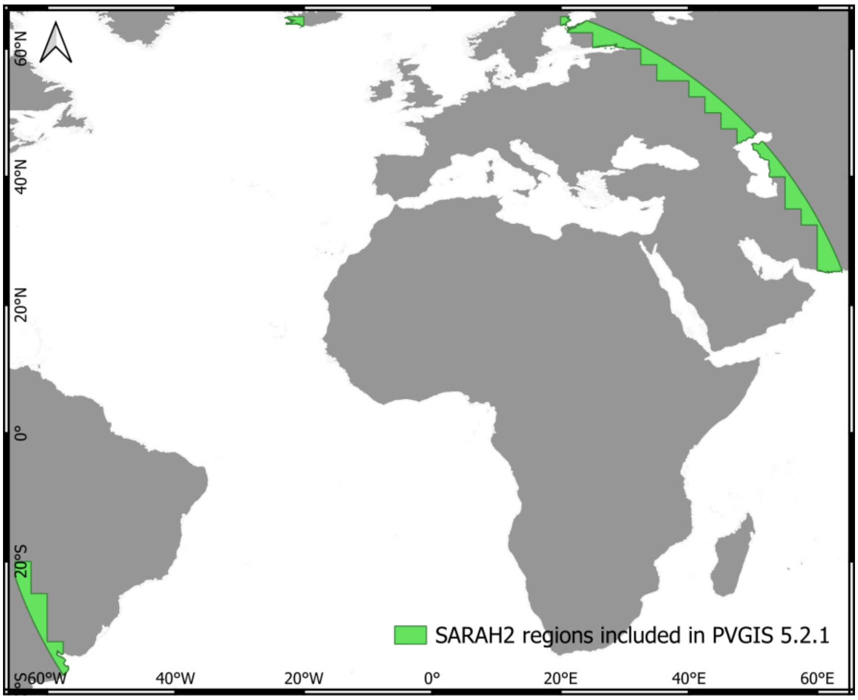
Up to now, PVGIS has applied a downscaling algorithm for temperatures, in part to compensate the low spatial resolution of ERA-Interim environmental data [3]. The PVGIS 5.2.1 release maintained this feature, although this now uses the ERA-Land data with a much higher spatial resolution. Recently checks found that although this downscaling algorithm improves accuracy for locations with large elevation discontinuities (e.g. valleys/mountains), it introduces artefacts on a wider scale. For this reason, it is now removed, pending a detailed study on the most appropriate downscaling methodology. This removal of downscaling for temperature might lead to slight variations in results for yearly PV energy production and year-to-year variability in PVGIS 5.3 compared to the previous version.

2.2 Gaps in Data

2.2.1 SARAH-2

The surface incoming direct (SID) and shortwave (SIS) radiation data have been extended to cover the entire region for which the SARAH-2 dataset is available. Before this update, SID and SIS data from other datasets, such as ERA5, were used as the default option for these regions. Figure 3 depicts the new regions in green, where the default irradiance dataset is now SARAH-2.

Figure 3. SARAH-2 regions added in PVGIS-5.2.1 highlighted in green colour.

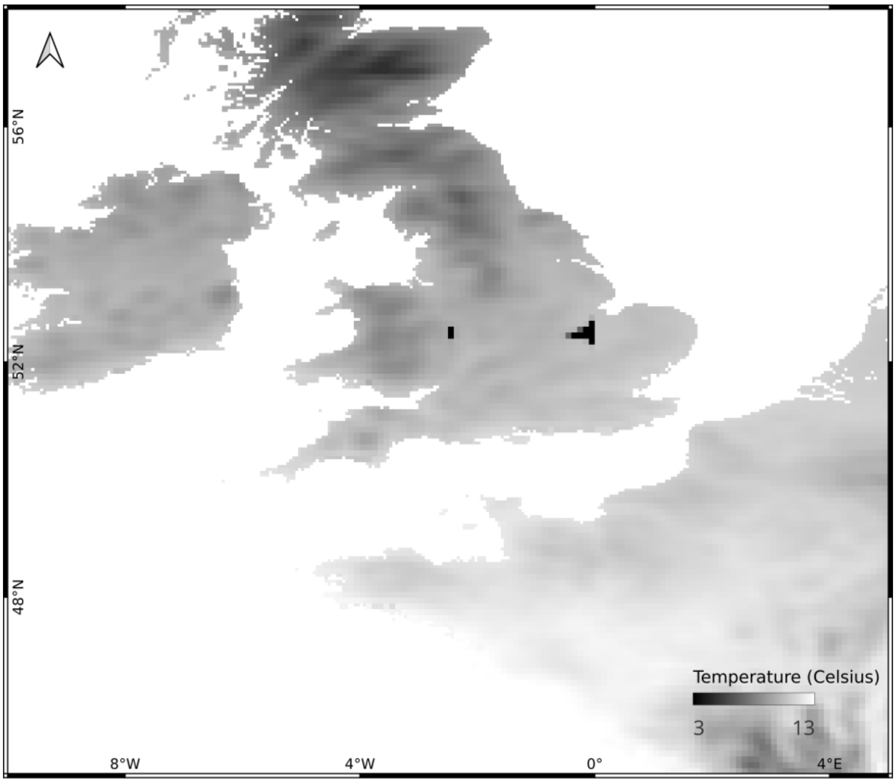


Source: Produced for the current report.

2.2.2 ERA5 Temperature

Missing/corrupted ERA5 temperature pixel values were replaced in the United Kingdom region, ranging from and latitude 51°N to 54°N and longitude 2.5°W to 0°W. The replaced pixels had very low or missing temperature values.

Figure 4. Temperature pixel values replaced in PVGIS 5.2.1.



Source: Produced for the current report.

2.2.3 Elevation and Horizon

Missing/corrupted elevation pixels were replaced in the north America region, close to longitude 180°, and others in the region between latitude 60°N to 62.5°N and longitude 167.5°W to 61°E. Also, missing/corrupted horizon height pixels were replaced in central South America region, close to latitude 17.5°S to 22.5°S and longitude 62.5°W to 60°W.

3 PVGIS 5.3

This section presents the PVGIS 5.3 updates and the validation of the datasets. Table 1 below provides an overview of the differences in the datasets supporting PVGIS 5.2 and PVGIS 5.3.

Table 1. Key features of the datasets supporting PVGIS 5.2.1 and PVGIS 5.3.

Parameter	PVGIS 5.2.1 (online)	PVGIS 5.3 (from September 2024)
Solar radiation (satellite)	CMSAF SARAH-2 Time frame: 2005-2020 Temporal resolution: 1 h Spatial resolution: 5 km Spatial extent: 65°W-65°E and 65°N -60°S	CMSAF SARAH-3 Time frame: 2005-2023 Temporal resolution: unchanged Spatial resolution: unchanged Spatial extent: unchanged
Solar radiation (reanalysis)	ECMWF ERA5 Time frame: 2005-2020 Temporal resolution: 1 h Spatial resolution: 31 km Spatial extent: 180°W-180°E and 75°N-60°S	ECMWF ERA5 Time frame: 2005-2023 Temporal resolution: unchanged Spatial resolution: unchanged Spatial extent: unchanged
Other ERA5 variables	Land: ERA5-Land & ERA5 Sea: not covered Temporal resolution: 1 h Spatial resolution: 9 km Spatial extent: 180°W-180°E and 75°N-60°S Temperature: No downscaling	Land: ERA5-Land & ERA5 Sea: 25 km sea zone covered by ERA5 Temporal resolution: unchanged Spatial resolution: unchanged Spatial extent: unchanged Temperature: unchanged
Spectral corrections	Monthly correction on energy yield, based on 2013 SARAH spectral data	Unchanged
Digital Elevation Model	- SRTM Spatial resolution: 90 m Spatial extent: 180°W-180°E and 60°N-60°S - GTOPO30 Spatial resolution: 1 km Spatial extent: 180°W-180°E and 75°N-60°N	Unchanged
Horizon	GRASS r.horizon command using SRTM & GTOPO30	Unchanged

Source: Produced for the current report.

3.1 Coastal Zones

To stay relevant with the proposals to deploy floating PV technology offshore in the future, data availability has been extended to cover 25 km of coastal waters. The extension of the coastline by 25 km towards the sea necessitated the creation of 17 new elevation tiles and about 111 new horizon tiles for the PVGIS grid. The DEM tiles for the area from latitude 60°N to 60°S are derived from Seamless Shuttle Radar Topography Mission (SRTM) 3 arc second (90m) provided by NASA, while for the area from latitude 75°N to 60°S, they are sourced from the global digital elevation model (GTOPO30) at 30 arc second (approximately 1 km), provided by USGS. The extraction of the horizon tiles was performed by selecting a 7.5-degree step starting from the east (East=0 degrees). Each horizon tile consists of 48 layers, one layer for each of the directions for calculating the horizon height using the GRASS command r.horizon. The image values are measured in degrees, and their calculation took into account an area of 3x3 tiles centred on the tile of interest each time. The max distance was considered to be the edges of this 3x3 area and not the values from the dist_infl map used in the past for which the maximum distance is up to 160 km. The new horizon distance values scale with latitude and are typically larger than the maximum distance considered in the past, reaching up to 280 km. The 3x3 areas of the tiles located in rows 6 and 7 of the PVGIS grid include both SRTM and GTOPO30, and for the extraction of the horizon values, up-sampling or down-sampling was required for 3 of the 9 tiles, with the target image resolution being that of the central tile. For the tiles located in the first and last column of the PVGIS grid, only 6 tiles were considered.

3.2 Dataset Updates

3.2.1 ERA5LandPlus

ERA5 and ERA5-Land are reanalysis datasets for global climate and weather, produced by the European Centre for Medium-Range Weather Forecasts (ECMWF) [4]. Both datasets provide hourly estimates for atmospheric and land-surface quantities. ERA5 offers a spatial resolution of 0.25° (approximately 31 km), while ERA5-Land (which is derived from ERA5) provides an improved resolution of 0.1° (approximately 9 km). However, ERA5-Land is available only for land areas, making its use in coastal regions challenging, as dataset coverage in these areas is limited. A significant number of pixels intersecting with coastlines are assigned a no-data value, as they are not classified as land due to partial overlap with water. To address this issue, in 2022 a synthetic dataset was developed to meet the needs of PVGIS [5]. The process has now been further refined, resulting in a new enhanced dataset called ERA5LandPlus.

The coastline considered for PVGIS 5.3 is derived from digital elevation models vectorization—SRTM 3arc second for latitudes 60°N to 60°S and GTOPO30 30 arc-second for latitudes 75°N to 60°S—buffered 25 km towards the sea to include areas where floating PV systems could potentially be installed. The enhanced ERA5LandPlus dataset refines ERA5-Land by supplementing coastal zones with pixel values derived from ERA5. To fill in the pixel values from ERA5 into ERA5-Land, it is first necessary to resample the ERA5 pixels based on the ERA5-Land pixels. In addition to this operation, there are other processes required to prepare the ERA data for use in PVGIS. These image processing operations are explained in detail below, as they were implemented for the preparation of the ERA5LandPlus dataset for PVGIS 5.3.

Table 2. Affine matrices and image dimension for the raw ERA5 and ERA5-Land datasets, and for the produced ERA5LandPlus dataset produced for the need of PVGIS 5.3, taking into account the spatial extent of the PVGIS tiling grid which ranges between (180°W, 180°E) and (75°N, 60°S). ERA5LandPlus SID and SIS variables have lower resolution since no ERA5-Land data are available.

Dataset	Affine Matrix (°)	Image Dimension (pixels)
ERA5-Land	(0.1, 0.0, -0.05, 0.0, -0.1, 90.05)	(1801, 3600)
ERA5	(0.25, 0.0, -0.125, 0.0, -0.25, 90.125)	(721, 1440)
ERA5LandPlus	(0.1, 0.0, -180.0, 0.0, -0.1, 90.0)	(1801, 3600)
	(0.25, 0.0, -180.0, 0.0, -0.25, 90.0)	(721, 1440)

Source: Produced for the current report.

In Table 2, the affine matrix that defines the georeferencing of the original data for both ERA5 and ERA5-Land is presented, along with the image dimensions. The coordinate reference system for both ERA5 and ERA5-Land is the World Geodetic System 1984 (WGS84), so the values in Table 2 are given in degrees (°). To enable pixel value extraction from ERA5 to ERA5-Land, the image dimensions must be aligned, and the ERA5 images must be resampled based on the ERA5-Land images, specifically to dimensions of (1801, 3600) rows and columns, with a pixel resolution of 0.1 degrees. In addition to resampling the ERA5 images, other image processing operations, such as image translations, are required. This is because the ERA5LandPlus dataset needs to be tiled according to the PVGIS tiling system. The input data for PVGIS are not global images but tiled images, a feature which contributes to the software's efficiency.

The geographic extent of the PVGIS tiling grid is (180°W, 180°E) and (75°N, 60°S), and the original ERA5 data have an origin point of coordinates (-0.125°, 90.125°), while ERA5-Land has an origin point of coordinates (-0.05°, 90.05°). This necessitates changing the origin point (upper-left corner coordinates) of the data in two ways:

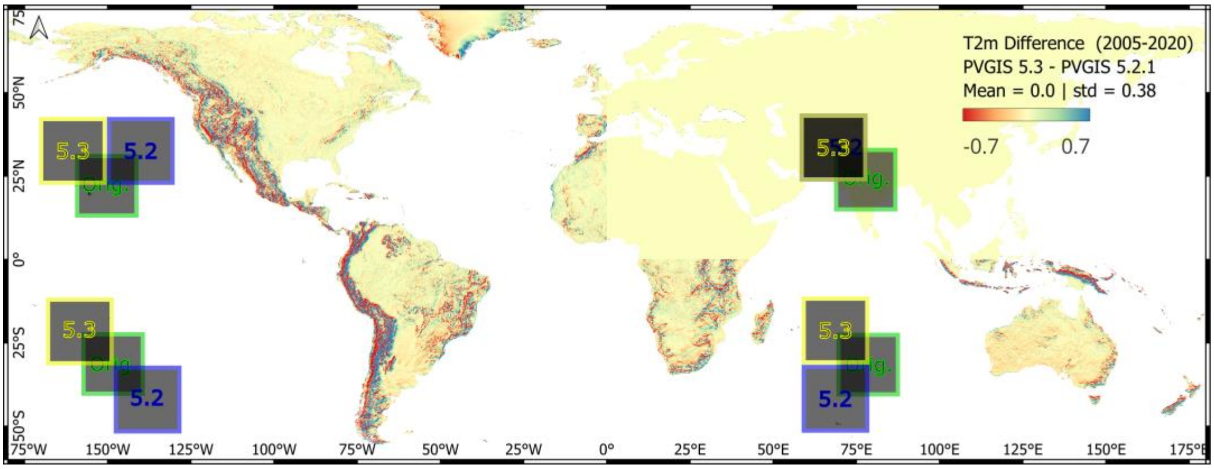
- First, the latitude values range must be adjusted from (-0.125°, 359.875°) for ERA5 and (-0.05°, 359.95°) for ERA5-Land, to range (180°W, 180°E) as required by the tiling grid, ensuring that no pixel intersection occurs with the boundaries of each tile during the tiling process. If pixel intersection was selected, resampling of the image for each tile would be required, as it is not possible to define a raster with a partial pixel.
- Second, a common longitude for the origin point must also be determined, consistent with the tiling grid, as ERA5 and ERA5-Land do not share the same origin point (Table 2). Based on these considerations, the affine transformation matrix for ERA5LandPlus is defined as Affine(0.1, 0.0, -180, 0.0, -0.1, 90), with image dimensions of (1801, 3600) for all environmental variables except ERA5LandPlus SID and SIS, which have an Affine matrix of (0.25, 0.0, -180, 0.0, -0.25, 90) and image dimensions of (721, 1440) since no ERA5-Land SID and SIS data are available.

In summary, the image transformations implemented to create the ERA5LandPlus dataset included an initial translation transformation of the ERA5 and ERA5-Land images by -180° along the latitude axis. A second translation transformation was applied to ERA5-Land by half a pixel, corresponding to 0.05° along the latitude axis and -0.05° along the longitude axis. Similarly, a half-pixel translation was applied to ERA5, corresponding to 0.125° along the latitude axis and -0.125° along the longitude axis. A scaling transformation was only implemented for the ERA5 data to increase the pixel resolution from 0.25° to 0.1°. The Nearest Neighbour resampling method was used due to its algorithmic speed. For more information on the image transformations, see the Wikipedia link [here]. All image processing operations were performed using the rioxarray library, an extension of xarray powered by rasterio, which is based on numpy and GDAL.

3.2.1.1 Differences with PVGIS 5.2.1

It should be noted that both random and systematic differences exist between the ERA5-Land data used by PVGIS 5.2.1 and 5.3. Large variations are considered random and are typically caused by outlier or missing pixel values, particularly in coastal areas. PVGIS 5.3 attempts to correct and avoid reproducing this kind of issues. Smaller but systematic discrepancies between the two versions can be attributed to methodological differences in data production, introduced by the different approach used in georeferencing the ERA5-Land data. These systematic discrepancies become evident in the temperature annual average maps, as presented in section 3.3.1 (Figure 18, Figure 19 and Figure 20), and in annual averages and trends plots, as presented in section 3.3.3, but are small enough to be evident in yield maps or plots. These discrepancies are on the order of 0 or 1 ERA5-Land pixel (approximately 9 km) between the two PVGIS versions. Compared to the original ERA5-Land dataset, the differences are on the order of half pixel for both PVGIS versions, but in different directions depending on the quadrant. Figure 5 illustrates the relative spatial position between the same pixel for PVGIS 5.2.1 and 5.3 in relation to the original ERA5 data depending on the quadrant considered quarter.

Figure 5. Relative position of ERA5-Land pixels between PVGIS 5.2.1, PVGIS 5.3 and the original ERA5-Land data after the translation transformation.



Source: Produced for the current report.

3.2.2 SARAH-3

The main dataset in PVGIS 5.2 and 5.2.1 provides data for Europe and Africa between 2005 and 2020. It contains geostationary satellite-retrieved irradiance values based on the Satellite Application Facility on Climate Monitoring (CMSAF) SARAH-2 product [6]. The data available in PVGIS has hourly values estimated from the analysis of one single image per hour, while the original CMSAF values are 30-minute instantaneous data. The spatial resolution of SARAH-2 data is about 5 km at nadir (0.05° x 0.05°). SARAH-2 data is available for the period from 1983 to 2020.

SARAH-3 is a further development of SARAH-2 with data extended to the present. It covers the same regions as SARAH-2 and has the same spatial resolution. The main innovation is for the estimation of surface solar radiation in case of snow-covered surfaces. As with SARAH-2, in the updated dataset only hourly observations are included in PVGIS.

3.3 Dataset Validation

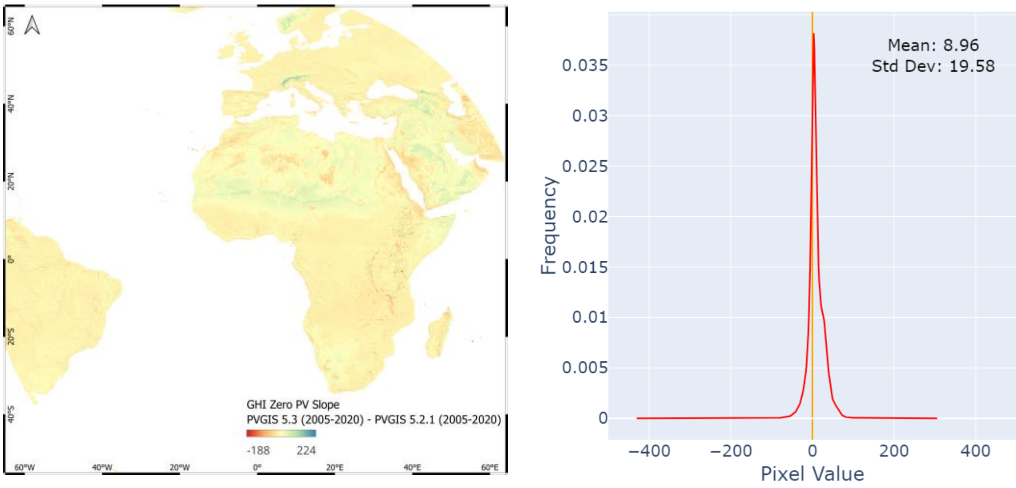
3.3.1 Comparison of PVGIS 5.3 vs. PVGIS 5.2.1

For the comparison between PVGIS versions 5.2.1 and 5.3, annual average maps of global irradiance (kWh/m^2), temperature (Celsius degrees) and photovoltaic (PV) energy yield (kWh/kWp) were generated for both a horizontal and an optimally tilted plane. The difference raster layers were then created by subtracting the PVGIS 5.2.1 maps from the corresponding PVGIS 5.3 maps. The irradiance datasets used were SARAH-2 for PVGIS 5.2.1 and SARAH-3 for PVGIS 5.3. Each set of maps was produced for three temporal ranges:

a) the overlapping years (2005-2020)
b) all the available years for each version (2005-2020 for PVGIS 5.2.1 and 2005-2023 for PVGIS 5.3)
c) the most recent 16-years period for each version (2005-2020 for PVGIS 5.2.1 and 2008-2023 for PVGIS 5.3)

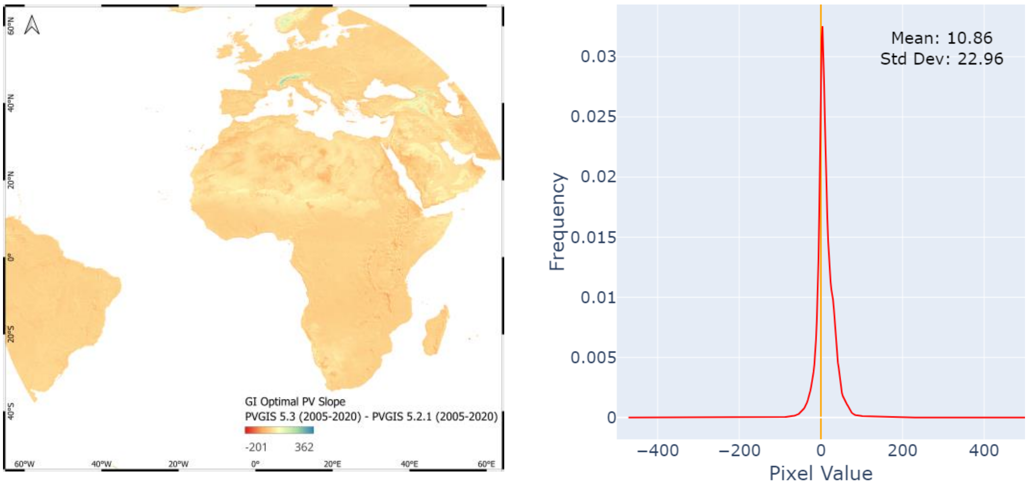
The following figures illustrate the difference raster layers for a fixed PV mounting type, including both cases of a zero-degree slope and an optimized PV slope, across the three temporal ranges.

Figure 6. Differences in the annual average of global horizontal irradiance (kWh/m2) for overlapping years between PVGIS 5.3 and 5.2.1.



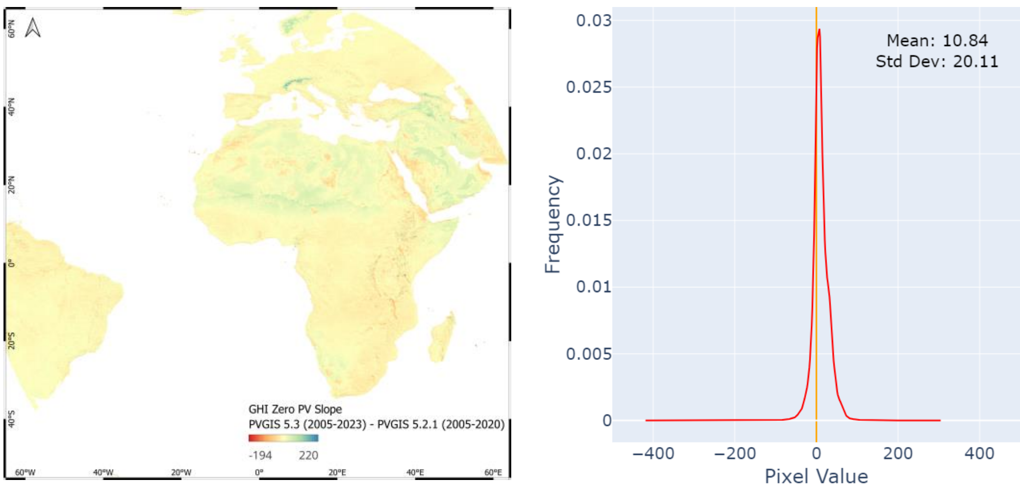
Source: Produced for the current report.

Figure 7. Difference in the annual average of global irradiance (kWh/m^2) on an optimal-inclined plane for overlapping years between PVGIS 5.3 and 5.2.1.



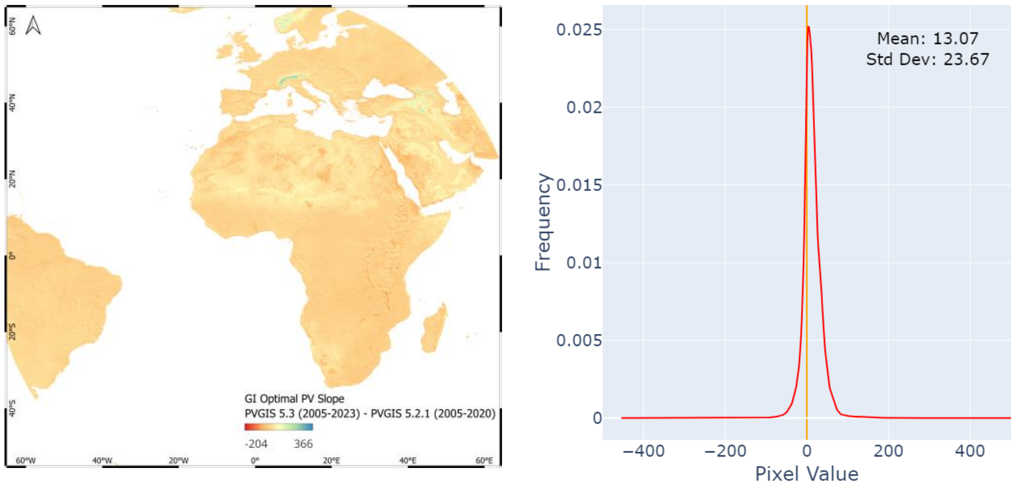
Source: Produced for the current report.

Figure 8. Differences in the annual average of global horizontal irradiance (kWh/m^2) for all available years between PVGIS 5.3 and 5.2.1.



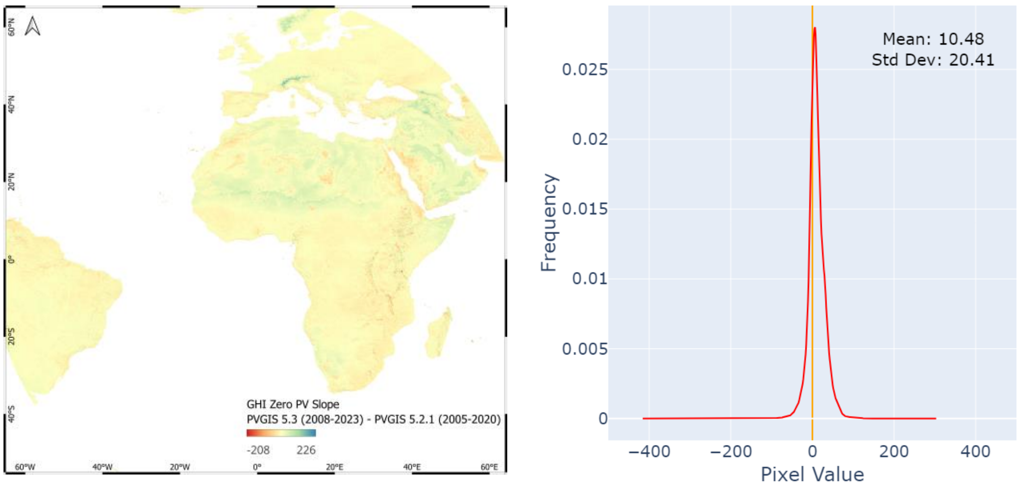
Source: Produced for the current report.

Figure 9. Difference in the annual average of global irradiance (kWh/m^2) on an optimal-inclined plane for all available years between PVGIS 5.3 and 5.2.1.



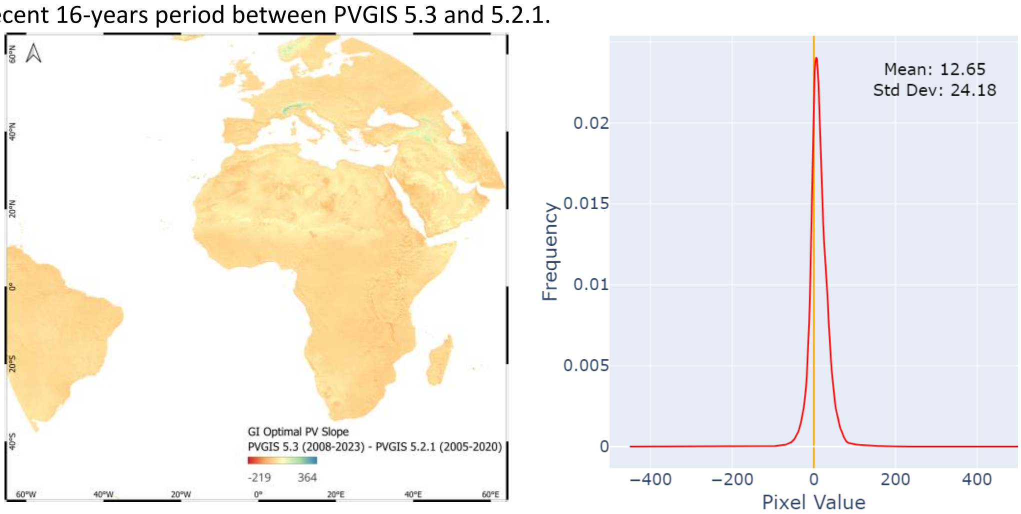
Source: Produced for the current report.

Figure 10. Differences in the annual average of global horizontal irradiance (kWh/m2) for the most recent 16-years period between PVGIS 5.3 and 5.2.1.



Source: Produced for the current report.

Figure 11. Difference in the annual average of global irradiance (kWh/m^2) on an optimal-inclined plane for the most recent 16-years period between PVGIS 5.3 and 5.2.1.



Source: Produced for the current report.

For the differences in the annual average of global horizontal irradiance, it is observed that for the overlapping years, the average value of the difference raster layer is 8.96 kWh/m² with a standard deviation of 19.58 kWh/m². PVGIS 5.3 tends to provide higher values, with the largest positive differences occurring in mountainous regions, such as the Alps.

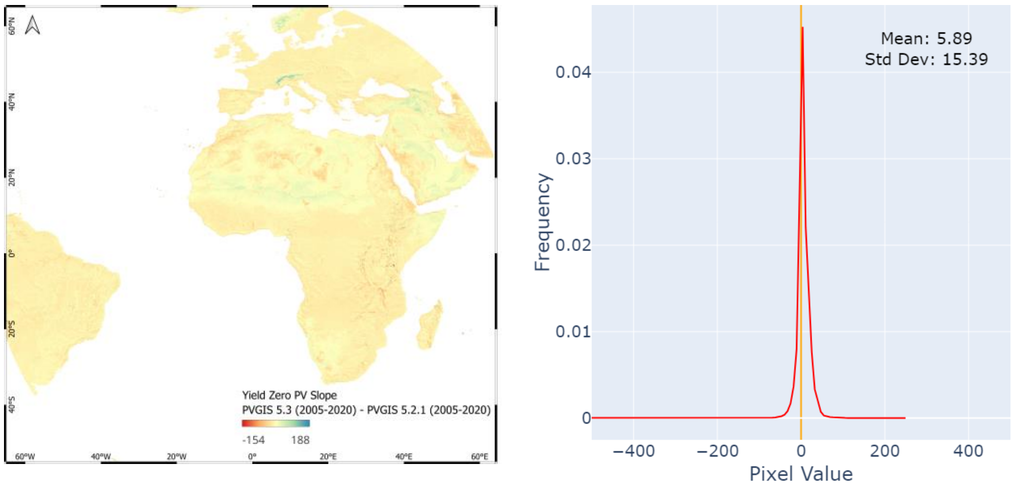
By adding data for the years 2021 through 2023 to PVGIS 5.3, the average value of differences in annual means increases by 1.88 kWh/m², while the standard deviation rises by 0.53 kWh/m², indicating an increase in solar radiation during these years. Examining the most recent 16-years period in comparison to all available years, the average difference decreased by 0.36 kWh/m², but the standard deviation increased by 0.30 kWh/m², suggesting that the exclusion of the years 2005–2007 from PVGIS 5.3 reduced the differences but their variability was increased.

Selecting the optimal PV slope for the overlapping years, the average difference is 10.86 kWh/m², with a standard deviation of 22.96 kWh/m², which is slightly higher than that observed for the horizontal plane. With the inclusion of all available years, the average value increases by 2.21 kWh/m², and the standard deviation by 0.67 kWh/m². For the most recent 16-years period compared to all available years, the average difference decreases by 0.42 kWh/m², while the standard deviation increases by 0.51 kWh/m². As a result, for the differences in the annual average of irradiance, the same pattern of variation is observed between the horizontal and optimal PV slope, with the latter consistently higher by a few units.

For the differences in the annual average of PV energy yield, it is observed that for the overlapping years, the average value of the difference raster layer is 5.89 kWh/kWp with a standard deviation of 15.39 kWh/kWp. PVGIS 5.3 tends to provide higher values, with the largest positive differences occurring in mountainous regions, such as the Alps. By adding data for the years 2021 through 2023 to PVGIS 5.3, the average value of differences in annual means increases by 1.12 kWh/kWp, while the standard deviation rises by 0.21 kWh/kWp, indicating an increase in energy yield during these years. Examining the most recent 16-years period in comparison to all available years, the average difference decreased by 0.41 kWh/kWp, but the standard deviation increased further by 0.27 kWh/kWp, suggesting that the exclusion of the years 2005–2007 from PVGIS 5.3 reduced the differences but their variability was increased since now slightly different temporal ranges are compared.

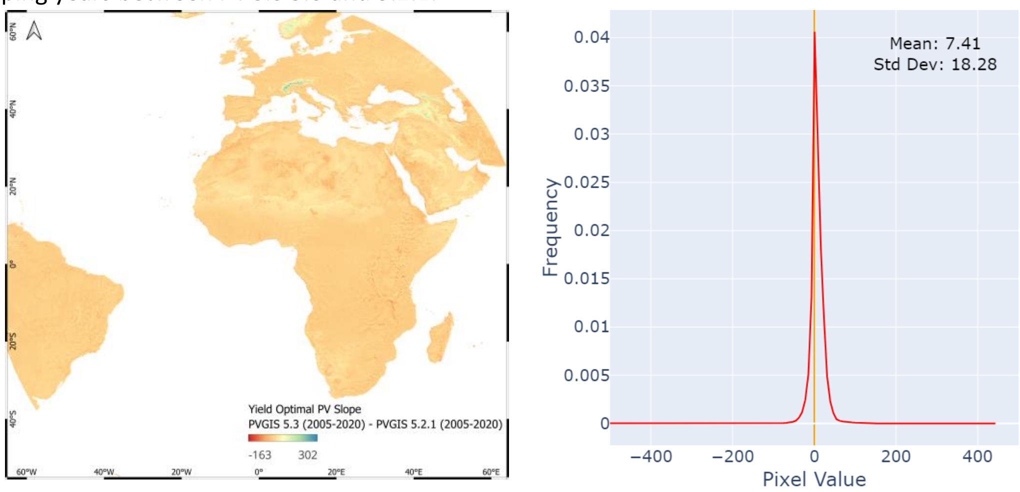
Selecting the optimal PV slope for the overlapping years, the average difference is 7.41 kWh/kWp, with a standard deviation of 18.28 kWh/kWp, which is higher than that for the horizontal plane. With the inclusion of all available years, the average value increases by 1.34 kWh/kWp, and the standard deviation by 0.56 kWh/kWp. For the most recent 16-years period compared to all available years, the average difference decreases by 0.49 kWh/kWp, while the standard deviation increases by 0.42 kWh/kWp. As a result, for the differences in the annual average of PV energy yield, the same pattern of variation is observed between the horizontal and optimal PV slope, with the latter consistently higher by a few units.

Figure 12. Difference in the annual average of PV energy yield (kWh/kWp) on a horizontal plane for overlapping years between PVGIS 5.3 and 5.2.1.



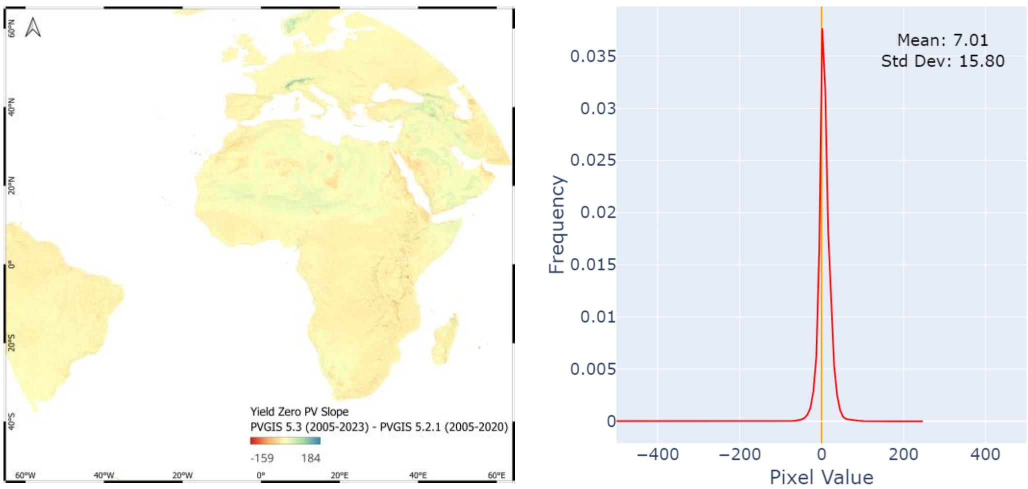
Source: Produced for the current report.

Figure 13. Difference in the annual average of PV energy yield (kWh/kWp) on an optimal-inclined plane for overlapping years between PVGIS 5.3 and 5.2.1.



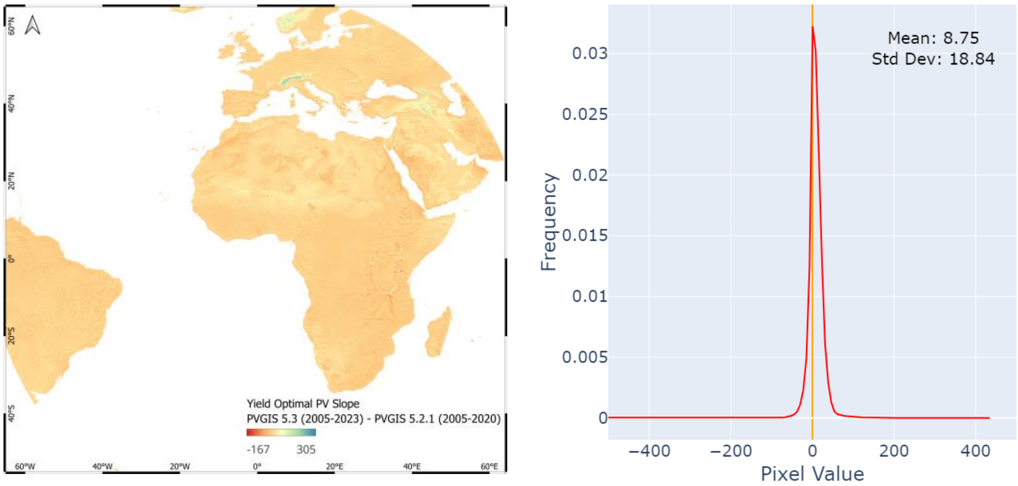
Source: Produced for the current report.

Figure 14. Difference in the annual average of PV energy yield (kWh/kWp) on a horizontal plane for all available years between PVGIS 5.3 and 5.2.1.



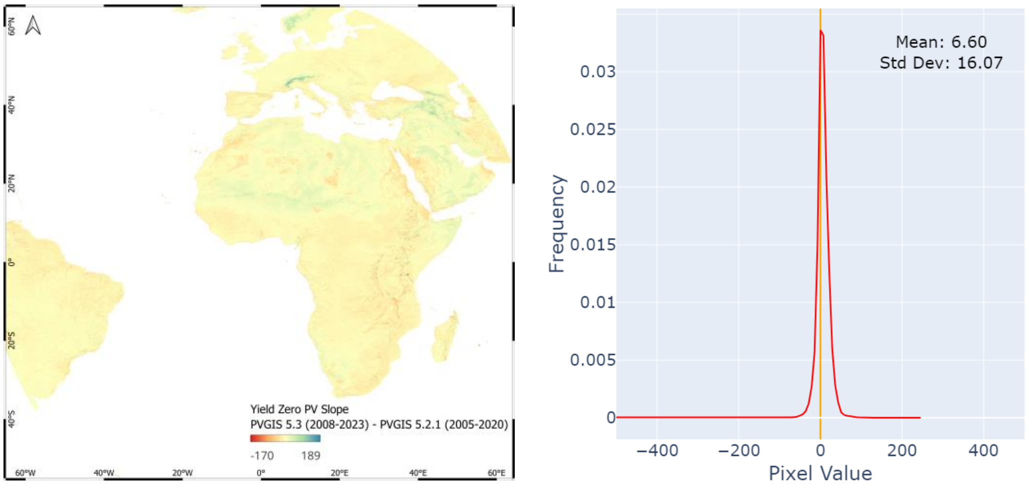
Source: Produced for the current report.

Figure 15. Difference in the annual average of PV energy yield (kWh/kWp) on an optimal-inclined plane for all available years between PVGIS 5.3 and 5.2.1.



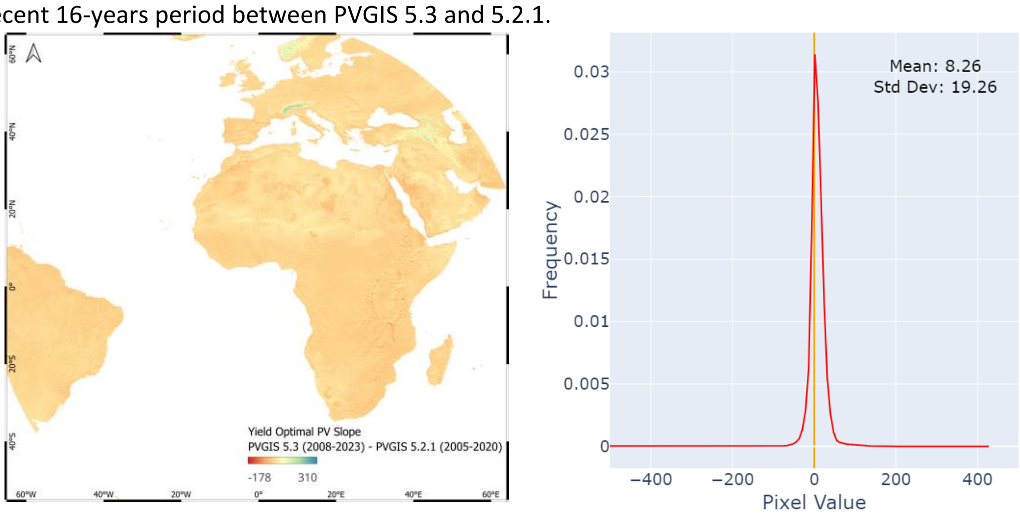
Source: Produced for the current report.

Figure 16. Difference in the annual average of PV energy yield (kWh/kWp) on a horizontal plane for the most recent 16-years period between PVGIS 5.3 and 5.2.1.



Source: Produced for the current report.

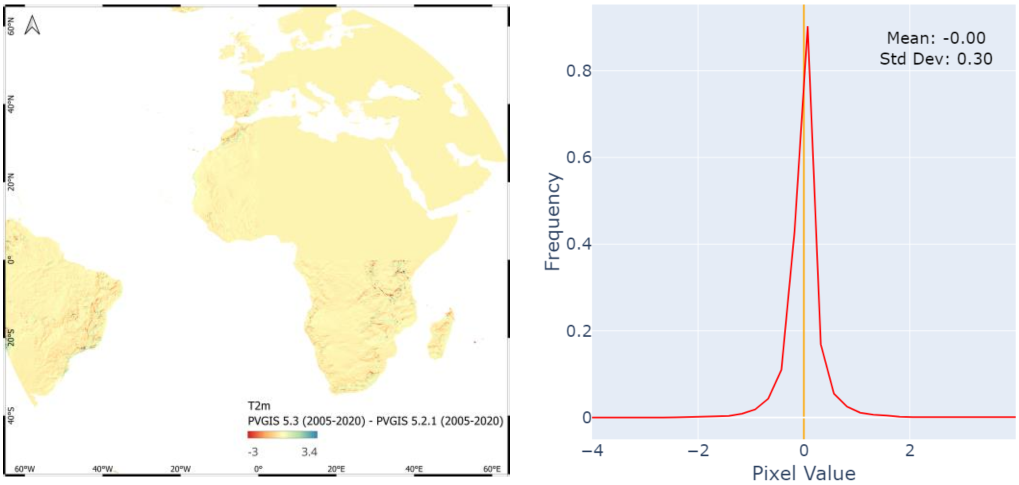
Figure 17. Difference in the annual average of PV energy yield (kWh/kWp) on an optimal-inclined plane for the most recent 16-years period between PVGIS 5.3 and 5.2.1.



Source: Produced for the current report.

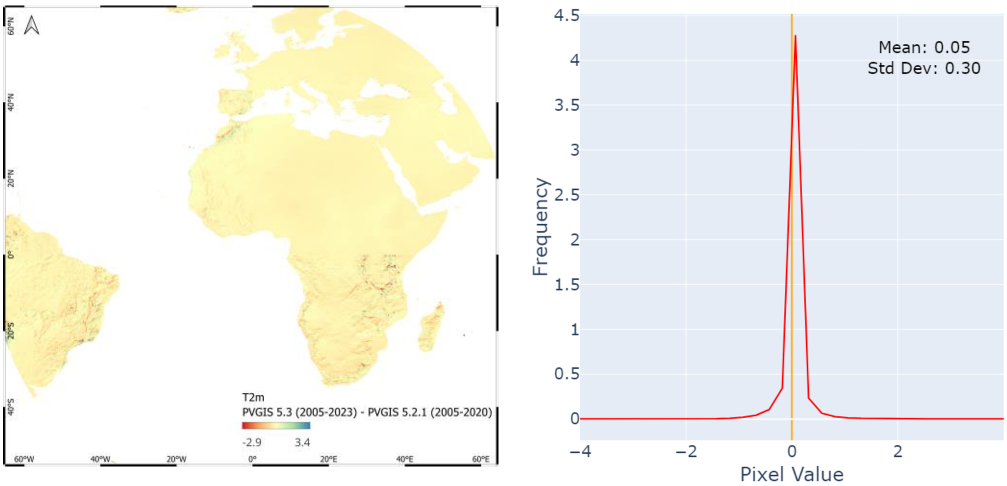
For the differences in the annual average of temperature, it is observed that for the overlapping years, the average value of the difference raster layer is zero, with a standard deviation of 0.30°C. In general, PVGIS 5.3 tends to exhibit marginally higher values, with some negative differences observed in mountainous regions. With the inclusion of additional years from 2021 to 2023 for PVGIS 5.3, the average value of the differences in annual mean temperatures increases by 0.05°C, while the standard deviation remains stable, indicating an increase in temperature during these years without a corresponding increase in the variability of the differences. Examining the most recent 16-years period in comparison to all available years, the average difference increased by another 0.05°C, and the standard deviation showed a minimal increase of 0.01°C. This suggests that the exclusion of the 2005–2007 period from PVGIS 5.3 further increased the difference values without affecting their deviation.

Figure 18. Difference in the annual average of temperature (Celsius) for overlapping years between PVGIS 5.3 and 5.2.1.



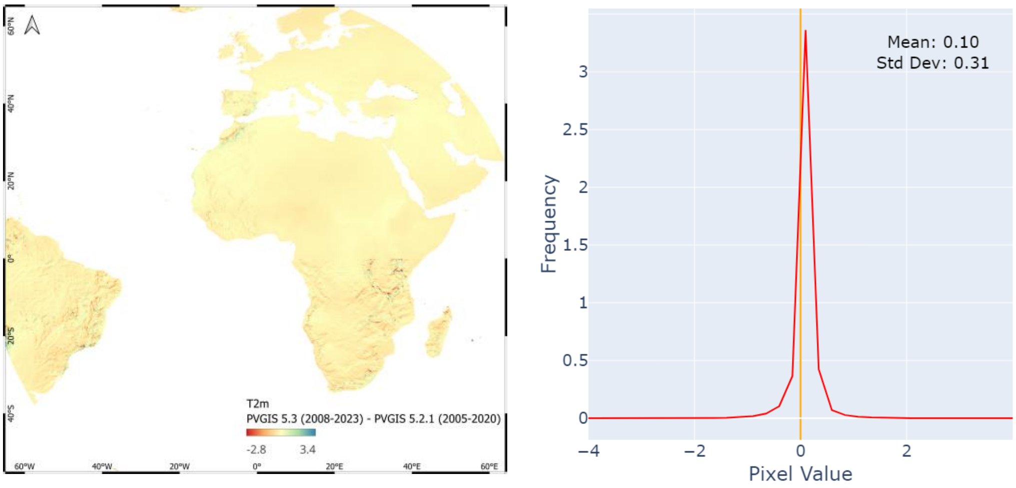
Source: Produced for the current report.

Figure 19. Difference in the annual average of temperature (Celsius) for all available years between PVGIS 5.3 and 5.2.1.



Source: Produced for the current report.

Figure 20. Difference in the annual average of temperature (Celsius) for the most recent 16-years period between PVGIS 5.3 and 5.2.1.



Source: Produced for the current report.

Table 3 summarises the statistics of the difference raster layers, which resulted from the subtraction of the PVGIS 5.2.1 from 5.3 pixel values in the annual average maps. The results show that PVGIS 5.3 provides slightly higher estimates compared to PVGIS 5.2.1 for all the examined periods. For the period of overlapping years, the global irradiance from PVGIS 5.3 shows a higher annual average by 8.96 kWh/m², for PV energy yield estimation is higher by 5.89 kWh/kWp and the temperature differences are close to zero. Such differences represent an increase of approximately 0.5% for irradiance and yield, and 0.1% for temperature when considering the common, overlapping years. It should be noted that this validation method is sensitive to outlier pixel values that might occur. Some large variations between the PVGIS 5.2.1 and 5.3 maps, particularly in coastal areas, can be attributed to methodological differences in data production. Also, smaller differences between PVGIS 5.2.1 and 5.3 are introduced by the differences in ERA5 data production as explained in paragraph 3.2.1.1.

Table 3. Summary of the results of comparisons between the annual average between PVGIS 5.2.1 and 5.3 for irradiance, temperature and PV yield.

Parameter (annual average)	**Module slope**	**PVGIS version and period**		**Difference (5.3 – 5.2.1)**		
		5.3	**5.2.1**	**Mean**	**Relative Mean (%)**	**St. Dev**
Irradiance (kWh/m²)	0	2005-2020	2005-2020	8.96	0.48	19.58
	optimum	2005-2020	2005-2020	10.86	0.55	22.96
	0	2005-2023	2005-2020	10.84	0.58	20.11
	optimum	2005-2023	2005-2020	13.07	0.68	23.67
	0	2008-2023	2005-2020	10.48	0.57	20.41
	optimum	2008-2023	2005-2020	12.65	0.65	24.18
PV yield (kWh/kWp)	0	2005-2020	2005-2020	5.89	0.41	15.39
	optimum	2005-2020	2005-2020	7.41	0.51	18.28
	0	2005-2023	2005-2020	7.01	0.51	15.80
	optimum	2005-2023	2005-2020	8.74	0.68	18.84
	0	2008-2023	2005-2020	6.60	0.49	16.07
	optimum	2008-2023	2005-2020	8.26	0.65	19.26
Temperature (Celsius)	n/a	2005-2020	2005-2020	0.00	0.1	0.30
	n/a	2005-2023	2005-2020	0.05	6.6	0.30
	n/a	2008-2023	2005-2020	0.10	18.6	0.31

Source: Produced for the current report.

3.3.2 Comparison with Ground Station Measurements

To further validate the PVGIS products, primarily in Europe and the surrounding regions, 16 Baseline Surface Radiation Network (BSRN) stations were selected based on their data availability and integrity [7], intersecting with the SARAH spatial extent. The global horizontal irradiance (GHI) and 2-meter temperature (T2m) outputs from PVGIS 5.2.1, using the SARAH-2 dataset, and from PVGIS 5.3, using the SARAH-3 dataset, were compared and validated against these 16 BSRN ground measurements. Figure 21 depicts the distribution of the considered BSRN stations.

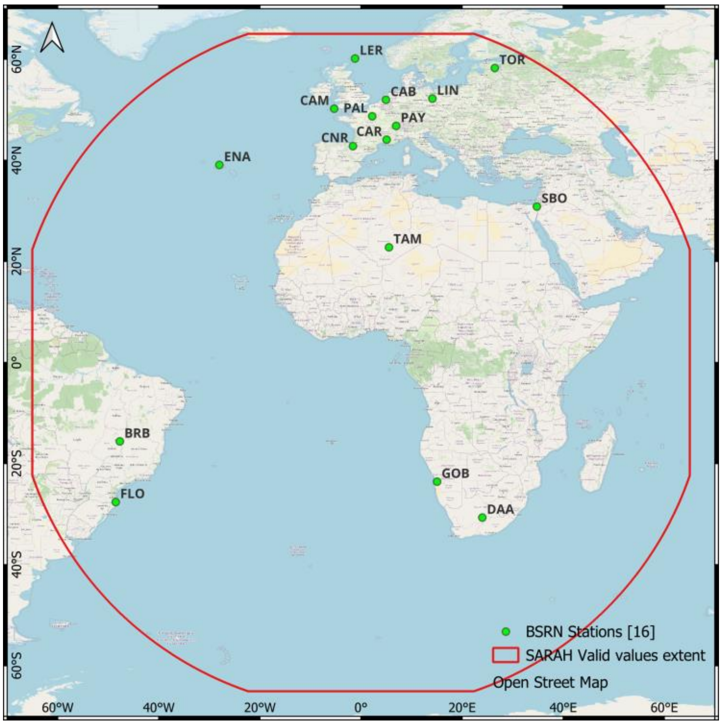
The BSRN network provides high-accuracy ground measurements of GHI and temperature at each station location. However, the operational periods of the stations and their instruments vary, leading to instances where GHI data may not be available when temperature data is, or vice versa. Given that the BSRN measurements are available at a per-minute frequency, while the PVGIS output is provided continuously with an hourly frequency over the selected temporal range, the BSRN measurements were aggregated to an hourly frequency through the following process, accounting for their integrity and availability:

i. GHI measurements from BSRN were filtered to exclude values outside the range of -10.0 to 3000 W/m², and temperature measurements were filtered to exclude values outside the range of -150 to 99 degrees Celsius.

ii. A ±15-minute window was applied around each hour for GHI in the PVGIS output, and a ±30-minute window around each hour for temperature in the PVGIS output.

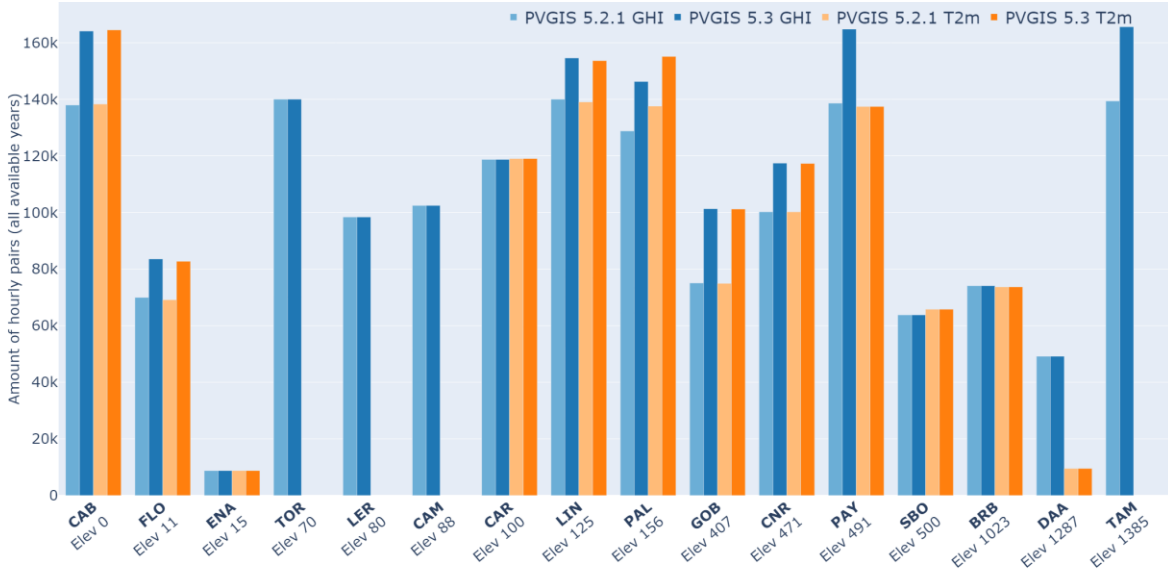
iii. Only windows containing more than two BSRN measurements were retained for GHI and more than four for temperature, and the average of these measurements was computed.

Figure 21. Considered BSRN stations for the validation of PVGIS output.



Source: Produced for the current report.

Figure 22. Amount of the hourly pairs used to calculate the metrics between BSRN ground station measurements and PVGIS versions 5.2.1 and 5.3, for all the available years between the two PVGIS versions.

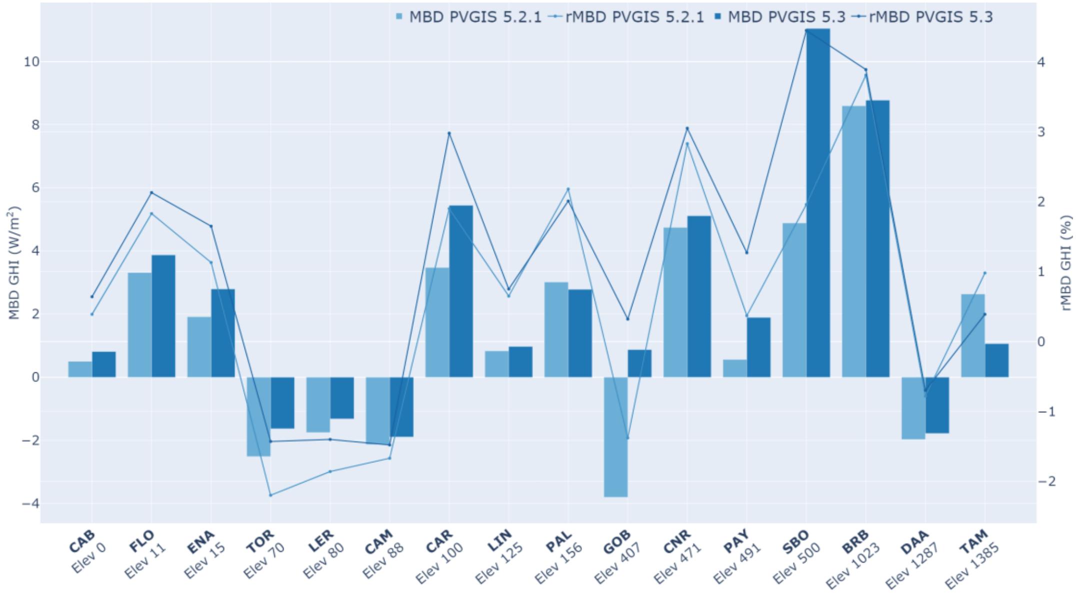


Source: Produced for the current report.

Following this process, hourly pairs between PVGIS outputs and BSRN measurements were prepared. The frequency of these pairs is hourly, accounting for the SARAH time offset specific to latitude of each BSRN station, as applied in PVGIS. The differing time windows in step ii were used since GHI is based on the SARAH dataset, which is originally generated in half-hour intervals and instantaneous values, while temperature is based on the ERA5 dataset, which is generated in hourly intervals. Figure 22 shows the number of hourly pairs for the following four combinations of PVGIS outputs and BSRN measurements: PVGIS 5.2.1 GHI vs. BSRN GHI, PVGIS 5.2.1 temperature vs. BSRN temperature, PVGIS 5.3 GHI vs. BSRN GHI, and PVGIS 5.3 temperature vs. BSRN temperature. The number of hourly pairs between PVGIS 5.3 and BSRN is greater than those between PVGIS 5.2.1 and BSRN, as the former includes data from 2005-2023, whereas the latter covers 2005-2020. For GHI, the number of hourly pairs is identical between the two PVGIS versions for 8 out of 16 ground stations, while the remaining 9 stations have more pairs in PVGIS 5.3. Regarding temperature, the number of hourly pairs is identical for 6 out of 16 stations, with 4 stations lacking temperature ground measurements, and 7 stations having more pairs in PVGIS 5.3.

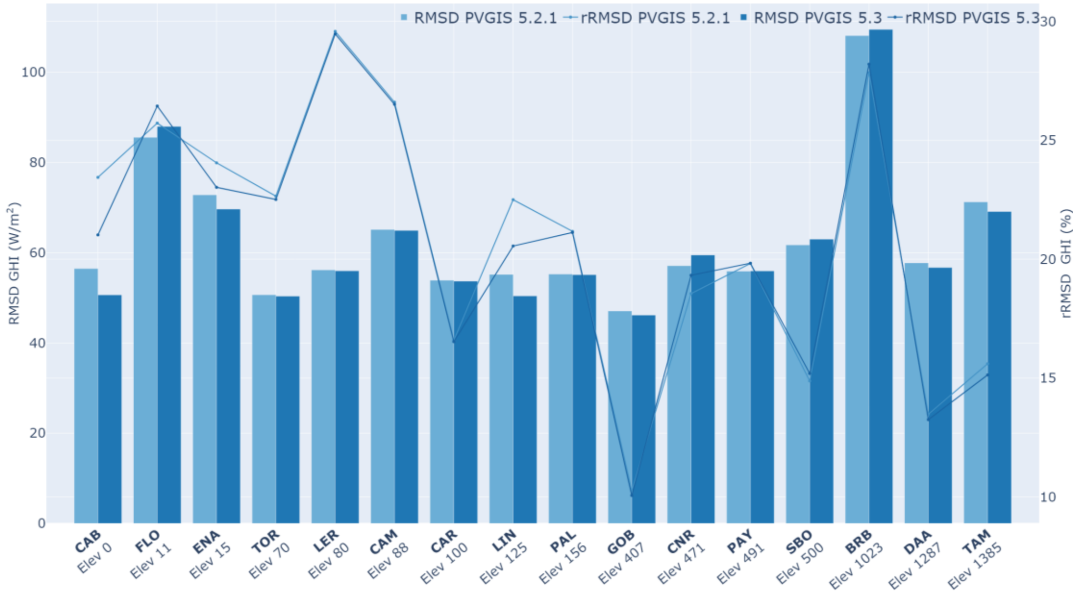
shows the absolute mean bias difference (MBD) in the left y-axis and the relative (rMDB) in the right y-axis for GHI. Figure 24 shows the absolute root mean square difference (RMSD) in the left y-axis and the relative (rRMSD) in the right y-axis for GHI. The same metrics are presented also for temperature in Figure 25 and Figure 26. In all plots, the BSRN stations are sorted on the x-axis by the elevation of the ground station. For GHI, MBD is reduced for 7 out of 16 stations and increased for 9 stations, with average difference in MBD values between the two PVGIS versions of 0.23 W/m^2 higher for PVGIS 5.3 which corresponds to 0.13% higher rMDB. RMSD is reduced for 11 out of 16 stations and increased for 5 stations, with average difference in RMSD values of 0.71 W/m^2 lower for PVGIS 5.3, which corresponds to 0.29% decrease in rRMSD. When considering the period of all available years for each PVGIS version and the comparison with BSRN, the differences in irradiance metrics between the two versions is 0.15 W/m^2 higher MBD for PVGIS 5.3, which corresponds to 0.07% increase in rMDB, and 1.19 W/m^2 lower RMSD corresponding to 0.45% decrease in rRMSD for PVGIS 5.3.

Figure 23. Global horizontal irradiance (SARAH) absolute and relative mean bias difference, between BSRN ground station measurements and PVGIS versions 5.2.1 and 5.3 (overlapping years 2005-2020).



Source: Produced for the current report.

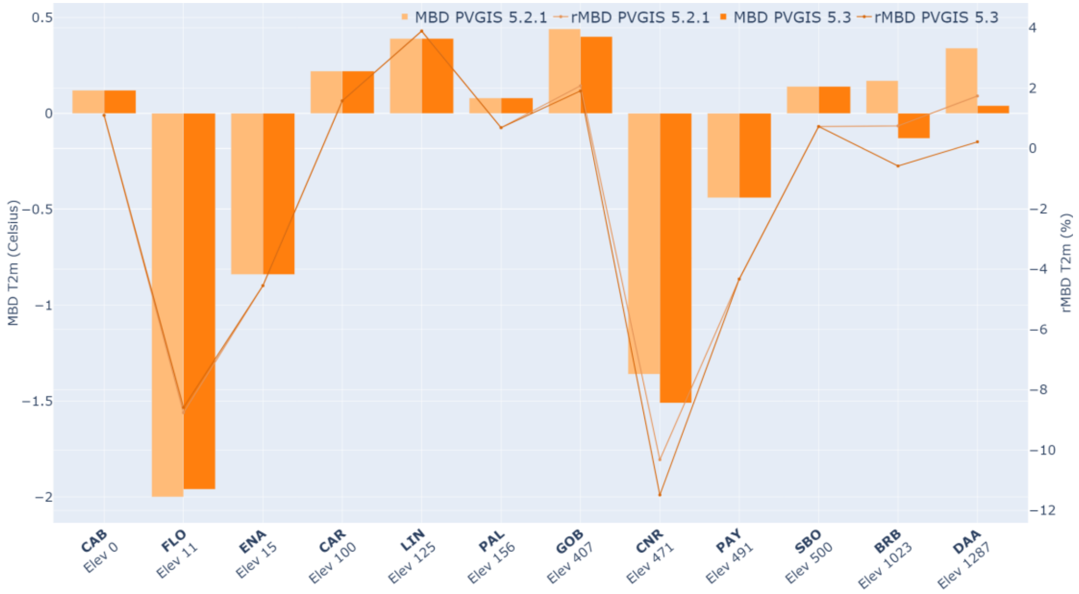
Figure 24. Global horizontal irradiance (SARAH) absolute and relative root mean square difference, between BSRN ground station measurements and PVGIS versions 5.2.1 and 5.3 (overlapping years 2005-2020).



Source: Produced for the current report.

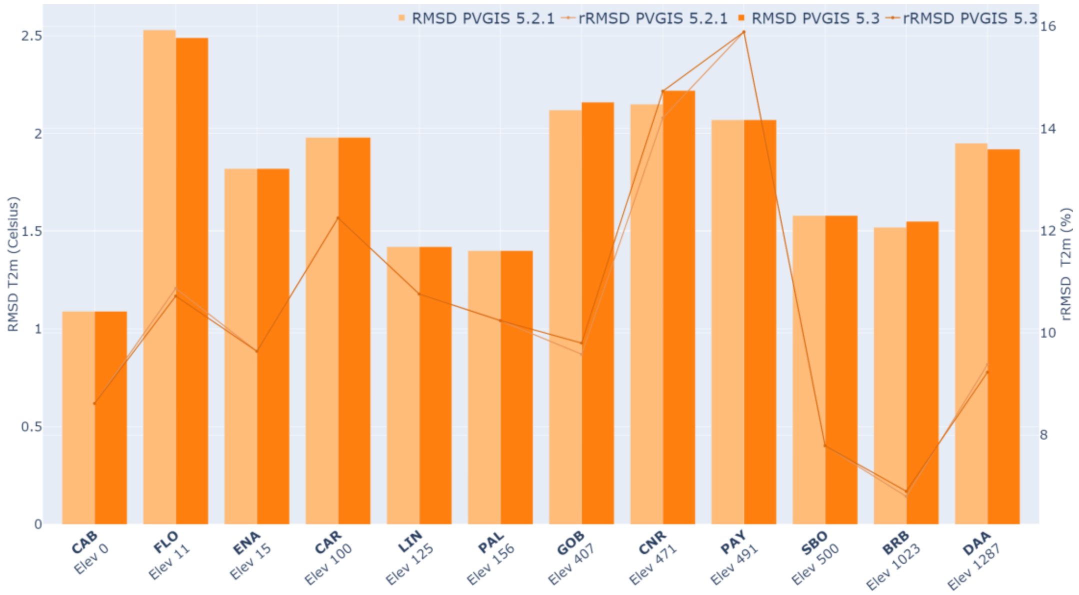
For temperature, MBD remains stable for 7 out of 12 stations, reduced for 4 stations and increases for 1 station, with average difference in MBD values of 0.04°C lower for PVGIS 5.3 which corresponds to 0.18% reduction in rMDB. RMSD remains stable for 8 stations, reduced for 1 station and increased for 4 stations, with average difference in RMSD values of 0.01°C higher for PVGIS 5.3 corresponding to 0.05% increase in rRMSD values. When considering the period of all available years, the difference in temperature metrics is 0.04°C lower MBD for PVGIS 5.3 which corresponds to 0.2% decrease in rMDB, and 0.03°C higher RMSD which corresponds to 0.11% higher rRMSD for PVGIS 5.3.

Figure 25. Temperature absolute and relative mean bias difference, between BSRN ground station measurements and PVGIS versions 5.2.1 and 5.3 (overlapping years 2005-2020).



Source: Produced for the current report.

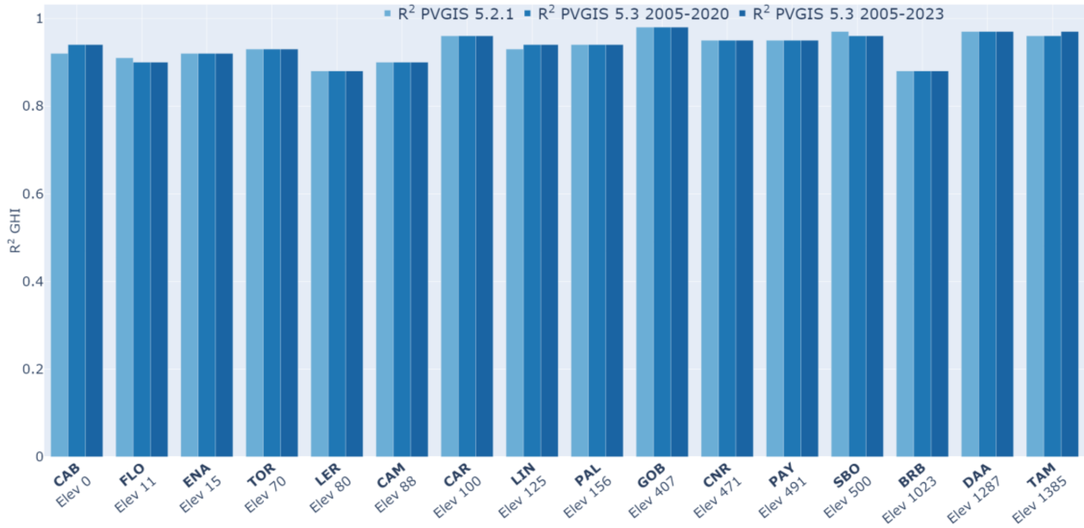
Figure 26. Temperature absolute and relative root mean square difference, between BSRN ground station measurements and PVGIS versions 5.2.1 and 5.3 (overlapping years 2005-2020).



Source: Produced for the current report.

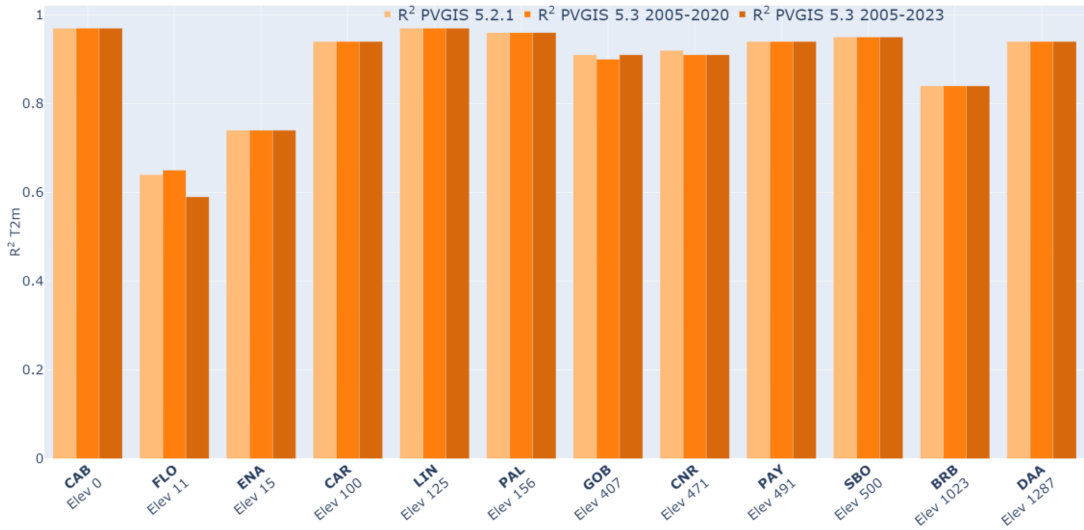
To further evaluate the alignment between PVGIS data and BSRN ground station measurements, the R^2 metric was calculated for both the overlapping years and the entire available period for version of PVGIS. Figure 27 and Figure 28 depict the R^2 metric for each station. For all ground stations, the R^2 metric for irradiance exceeds 88% for the overlapping years period and for all available years across both versions of PVGIS. Specifically, for PVGIS 5.3, the R^2 metric increased by 2% and 1% at stations CAB and LIN, respectively, for both periods, while at station TAM, it increased by 1% for the 2005–2023 period. Conversely, at stations FLO and SBO, the R^2 metric decreased by 1%. For temperature, the R^2 values are above 84% for the majority of stations. In PVGIS 5.2.1, the R^2 value for station ENA was 64%, which increased by 1% for the overlapping years in PVGIS 5.3, but decreased by 6% for the entire available period in PVGIS 5.3. At station CNR, the R^2 metric increased by 1% for PVGIS 5.3, while for all other stations, the R^2 values remained unchanged across both versions.

Figure 27. Global horizontal irradiance (SARAH) R2, between BSRN ground station measurements and PVGIS versions 5.2.1 and 5.3 for overlapping and for all available years (2005-2020 for PVGIS 5.2.1, 2005-2020 and 2005-2023 for PVGIS 5.3).



Source: Produced for the current report.

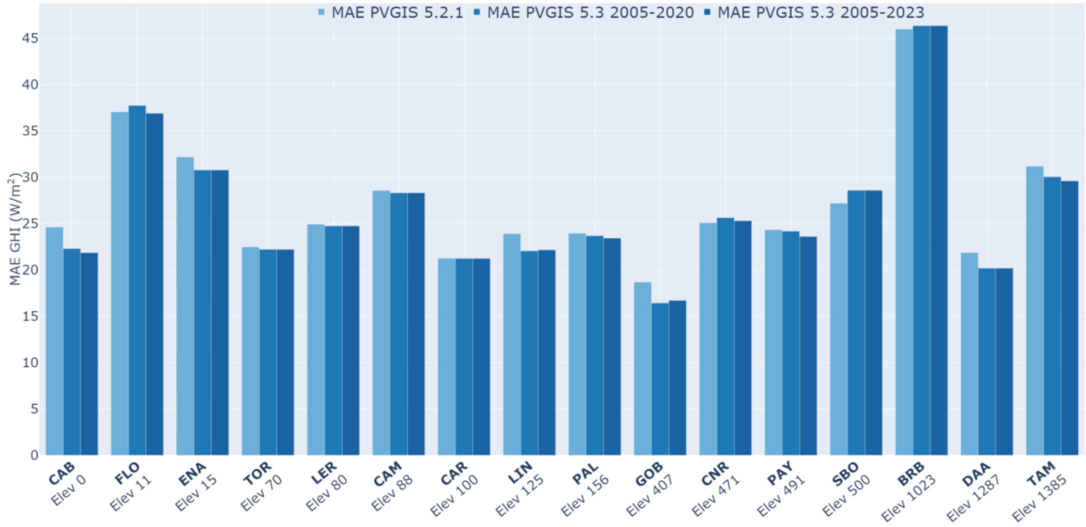
Figure 28. Temperature R^2, between BSRN ground station measurements and PVGIS versions 5.2.1 and 5.3 for overlapping and for all available years (2005-2020 for PVGIS 5.2.1, 2005-2020 and 2005-2023 for PVGIS 5.3).



Source: Produced for the current report.

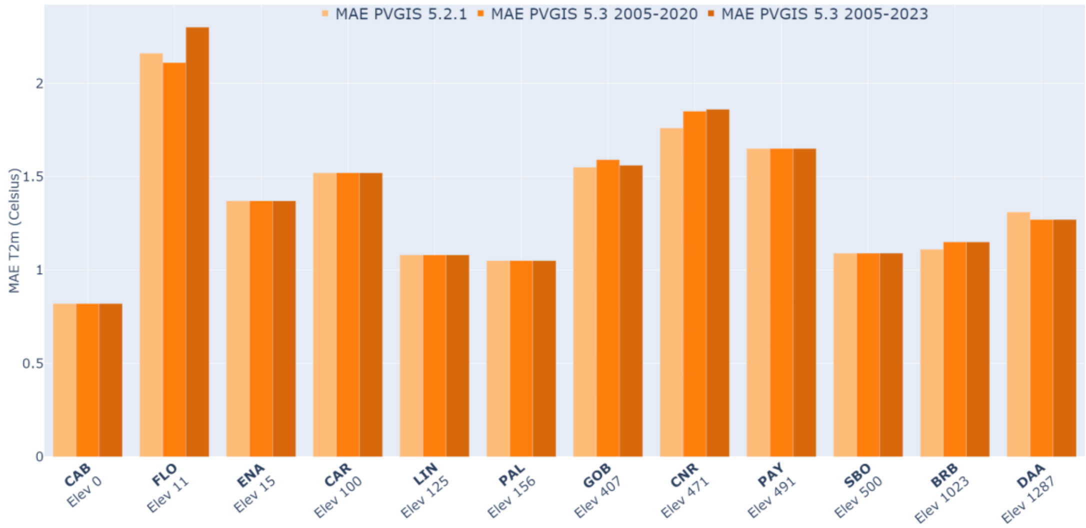
For the quantification of the observed differences, Figure 29 and Figure 30 depict the mean absolute error (MAE) between the BSRN ground measurements and PVGIS 5.2.1 and PVGIS 5.3 for the periods 2005-2020 and 2005-2023. For irradiance, the MAE decreased for 13 stations, with a maximum reduction of 2.3 W/m² for the CAB station, and increased for 3 stations, with a maximum increase of 1.4 W/m² for the SBO station. For temperature, the MAE metric remained stable or varied by less than 0.01°C for 10 stations, and increased by 0.1°C for the FLO and CNR stations. The variations in the mean absolute values observed for the BSRN stations examined, both for irradiance and temperature, can be compared to the target accuracies of the BSRN ground measurements, which range from ±5 W/m² for global horizontal irradiance and ±0.3°C for temperature [8]. The observed variations between the PVGIS datasets are within these limits, making them acceptable for the current application.

Figure 29. Global horizontal irradiance (SARAH) mean absolute error (MAE), between BSRN ground station measurements and PVGIS versions 5.2.1 and 5.3 for overlapping and for all available years (2005-2020 for PVGIS 5.2.1, 2005-2020 and 2005-2023 for PVGIS5.3).



Source: Produced for the current report.

Figure 30. Temperature mean absolute error (MAE), between BSRN ground station measurements and PVGIS versions 5.2.1 and 5.3 for overlapping and for all available years (2005-2020 for PVGIS 5.2.1, 2005-2020 and 2005-2023 for PVGIS 5.3).



Source: Produced for the current report.

Table 4 and Table 5 summarise the average difference between the PVGIS 5.3 and PVGIS 5.2 metrics compared to BSRN ground measurements data. The tables show the subtraction of the PVGIS 5.2 metrics from the PVGIS 5.3 metrics, where BSRN data is used as the reference for GHI and for temperature, for the periods 2005-2020 and 2005-2023.

Table 4. Average difference between the PVGIS 5.3 and PVGIS 5.2 metrics compared to BSRN ground measurements data. The table shows the subtraction of the PVGIS 5.2 metrics from the PVGIS 5.3 metrics, where BSRN data is used as the reference for GHI.

	ΔMBD (W/m²)	ΔrMBD (%)	ΔRMSD (W/m²)	ΔrRMSD (%)	ΔR^2 (%)	ΔMAE (W/m²)
2005-2020	0.23	0.13	-0.71	-0.29	0.06	-0.55
2005-2023	0.15	0.07	-1.19	-0.45	0.12	-0.71

Source: Produced for the current report.

Table 5. Average difference between the PVGIS 5.3 and PVGIS 5.2 metrics compared to BSRN ground measurements data. The table shows the subtraction of the PVGIS 5.2 metrics from the PVGIS 5.3 metrics, where BSRN data is used as the reference for temperature.

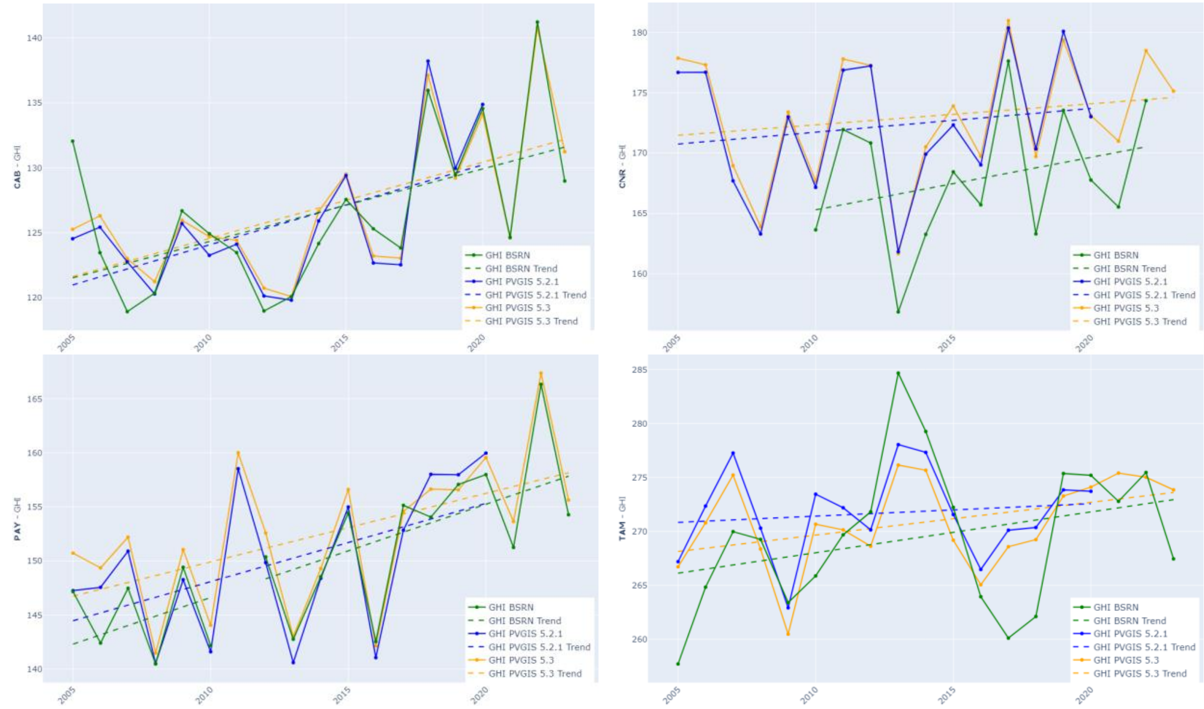
	ΔMBD (°C)	ΔrMBD (%)	ΔRMSD (°C)	ΔrRMSD (%)	ΔR^2 (%)	ΔMAE (°C)
2005-2020	-0.04	-0.18	0.01	0.05	-0.08	0.01
2005-2023	-0.04	-0.20	0.03	0.11	-0.50	0.02

Source: Produced for the current report.

3.3.3 Time Series Trends

To estimate the trends in global horizontal irradiance and temperature over time, four BSRN stations were selected for each variable based on the data availability at both the beginning and the ending of the examined period, to ensure a reliable estimation of trends over this period. Figure 31 and Figure 32 present the PVGIS 5.2.1, PVGIS 5.3 values, and the BSRN measurements for global horizontal irradiance and temperature, respectively, along with the corresponding trends. In Figure 31, for the selected stations, the addition of data from 2021-2023 reduces the slope of the trends, though they remain positive. Similarly, in Figure 32, the inclusion of the additional data reduces the slope of the trends for three out of the four stations, although the trend continues to be positive. For both variables, the BSRN measurements appear to follow similar trends.

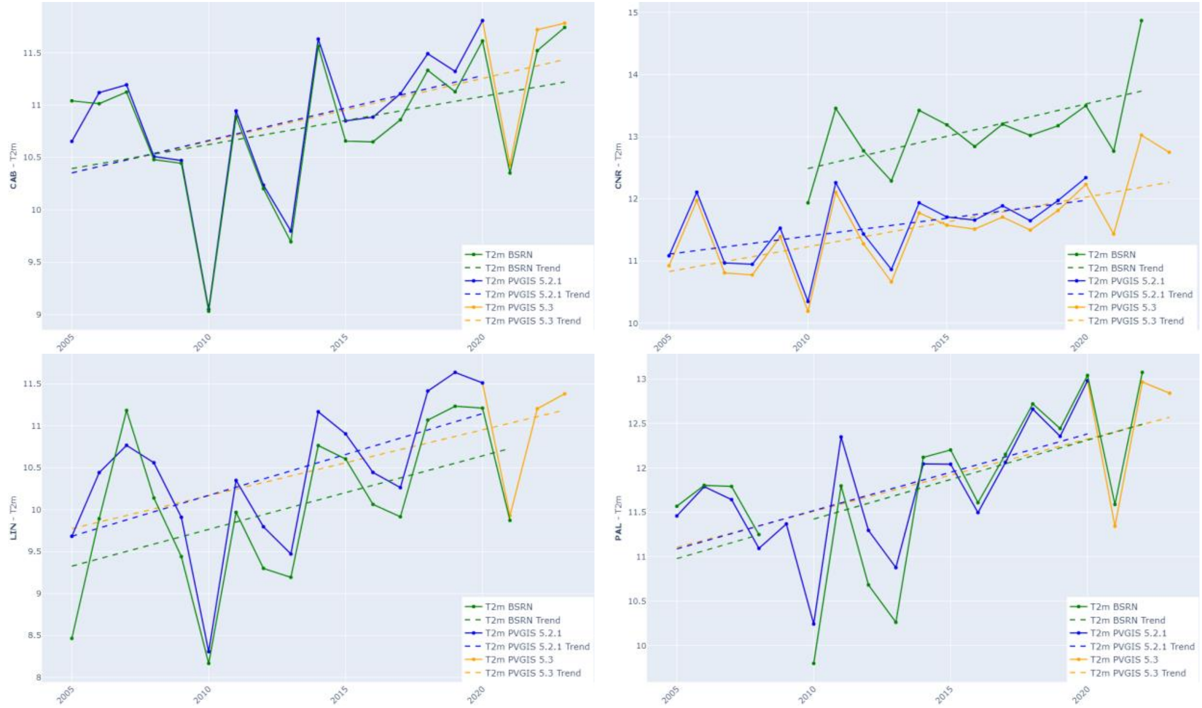
Figure 31. Yearly GHI trends (kWh/m^2) for BSRN stations, PVGIS 5.2.1 and PVGIS 5.3.



Source: Produced for the current report.

Figure 32 illustrates the differences in annual average values between PVGIS 5.2.1 and PVGIS 5.3 highlighting the extent of these differences. BSRN stations CAB, LIN and PAL are located in the coordinate's quarter where the temperature data from both PVGIS versions and original ERA5-Land align, while station CNR is located in a coordinates quarter where the ERA5-Land data and PVGIS versions do not align (see Figure 5). The annual average temperature PVGIS 5.2.1 values are closer to the BSRN measurements for this station. It was observed that for each BSRN station, the PVGIS version that most closely matches the ground measurements depends on the exact location of the ground station and whether the location falls within the overlapping region between PVGIS 5.2.1 and the original ERA5-Land pixel, or within the overlapping region between PVGIS 5.3 and the original ERA5-Land pixel.

Figure 32. Yearly temperature (°C) trends for BSRN stations, PVGIS 5.2.1 and PVGIS 5.3.



Source: Produced for the current report.

Conclusions

The PVGIS database for solar irradiation and environmental parameters has been extended to 2023, so that the PVGIS 5.3 release will now provide average annual PV energy yield estimates for the period 2005-2023, compared to 2005-2020 for PVGIS 5.2.1.

The data processing pipeline for converting the input hourly raster data in NetCDF files into the PVGIS format of spatially tiled and time-contiguous data cubes has been comprehensively adapted and improved.

For solar radiation, the SARAH data is now based on SARAH-3, replacing the previously SARAH-2 satellite product, while ERA5 irradiance data are used in all the other regions where SARAH data is not available. The ERA5-Land dataset for environmental variables (in particular ground temperature, dewpoint temperature, relative humidity and wind speed and direction) has also been extended to 2023. Furthermore, a 25 km coastal area is now covered by all the datasets.

Validation is performed for the produced data by comparison with the previous version of PVGIS as well as with ground measurements from 16 BSRN stations. Validation is carried out for three time periods: the years 2005–2020, common between PVGIS 5.2.1 and PVGIS 5.3 datasets, all available years for each version, and the most recent 16-years period for each PVGIS version. Specifically:

- The difference in annual averages between the two PVGIS versions is studied using maps for average values of irradiance, PV energy yield, and temperature variables for the three time periods. The average, the standard deviation of the differences, and the average percentage change are calculated. It is found that PVGIS 5.3 provides slightly higher estimates compared to PVGIS 5.2.1 for all examined periods. These differences represent a relative increase of approximately 0.5% for irradiance and yield, and 0.1% for temperature when considering the common overlapping years.

- A time series comparison between the two PVGIS versions and ground station measurements was conducted for irradiance and temperature variables, using metrics such as MDB, rMDB, RMSD, rRMSD, MAE, and R^2 for the periods 2005–2020 and 2005–2023. It is found that for GHI, the average difference in the metrics calculated by comparing PVGIS 5.3 with BSRN stations and those calculated by comparing PVGIS 5.2.1 with BSRN stations increases for MDB and rMDB, decreases for RMSD and rRMSD, decreases for R^2, and decreases for MAE in both examined periods. Similarly, for temperature, MDB and rMDB decrease, RMSD and rRMSD increase, R^2 decreases, and MAE increases in both examined periods. However, these changes are negligible, with absolute values showing changes smaller than 0.71 W/m² for irradiance and smaller than 0.02°C for temperature.

- The time series trend for the two PVGIS versions and the BSRN stations for irradiance and temperature variables over the period 2005–2023 was studied. It is found that the time series trends of both PVGIS versions and the BSRN stations with sufficient data for the full period 2005–2023 follow the same slope, usually with only slightly different gradients.

References

[1] A. A. N. Martinez, G. Arcaro, N. Taylor, S. Szabo, A. Chatzipanagi, F. Fahl and L. Mercado, “Photovoltaics Geographical Information System 2022 Status and PVGIS 5.2 Release,” European Commission, 2022.

[2] A. M. G. Amillo, N. Taylor, A. M. Fernandez, E. Dunlop, P. Mavrogiorgios, F. Fahl, G. Arcaro and I. Pinedo, “Adapting PVGIS to Trends in Climate, Technology and User Needs,” in *Proc. 38th European Photovoltaic Solar Energy Conference and Exhibition*, 2021.

[3] T. Huld and I. P. Pascua, “Spatial Downscaling of 2-Meter Air Temperature Using Operational Forecast Data,” *Energies,* vol. 8, pp. 238-2411, 2015.

[4] J. Muñoz-Sabater, E. Dutra, A. Agustí-Panareda, C. Albergel, G. Arduini, G. Balsamo, S. Boussetta, M. Choulga, S. Harrigan, H. Hersbach, B. Martens, D. G. Miralles, M. Piles, N. J. Rodríguez-Fernández, E. Zsoter, C. Buontempo and T. J. N., “ERA5-Land: a state-of-the-art global reanalysis dataset for land applications,” *Earth System Science Data,* vol. 13, pp. 4349--4383, 2021.

[5] A. Martinez, N. Alexandris, N. Taylor, O. Gounari, S. Szabo, A. Chatzipanagi and L. Mercado, “Photovoltaics Geographical Information System: Status Report 2023,” European Commission, 2023.

[6] U. Pfeifroth, S. Kothe, J. Drücke, J. Trentmann, M. Schröder, N. Selbach and R. Hollmann, “Surface Radiation Data Set - Heliosat (SARAH) - Edition 3,” Satellite Application Facility on Climate Monitoring (CM SAF), 2023.

[7] A. Driemel, J. Augustine, K. Behrens, S. Colle, C. Cox, E. Cuevas-Agullo, F. M. Denn, T. Duprat, M. Fukuda, H. Grobe, M. Haeffelin, G. Hodges, N. Hyett, O. Ijima, A. Kallis, W. Knap, V. Kustov, C. N. Long, D. Longenecker, A. Lupi, M. Maturilli, M. Mimouni, L. Ntsangwane, H. Ogihara, X. Olano, M. Olefs, M. Omori, L. Passamani, E. B. Pereira, H. Schmithusen, S. Schumacher, R. Sieger, J. Tamlyn, R. Vogt, L. Vuilleumier, X. Xia, A. Ohmura and G. Konig-Langlo, “Baseline Surface Radiation Network (BSRN): structure and data description (1992-2017),” *Earth System Science Data,* vol. 10, pp. 1491-1501, 2018.

[8] L. McArthur, “World Climate Research Programme-Baseline Surface Radiation Network (BSRN)-Operations Manual Version 2.1,” Experimental Studies Division, Atmospheric Environment Service, 2005.

Table of Tables

Table of Figures

List of Abbreviations

BSRN	Baseline Surface Radiation Network
CMSAF	Satellite Application Facility on Climate Monitoring
ECMWF	European Centre for Medium-Range Weather Forecasts
EUMETSAT	European Organisation of Meteorological Satellites
ERA5	ECMWF Re-Analysis
GHI	Global Horizontal Irradiance
GIS	Geographic Information System
GRASS	Geographic Resource Analysis Support System
GTOPO30	Global Topography at 30 arc-seconds resolution
MAE	Mean Absolute Error
MBD	Mean Bias Difference
NASA	National Aeronautics and Space Administration
PV	Photovoltaic
PVGIS	Photovoltaic Geographical Information System
RMSD	Root Mean Square Difference
SARAH	Surface Solar Radiation Climate Data Record
SID	Surface Incoming Direct Radiation
SIS	Surface Incoming Shortwave Radiation
SRTM	Seamless Shuttle Radar Topography Mission
T2m	2-meter Temperature
USGS	United States Geological Survey
WGS84	World Geodetic System 1984
NetCDF	Network Common Data Form
rMBD	Relative Mean Bias Difference
rRMSD	Relative Root Mean Square Difference

Getting in touch with the EU

In person

All over the European Union there are hundreds of Europe Direct centres. You can find the address of the centre nearest you online (european-union.europa.eu/contact-eu/meet-us_en).

On the phone or in writing

Europe Direct is a service that answers your questions about the European Union. You can contact this service:

— by freephone: 00 800 6 7 8 9 10 11 (certain operators may charge for these calls),

— at the following standard number: +32 22999696,

— via the following form: european-union.europa.eu/contact-eu/write-us_en.

Finding information about the EU

Online

Information about the European Union in all the official languages of the EU is available on the Europa website (european-union.europa.eu).

EU publications

You can view or order EU publications at op.europa.eu/en/publications. Multiple copies of free publications can be obtained by contacting Europe Direct or your local documentation centre (european-union.europa.eu/contact-eu/meet-us_en).

EU law and related documents

For access to legal information from the EU, including all EU law since 1951 in all the official language versions, go to EUR-Lex (eur-lex.europa.eu).

EU open data

The portal data.europa.eu provides access to open datasets from the EU institutions, bodies and agencies. These can be downloaded and reused for free, for both commercial and non-commercial purposes. The portal also provides access to a wealth of datasets from European countries.

Science for policy

The Joint Research Centre (JRC) provides independent, evidence-based knowledge and science, supporting EU policies to positively impact society