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CAMS Solar radiation products

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► **To cite this version:**

Mireille Lefèvre, Natalie Hanrieder. CAMS Solar radiation products: Ground measurements catalogue, December 2021.. [Research Report] Copernicus Atmosphere Monitoring Service. 2021. hal-03622010

HAL Id: hal-03622010

<https://minesparis-psl.hal.science/hal-03622010>

Submitted on 28 Mar 2022

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Ground measurements catalogue

Status December 2021 Solar radiation products

Issued by: Armines / M. Lefèvre

Date: 02/12/2021

Ref: CAMS2_73_2021SC1_D1.4.1-2021Q4_ground_catalogue_202112_v3

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1. Introduction

Measurements of solar radiation performed in ground-based stations are needed for the validation of the CAMS solar Radiation Service (CRS). Task 7313 “CRS evaluation and quality control (CRS-EQC)” and task 7314 “Obtaining ground-based observations for CRS-EQC” of WP 7310 “Provision of CAMS service for solar radiation” aims at creating access to such measurements and accessing them in a periodic way.

The present document reports the updated catalogue of ground-based observations. It presents the wishes and constraints on measurements for the purpose of validating the CAMS radiation service. It lists the contacts made with possible providers of measurements and the data that has been obtained. Finally, it provides the list of stations whose data is being collected for the CAMS Radiation Service Evaluation and Quality Control (CRS-EQC) quarterly reports. [Figure 3.4](#) presents the evolution of the dataset along with the evolution of the CRS validation from first issues until the 2021 Q4 issue #34.



2. Wishes and constraints

The CAMS Radiation Service (CRS) delivers data on the global (GHI or G) and diffuse (DHI or D) irradiation received on a horizontal surface and on the direct irradiation received on a plane always facing the sun at normal incidence (DNI or B). An evaluation is periodically performed. Quarterly validation reports aim at providing users of the CRS with information on uncertainties, helping users to gain confidence in the service, and to better handle and exploit the CAMS Radiation products. From #33 issue (Sept. 2021) onwards, the validation of McClear (the cloud-free module of the CRS) is performed along with the CAMS-RAD module for all-sky conditions.

That leads to the wishes below:

- ✓ Measurements used in the validation must be recent, with short integration time, i.e. every 15 min or less, preferably. For the validation of McClear the station must deliver at least 2 products (G and either D or B) with a integration time of 1 minute. These constraints are required by the procedure of cloud-free skies selection.
- ✓ A validation report issue deals with data measured 7 to 9 months ago, i.e., the issue of December 2021 needs stations updated for March to May 2021. This restricts the number of stations available for the quarterly CRS-EQC.
- ✓ A variety of geographical regions and climate conditions in the CRS coverage should be represented.
- ✓ One or more measuring stations should be located at the outer area of the Meteosat field of view. This is desirable in order to obtain a fair estimate of the accuracy at the edge of the validity of the assumptions made in Heliosat-4 method for the retrieval of cloud properties. Due to low satellite viewing angles, lower CRS quality is expected for these stations. Nevertheless, they provide some insight on the area where the CRS may become unreliable.
- ✓ The same group of measuring stations should be available at least for several years to allow comparisons of performances over time. One of the objectives is to monitor changes in quality from one year to the next.
- ✓ Automatic access to measurements must be prioritized. The evaluation should follow an established protocol and automatization is desirable for at least two reasons: decreasing the requested manpower and speeding up the availability of the validation report, and ensuring replicability of the validation process.



3. Collection of data

A thorough survey of various sources of data in solar irradiation has been performed. This part has already been presented in detail in the first report dated April 2016 and is recalled in the Appendix A. Several networks have been identified and approached as well as national meteorological and hydrological services (NMHS) (see Appendix B).

Data sets depend very much of the provider. Data may be for pay or for free, with large differences in price. Data may be available after a delay of 1 month up to more than 1 year. Means of access to measurements vary greatly, from push to our own ftp site to periodic requests to the provider.

As a whole, we have met great help from the NMHS and other institutes and we have been able to set up a series of collaboration for the provision of measurements. A few NMHS in Europe proposed data for a fee. It appeared that paying for data does not make them necessarily faster to obtain or does not ensure that they have been through a thorough quality check.

One of the many difficulties in such collection is that data does not obey exactly the same standards, whether in format, access to data or time system. This implies that we have been obliged to establish a supply chain for each of the providers. These practical aspects have played a key role in the final selection of the stations for the validation.

In addition, source ground data does not go through a thorough quality control. This has to be done by the CAMS Radiation Service team. It is a time-consuming process as not all operations must be automated; a visual screening is necessary. A screening of the most recent data has decided which stations to keep from each provider. The screening is performed regularly and the list of stations may change accordingly. We privilege also stations for which there are indicators that measurements will still be made in the next few years to avoid too many changes in the list of retained stations.

A further constraint is the fast access to recent data. For several providers, measurements may be made available 1 month to 6 months after the end of the month. Considering the necessary time to handle data, process them and establishing the report, the validation report will be made available 7 months after the quarter to be evaluated.

3.1 Update of 2021 stations list

A dataset of measurements ranging from June 2018 to May 2021 covers the CRS-EQC validation reports issues #23 to #34. During this period, some stations have been removed from the set of usual stations, and some others have been added (see maps on [Fig.3.1](#) for Europe and [Fig.3.2](#) for Africa and South America) notably outside the Meteosat field-of-view ([Fig.3.3](#)) for the validation of the global cloud-free McClear module. Stations too close to the sea like Hoorn (see [3.3.1](#) for the report of the problem) and Vlissingen in the Netherlands have been removed and replaced by Leeuwarden and Maastricht. Some stations have been closed by the providers like Carpentras and Dobeles in December 2018, Rucava in September 2018, Camborne interrupted since 2017, or are not

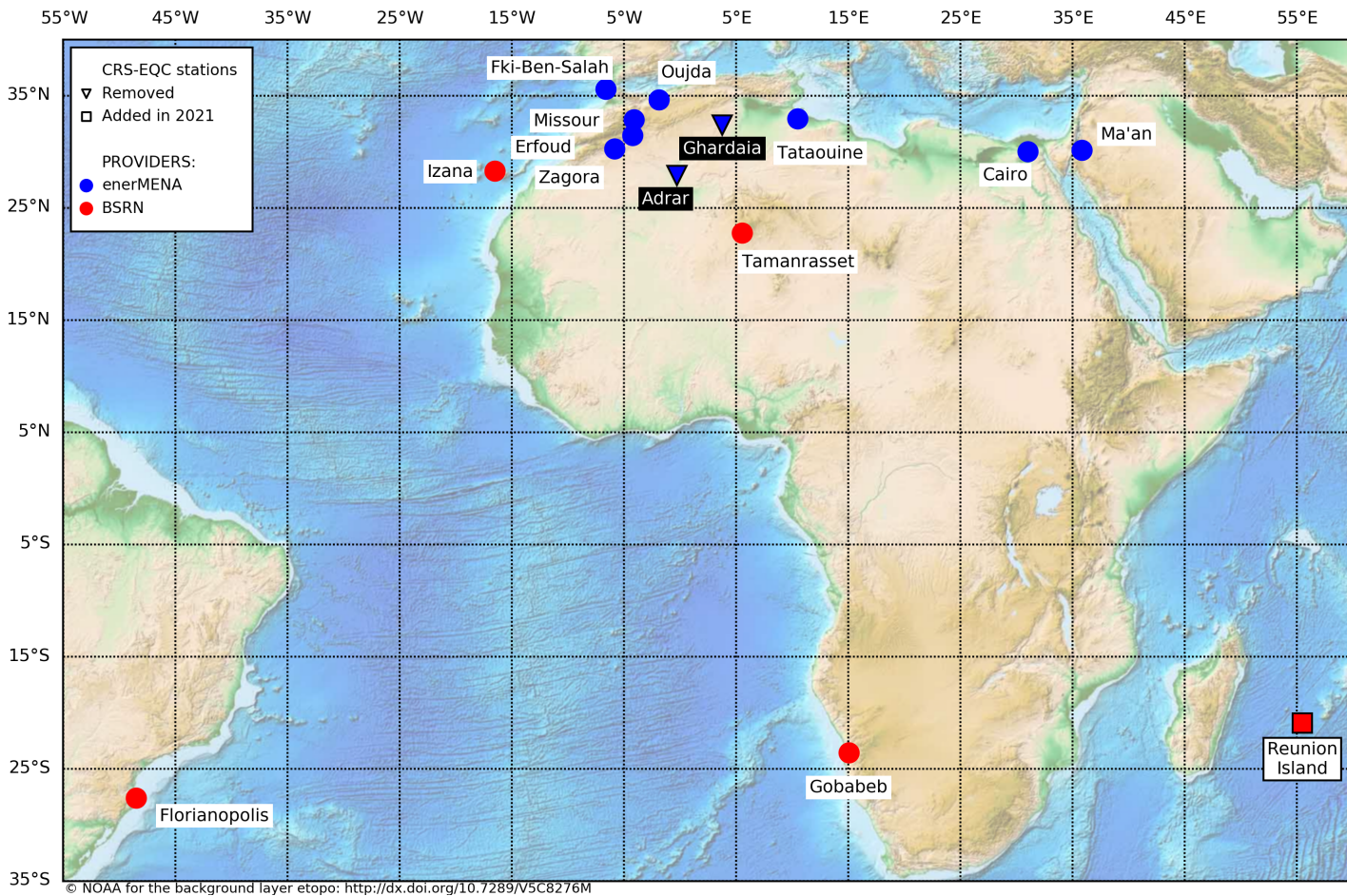


Figure 3.2. Maps of the 13 stations available, and 2 removed in Africa and South America during 2018-2021. Stations in black and identified by a triangle are not anymore provided. Stations identified by a square are added in 2021 to the dataset. See [Tab. 6.2](#) for details on the providers and [Tab. 6.3](#) for details on the stations.

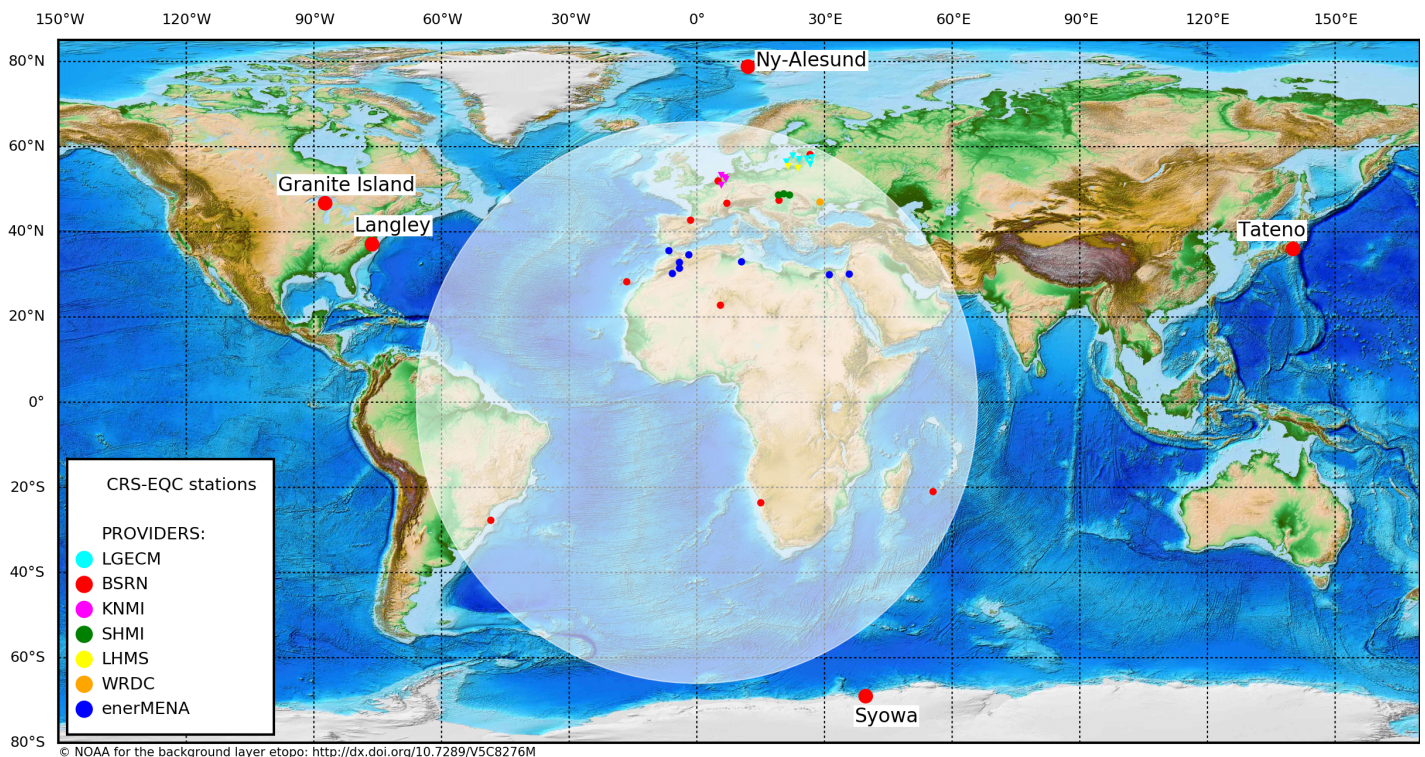


Figure 3.3. Maps of the 5 stations available outside the Meteosat field-of-view (shaded disk), added in 2021. See [Tab. 6.2](#) for details on the providers and [Tab. 6.3](#) for details on the stations.

3.2 Evolution of available stations for the CRS-EQC

As noted above, the main constraint is to get ground measurements as recent as possible, i.e. not older than 9 months at the date of the deliverable. As a whole, the number of stations has been constantly increasing from 2014 to reach 36 in 2021. Among it 34 stations deliver *G* products, 23 deliver *D* products, and 23 deliver *B* products. [Figure 3.4](#) displays the evolution of available products for each quarter, along with the progress in the validation approach: between issues #14 and #15, the protocol switched from daily to hourly summarization, and the quarter period to a seasonal representation instead of civil quarter. Between issues #17 and #18, the CRS switched to the v3 version. From #30 onwards, no threshold on irradiance value is applied anymore on *B*. A new threshold on solar elevation ($>10^\circ$) is applied in order to avoid horizon obstructions and directional response of pyranometers. From #31 onwards the same protocol is applied for *G* and *D*, in order to be consistent with *B*. From #33 onwards the validation of the McClear module leads to an increase of the number of stations located outside the Meteosat field-of-view.

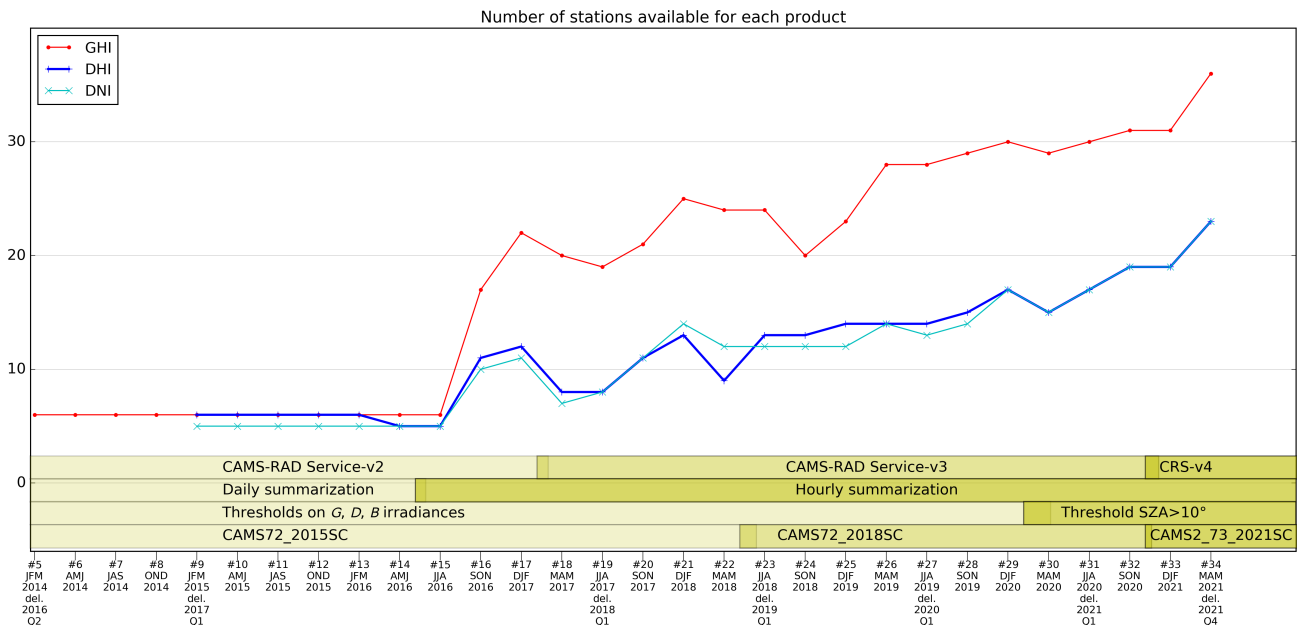


Figure 3.4. Evolution of the number of stations used for each product from 2014. On the x-axis are the deliverables identified by their issue number and the months and years corresponding to the measurements.

3.3 Stations removed

3.3.1 KNMI station of Hoorn

On the times-series presented (Fig.3.5) CAMS-RAD systematically underestimates *G*, although the correlation coefficient is as high as for other stations in the Netherlands. This underestimation is not observed at any other KNMI retained station. The localization of Hoorn close to the North Sea may be a reason (Fig.3.7).

Jan Fokke Meirink at the KNMI has been contacted. The hourly means retrieved with SICCS (Greuell et al., 2013) also have relative underestimations at some of the coastal stations as seen on Fig.3.6. Station Hoorn, coded 251, and station De Kooy, coded 235, show even more underestimation. All five blue points below the 1-1 line, are coastal stations. According to Jan Fokke Meirink there is no reason to doubt these stations particularly, but there are representativity issues.

This station has been removed from the set used for the quarterly validation, but is reported for information and as a warning to users at the coastal limit.

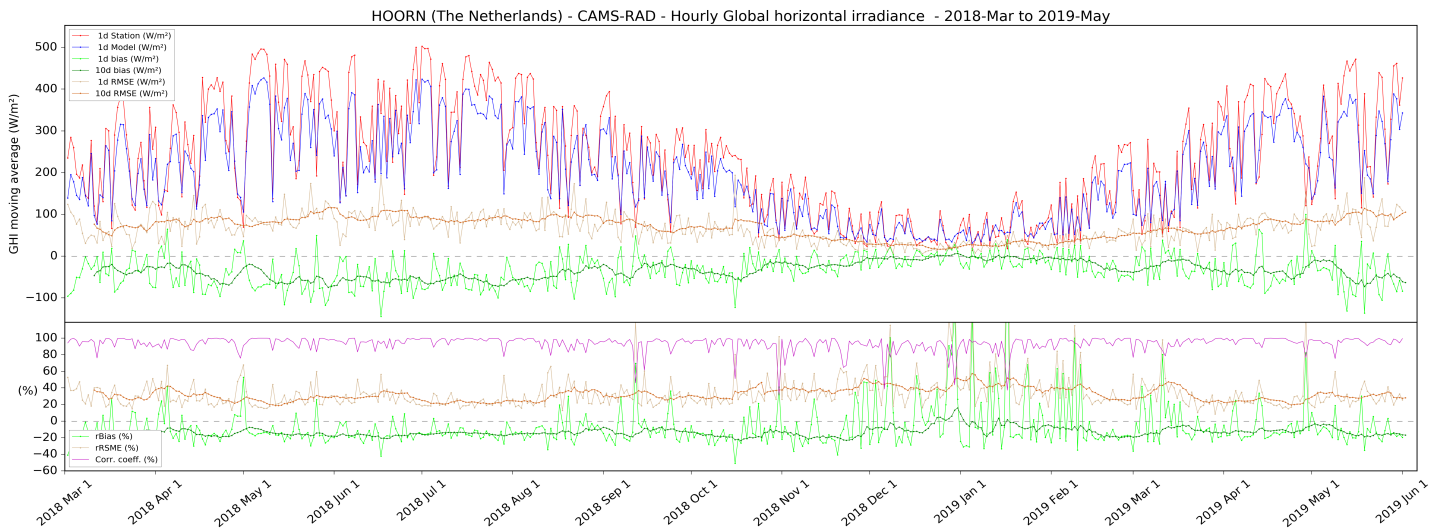


Figure 3.5. Station Hoorn, daily average of global irradiances: measurements (red) and CRS (blue). Daily mean and 10 days running average of bias (green) and RMSE (brown). Top: values (W/m^2), bottom: relative values (%) from March 2018 to May 2019.

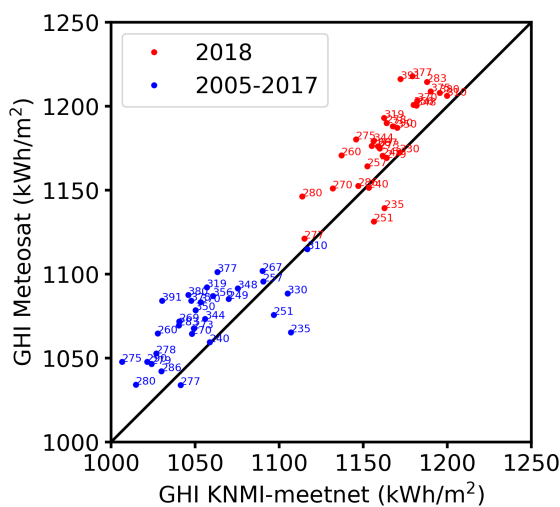


Figure 3.6. Scatter plot of mean 2005-2017 G and 2018 G SICCS vs surface stations (courtesy of Jan Fokke Meirink, KNMI)

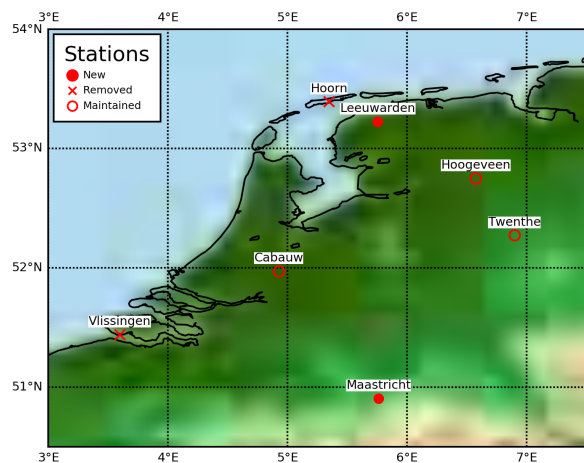


Figure 3.7. Localization of the KNMI stations used in the validation reports.

3.3.2 The PIRATA network

Measurements of global solar radiation are made every 2 min. In this resolution 18 stations at the surface ocean can be gathered from the [PIRATA](#) web service of the NOAA. They are not regularly updated. By December 2021, only one station is available in this resolution with only Jan. and Feb. provisioned. They have been analyzed to better understand their quality as they are mounted on buoys (Trolliet et al., 2018), but for the reason of long delay to obtain measurements these stations



cannot be used for the quarterly validation reports. In the 1 hr resolution, 8 stations are available for 2021, 2 of them being uncomplete. A monitoring of the availability is needed to see if one of them could be used on a regular basis.

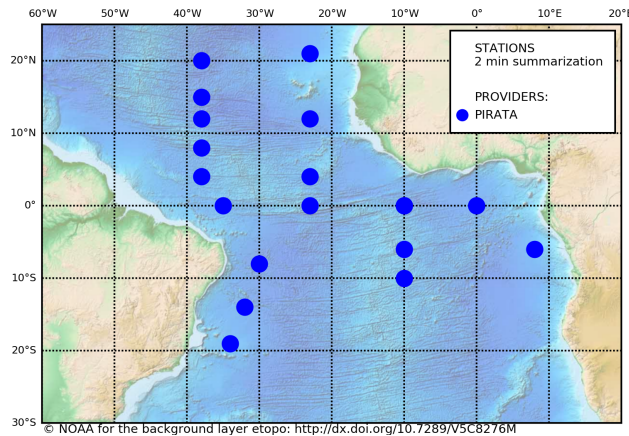


Figure 3.8. Maps of PIRATA stations with 2 min summarization.

3.3.3 National Meteorological Services

A total of 6 stations, all of them in Europe, have been gathered from National Meteorological Services (Fig.3.9) that are not used for the quarterly validation reports as they could not be updated regularly.

Measurements from five stations have been offered by the [Romania service](#) (red markers in the map) with measurements of global and diffuse radiations, at 10 min resolution. The dataset ends on October 2015. The [Cyprus service](#) offered measurements of the global and direct components for one station (yellow marker in the map), at 10 min resolution. The dataset ends on December 2015.

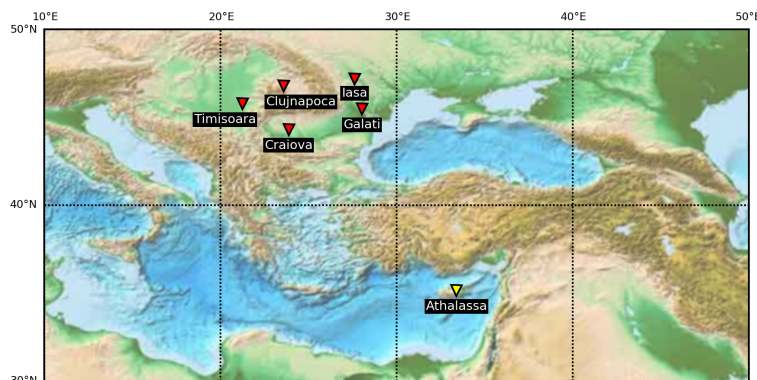


Figure 3.9. Map of stations with 10 min summarization not anymore provided.



4. Stations with 1 min resolution dataset

Having 1 min measurements of the three components helps in controlling the quality of the measurements, in understanding the effect of the broken clouds and in constructing 1 h pseudo-measurements to be compared to CRS products. At least 2 products (*G* and either *D* or *B*) are needed for the selection of cloud-free observations. Stations available for the validation of CAMS-RAD are all in the Meteosat field-of-view (Fig.4.1) while stations available for the validation of McClear are globally located (Fig.4.2).

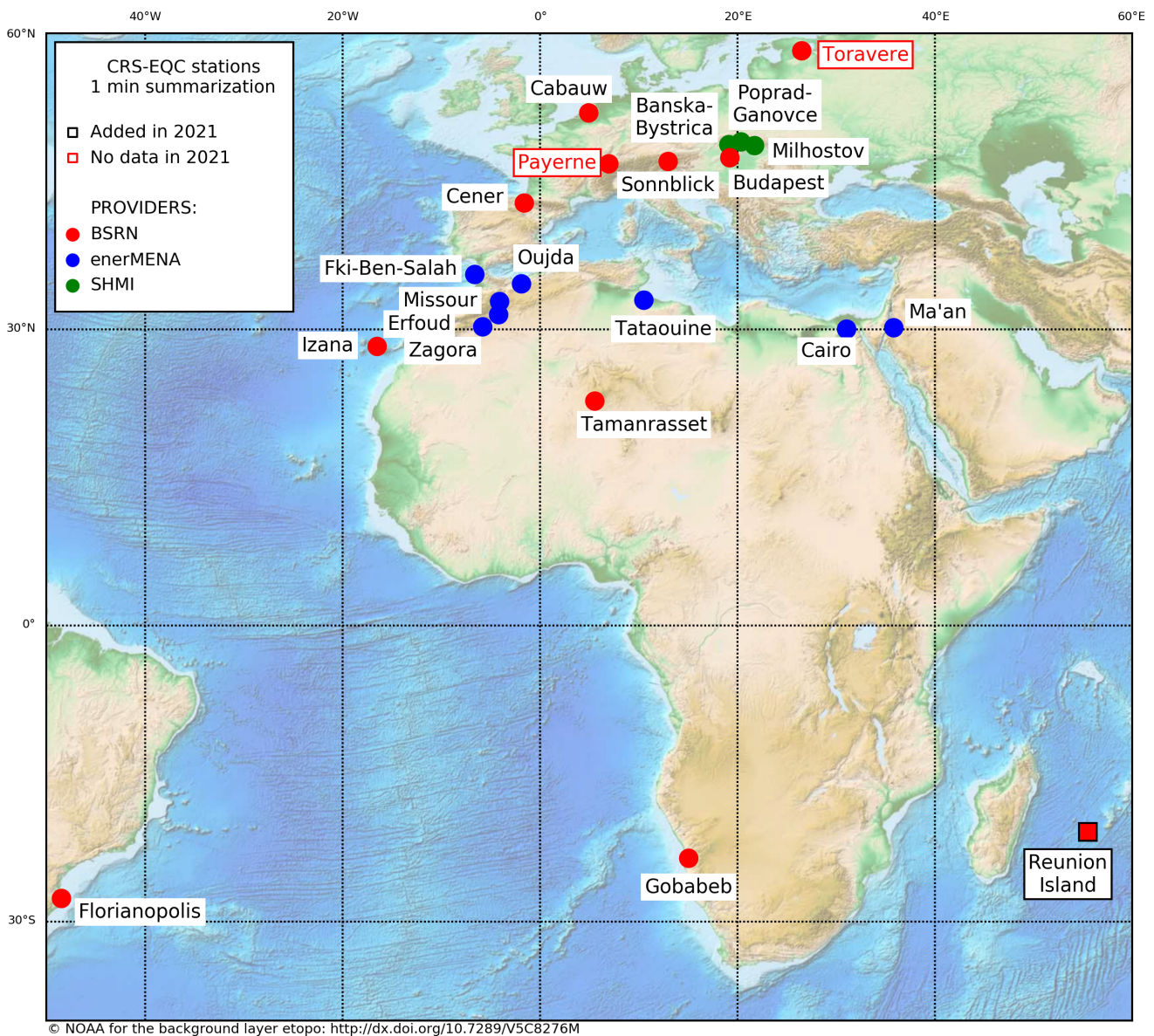


Figure 4.1. Map of 20 stations inside MSG field-of-view available in 2021 with 1 min resolution data set.

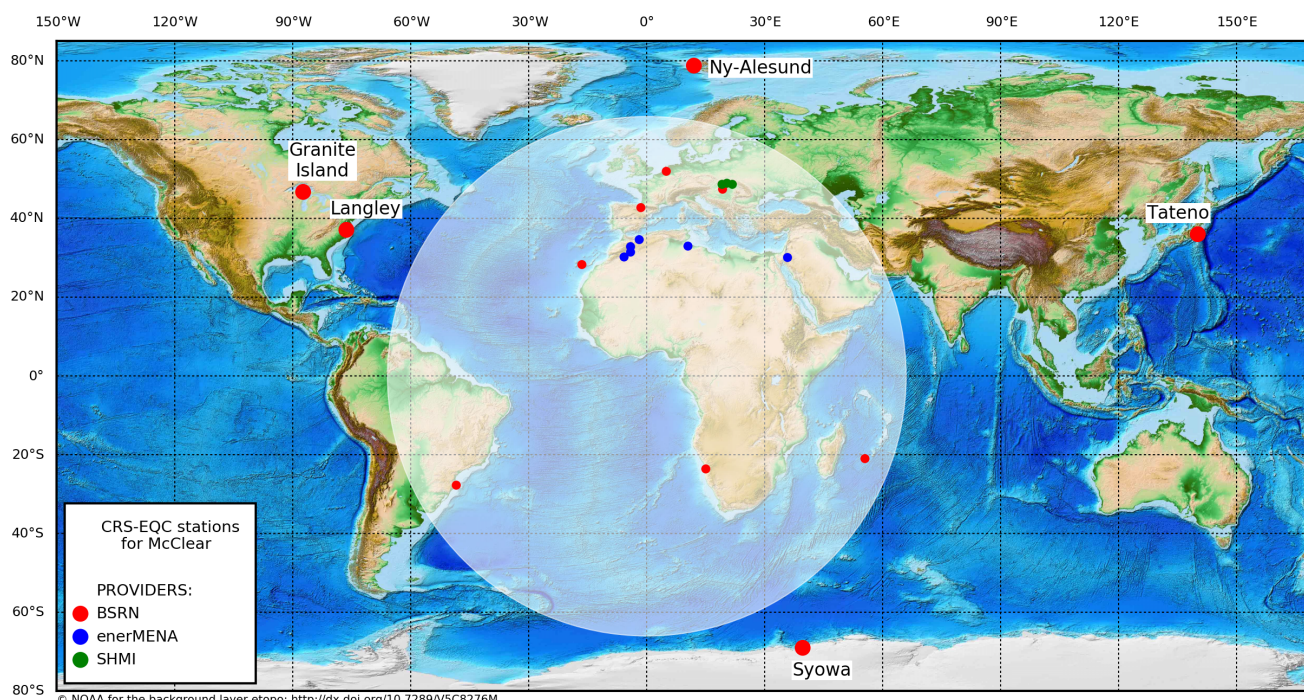


Figure 4.2. Map of 21 stations available in 2021 with 1 min resolution and with at least 2 products needed for the cloud-free selection procedure. Outside MSG field-of-view (symbolized by a circle) are 5 stations used for McClear validation only. Inside MSG field-of-view are stations (detailed in [Fig.4.1](#)) used for both McClear and CAMS-RAD validations.

Table 4.1. Stations with 1 min measurements as on the maps [Fig.4.1](#) and [Fig.4.2](#).

Marker	Provider (see Table 6.2)	Number of stations Operational for 2021 quarterly reports (see Table 6.3)	
		CAMS-RAD	McClea
Red	BSRN	9	12
Blue	enerMENA	8	6
Green	SHMI	3	3
		20	21

Out of 25 stations offering 1 min measurements, 7 are in the European area, 9 sites are in the MENA (Middle-East, North Africa) area, 2 are located in an island environment, 3 are in the southern part of the Meteosat field-of-view, and 5 are outside the Meteosat field-of-view. They represent 11 climate zones ([Table 6.5](#)). Note that Toravere, Florianopolis and Reunion Island are located at the edge of the Meteosat field of view with restrictions expected in retrieval quality as well as Izaña and Sonnblick with a high altitude (2373 m and 3109 m respectively).

4.1 Baseline Surface Radiation Network (BSRN)

Measurements from the network may be accessed at the central archive managed by the Alfred-Wegener-Institute. Access to data can be automated. All variables are available: global, diffuse, and direct at normal incidence, every 1 minute ([Table 6.2](#)).



Only 19 BSRN stations are operational in May 2021 i.e. for the December issue #34. Nine of them are in the field-of-view of the Meteosat satellites (red markers in [Fig.4.1](#)): 4 in Europe, 4 in Africa and Indian Ocean, and 1 in South America. Five stations out of 10 outside the field-of-view of the Meteosat satellites ([Fig.4.2](#)) have been added in 2021 for the McClear validation.

Generally, the upgrade for these stations is done on time for the validation report issue.

Nevertheless, there may be some delay, for example Payerne and Toravere are not updated in 2021 and Florianopolis since April 2021. That makes some gaps in the times-series at the issue date, even if the series is completed later.

4.2 enerMENA network

In the MENA (Middle East and Northern Africa), a region of special interest for concentrating solar power (CSP), a network of 10 stations of high accuracy measurements has been deployed in 2010. The data quality of the measurements required for validation of models and estimation of the solar resource has been analysed by Schüler et al. (2016).

Eight stations are operational (blue markers in [Fig.4.1](#)). Some stations (Ghardaia, Adrar) will not be recovered due to missing collaboration of the Algerian partner. A new station, Fki Ben Salah in Morocco, was operational on October 2019.

Measurements of global, direct and diffuse are made every 1 min, except for Fki Ben Salah which do not provide global radiation (pyranometer broken and sent for repair).

Data is made available by DLR approximately 3 months after acquisition for these stations ([Table 6.2](#)), along with a file containing information on the status of instruments quality, the quality of their maintenance, and potential problems of datalogger ([Table 6.5](#)).

Some restrictions in retrieval CRS quality can be explained by problems inherent to the ground measurements. Within the next sections some investigation on observed bad performances and their potential reasons are presented. This is the case for the Moroccan stations where we observed some discrepancies between estimated CRS and measurements, and for Cairo where outstanding values was observed. This investigation has been made possible with the support of the DLR team at Almería.

4.2.1 Cairo: data file structure

During the 2019 JJA quarter some bad values for the *D* component appeared at Cairo which were not eliminated with the quality check process. A manual elimination of the problematic days had to be done. Once corrected (and without manual elimination) results return to better values. The original MESOR data format of the ground data includes several data flags indicating e.g. a tracker failure, shadows or dew on a sensor, inaccurate sensor alignment or soiled sensors. These flags occur in different columns within the MESOR file dependent on how many different flags have been set within the particular data period. As processing several different flags in changing columns is challenging, the DLR enerMENA team in Almería introduced in October 2020 only one flag indicating “not recommended to use for satellite validation” which includes all other single flags..



4.2.2 Erfoud: maintenance of the instrument

On the station of Erfoud a continuous decrease in irradiance measurements from October 2019 to mid-January 2020 has been found. This has been caused by continuous soiling of the RSI sensor as no regular cleaning can be provided at this remote site. Thus, continuously increasing deviations, caused by dirt on the RSI sensor from summer 2019 until January 2020 have been observed. In January 2020 the RSI sensor has been replaced and cleaned.

4.2.3 Zagora: calibration change

The RSI sensor in Zagora has been exchanged in mid-January 2020. For the first analysis, a wrong calibration constant had been applied to the measurements which created a discrepancy between measured and estimated G and B from mid-January to July while it seemed like the wrong calibration constant cancelled out other discrepancies for B which resulted in smaller deviations for this parameter (Fig.4.3). After correcting the data set with the correct calibration constant the in-situ G component fits well to the modelled data (Fig.4.4). Nevertheless, B which is calculated from G and D , presents since then a discrepancy with estimated CRS that was not observed before.

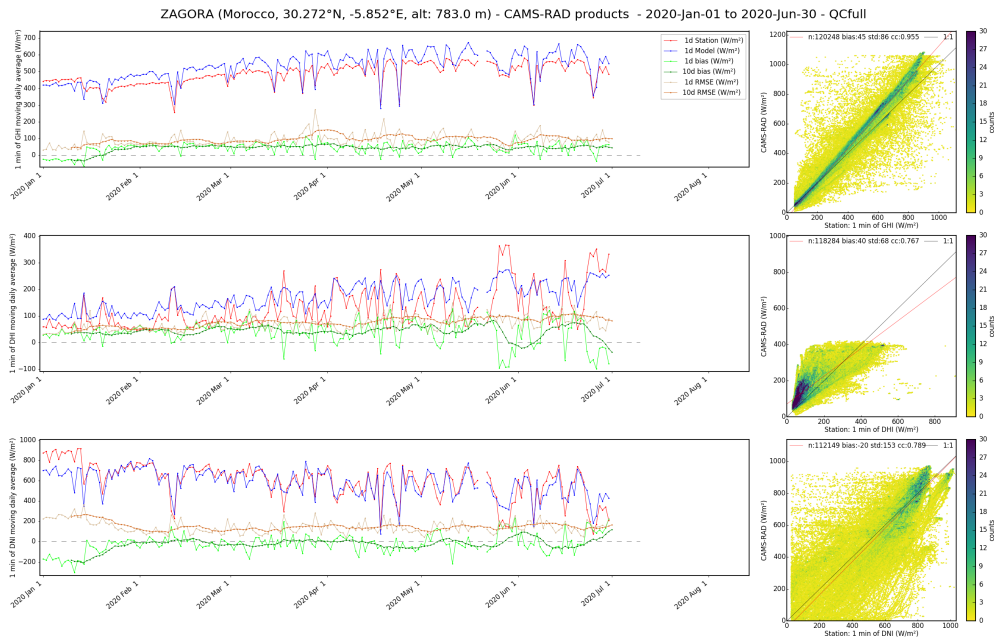


Figure 4.3. Station Zagora, daily average of global irradiances: measurements (red) and CRS (blue). Daily mean and 10 days running average of bias (green) and RMSE (brown) from January to July 2020 (data source with wrong calibration constant applied) Top: Global, middle: Diffuse, bottom: Direct normal irradiance

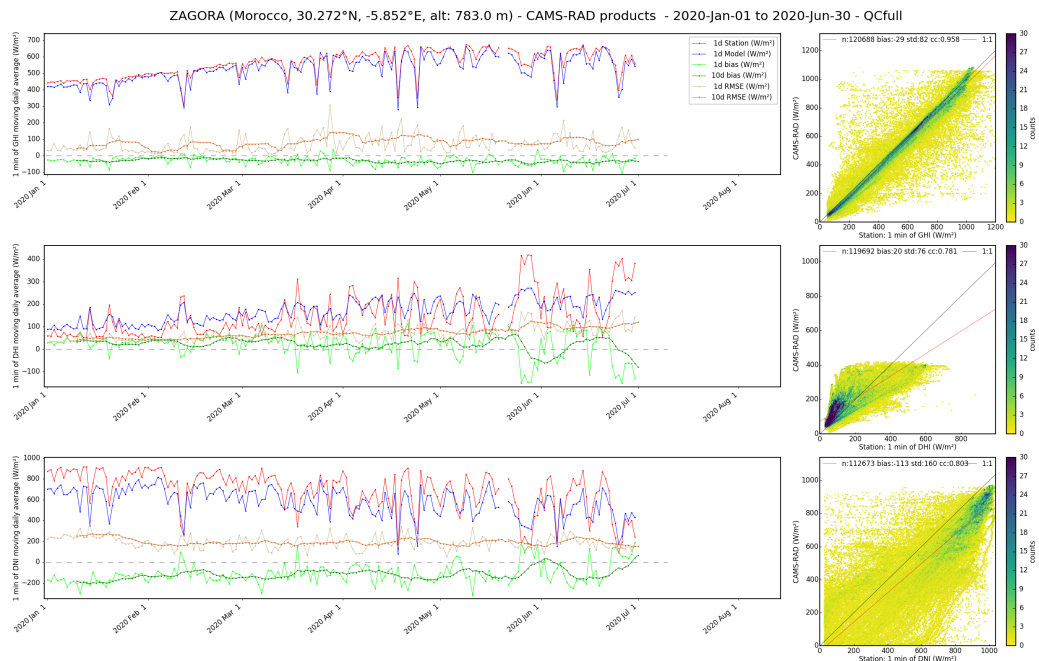


Figure 4.4. Station Zagora, daily average of global irradiances: measurements (red) and CRS (blue). Daily mean and 10 days running average of bias (green) and RMSE (brown) from January to July 2020 (data source with correct calibration constant applied) Top: Global, middle: Diffuse, bottom: Direct normal irradiance



4.2.4 Oujda: instrument level

The station Oujda observes a sudden decrease of G in August 2019, more obvious with the selection of the clear skies (Fig.4.5). In this case, one of the pyranometers may be not well levelled since the new calibration in August 2019. Further, the BSRN calibration which has been performed in August 2019 might deliver erroneous calibration constants due to alternating weather conditions during the calibration. The DLR enerMENA team solved this issue and provided the corrected data set from August 2019 until October 2020 which is not yet included in this report.

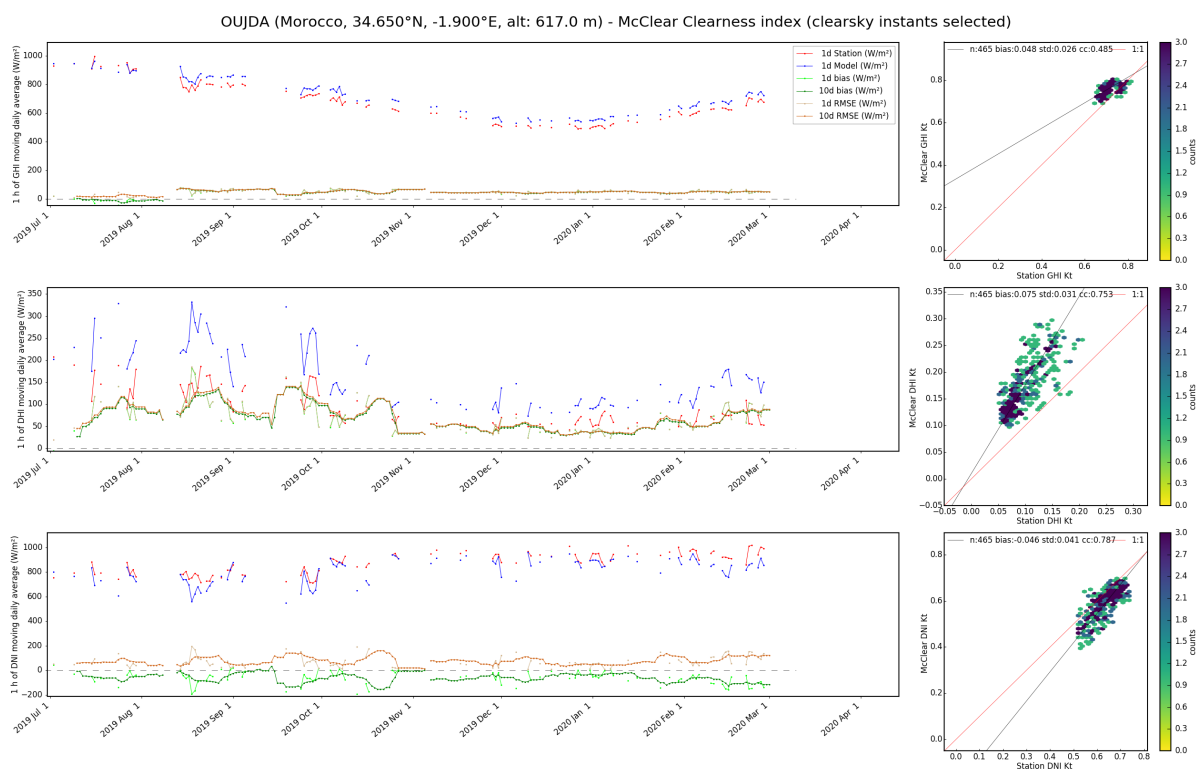


Figure 4.5. Station Oujda, daily average of clearness index: measurements (red) and CRS (blue). Daily mean and 10 days running average of bias (green) and RMSE (brown) from July 2019 to February 2020. Top: Global, middle: Diffuse, bottom: Direct normal clearness index.

4.3 Slovak Hydrometeorological Institute (SHMI)

Measurements of global, direct and diffuse are made every 1 min at one Slovak station (green markers in Fig.4.1). Two other Slovak stations offer measurements of global and diffuse. Data is made available for CAMS2_73 every 6 months for these stations, i.e. January to June 2021 was got in August 2021, and July to December 2021 will be provided in Feb. 2022. Some problems occurred with the files format or naming, but the SHMI (Table 6.2), is very reactive and sent new files promptly.



5. Stations with 1 hour resolution dataset

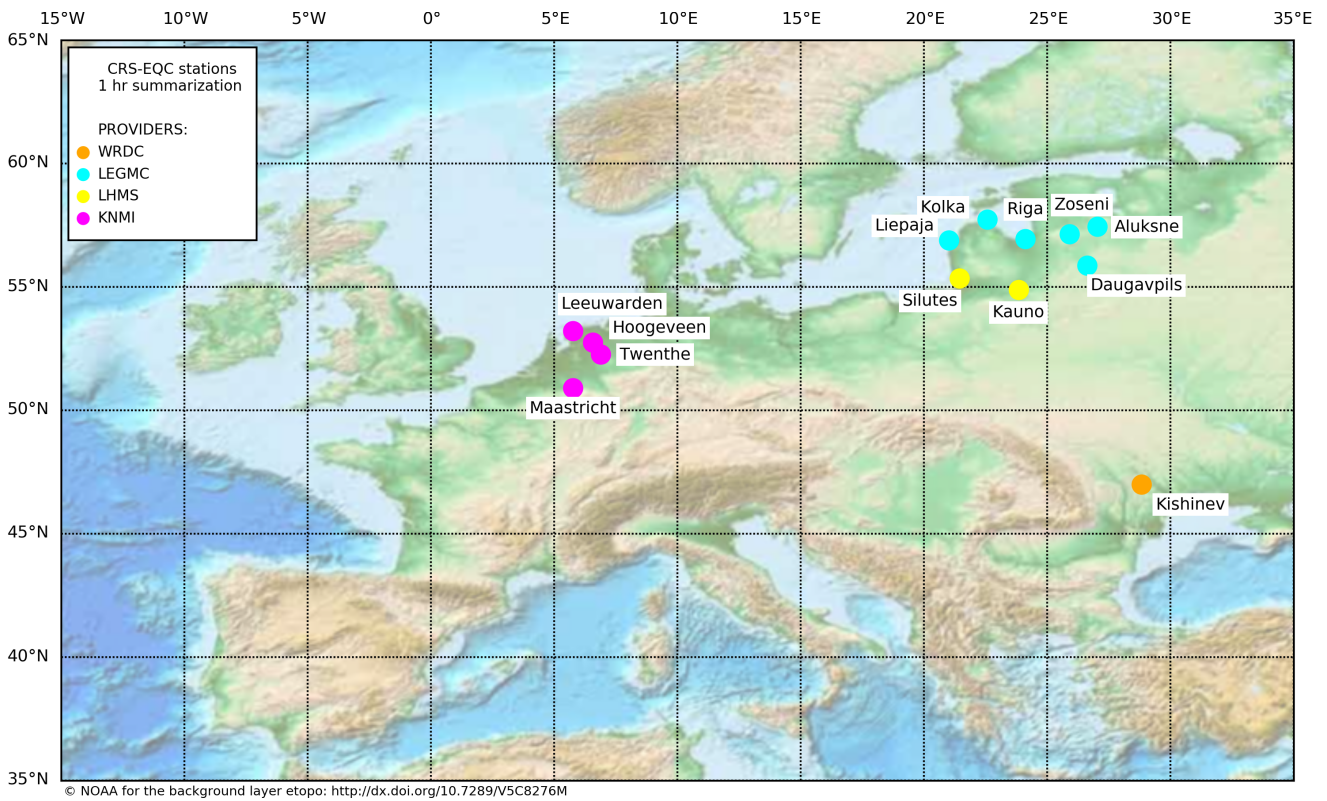


Figure 5.1. Map of 13 stations with 1 h data set.

Table 5.1. Stations with 1 h measurements figuring on the map (Fig.5.1).

Marker	Provider (see Table 6.2)	Number of stations Operational for 2019 quarterly reports (see Table 6.3)
Yellow	LHMS (Lithuania)	2
Cyan	LEGMC (Latvia)	6
Purple	KNMI (The Netherlands)	4
Orange	WRDC / GAW	1
		13

Data of hourly measured radiation have been collected with an emphasis on the assessment of spatial consistency of the performances. There is a total of 13 stations offering recent 1 h measurements that may be used to compare with CRS products of hourly irradiation. Most of the measurements are only for global radiation. There are 2 regional sets of stations provided by 3 national meteorological networks: the Netherlands (4), Latvia and Lithuania (8). They will help in assessing the intra-group consistency.

Due to low satellite viewing angles, lower CRS quality is expected for stations in Latvia and Lithuania. Nevertheless, they provide some insight on the area where the CRS may become unreliable and therefore, this information is kept in this user-oriented report.



5.1 Lithuanian Hydro-Meteorological Service (LHMS)

The LHMS (Table 6.2) is offering measurements from 2 stations (yellow markers in Fig.5.1) for global and direct radiation. Data is put on an ftp site since November 2016 and is regularly made available each month, i.e. November 2021 is available in early December 2021.

These stations are located in the outer area of the Meteosat field of view where degraded service quality is expected. Both Lithuanian stations Silutes and Kauno, used to give bad results. Actually, we observed a shift of several hours in the time stamp of ground observations. The quality check process eliminates some data but do not solve the problem. After multiple tests and visual controls, a time shift correction identified for each month of the full time-series from 2017 has been set. Both stations have been corrected with a time shift ranging from -4 h to +2 h depending on the month. Figure 5.2 (Kauno) and Fig.5.3 (Silutes) present the corresponding 2D-histograms and the hourly average before and after the correction.

A renovation of the equipment has been done in late 2019 and January 2020, and since February 2020 the time shift correction is no more necessary, and results are much satisfactory.

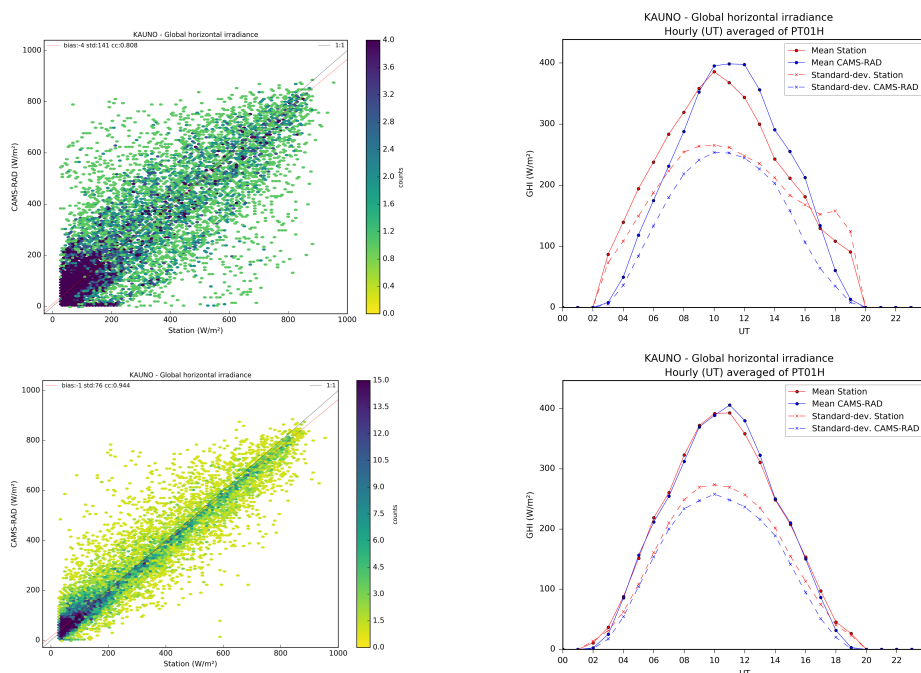
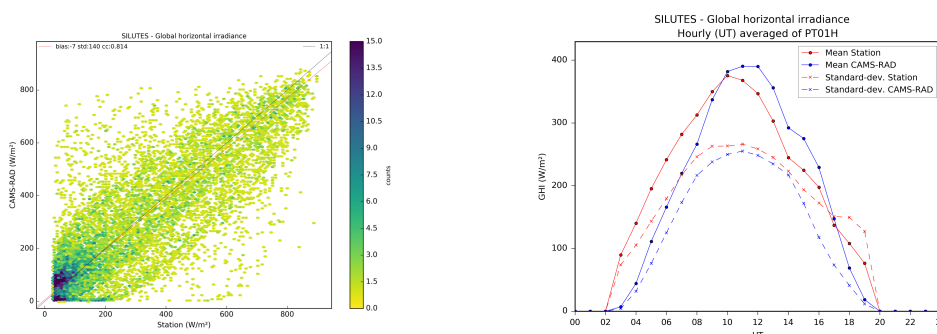


Figure 5.2. Station Kauno: 2D-histogram (left) and hourly average (right) from 2017 to 2019. Top: station data source. Bottom: data source with a time shift correction.



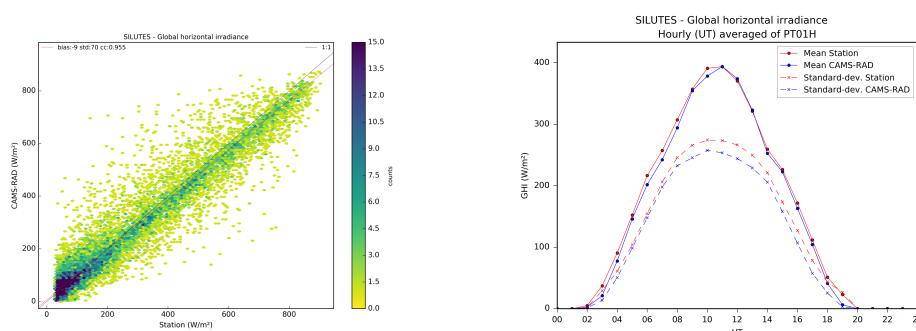


Figure 5.3. Station Silutes: 2D-histogram (left) and hourly average from 2017 to 2019. Top: with station data source. Bottom: data source with a time shift correction.

5.2 Latvian Environment Geology and Meteorology Centre (LEGMC)

The LEGMC ([Table 6.2](#)) is offering regularly global radiation for 6 stations (cyan markers in [Fig.5.1](#)), putting them on an ftp site every month. Monthly dataset is available after the end of the month, i.e. November 2021 is available in early December 2021. In 2018, 2 stations have been stopped but replaced with 2 new ones: Aluksne from January 2019 and Kolka from March 2019 onwards. Both new stations provide global horizontal irradiance observations.

These stations are located in the outer area of the Meteosat field of view where degraded service quality is expected.

5.3 Dutch National network of the KNMI

On the KNMI ([Table 6.2](#)) website are available 32 stations which 4 have been retained for the quarterly validation reports (pink markers in the map [Fig.5.1](#)). Only the global radiation before day -1 can be downloaded in free access. From issue #31 the KNMI dataset of Cabauw has been replaced by the BSRN one, with a better time resolution and a provision of the 3 products G , D , B instead of one.

5.4 WRDC network / GAW

The GAW ([Table 6.2](#)) provides ground measurements with free access, but are not regularly updated, except for the station Kishinev in Moldova (orange marker in the map [Fig.5.1](#)). A visit to the website is regularly needed to check new data set.



6. Dataset Collection

Considering the wishes constraints presented in [section 2](#) the dataset collection is detailed in the form of 4 tables. These tables may contain redundant information. They are structured in order to ease the search:

- for relevance to the validation process with respect to the variables (global, diffuse or direct irradiances) as well as timeliness of access ([Table 6.1](#)),
- for a specific provider ([Table 6.2](#)),
- for geographical location of the stations with the dates of the dataset ([Table 6.3](#)),
- for the instruments used for the measurements when they are known ([Table 6.4](#)),
- for the climate ([Table 6.6](#)).

The dataset contains the overall stations that have been collected from 2015, even those which have been excluded because they do not meet the constraints outlined in [section 2](#). Statistical indicators from some stations used in the past but no longer updated, or further completed, may be used punctually, if needed by users of the solar energy portal [SoDa](#) on their region of interest.

6.1 By relevance

The Table 6.1 below lists the collected stations in a relevant order with:

- recent and regularly available data including at least 2 products,
- recent and regularly available data with only 1 product,
- recent but not regularly available data,
- not regularly available data.

Table 6.1. Summary of data sets ordered by relevance. *G* and *D* are the global and diffuse irradiances on horizontal surface, and *B* is the direct irradiance at normal incidence. Time reference is UT: Universal Time, or TST: True Solar Time, or GMT: Greenwich Meridian Time. Shaded ones are either no more available or used punctually. The other ones are those currently used for the CRS-EQC validation quarterly reports.

Country	Number of stations (Table 6.3)	Provider (Table 6.2)	Product	Unit	Time Resolu- -tion	Time Ref.	Acquisition mode
Stations with 2 or 3 variables regularly obtained							
Worldwide	15	BSRN	<i>G, D, B</i>	W/m ²	1 min	UT	Regularly automatically downloaded
Middle-East North Africa	8	EnerMENA	<i>G, D, B</i>	W/m ²	1 min	UT	Upload on ftp server every 3 months
Slovakia	1	SHMI	<i>G, D, B</i>	W/m ²	1 min	UT	Deposit on ftp site every half year
	2		<i>G, D</i>	W/m ²	1 min	UT	Deposit on ftp site every half year
Lithuania	2	LHMS	<i>G, B</i>	kW/m ²	1 hr	UT	Deposit on ftp site each month



Country	Number of stations (Table 6.3)	Provider (Table 6.2)	Product	Unit	Time Resolu- -tion	Time Ref.	Acquisition mode
Stations with 1 variable regularly obtained							
Middle-East North Africa	1	BSRN	G	W/m ²	1 min	UT	Regularly automatically downloaded
The Netherlands	4	KNMI	G	J/cm ²	1 hr	UT	Free access on the KNMI website until day -1
Latvia	6	LEGMC	G	W/m ²	1 hr	TST	Deposited on a ftp site each month
Moldova	1	WRDC/GAW	G, D, B	J/cm ²	1 hr	GMT+2	Free access on the WRDC/GAW website
Stations with recent data but not regularly updated							
Atlantic Ocean	11	PIRATA	G	W/m ²	1 hr	UT	Free access on the NOAA website
Austria	3	WRDC/GAW	G	J/cm ²	1 hr	GMT+1	Free access on the WRDC/GAW website
Iceland	1		G	J/cm ²	1 hr	GMT	
Argentina	1		G	J/cm ²	1 hr	GMT-3	
Germany	1		G	J/cm ²	1 hr	GMT	
Ireland	1		G, D	J/cm ²	1 hr	GMT	
Europe South-America South Africa		BSRN	G, D, B	W/m ²	1 min	UT	Regularly automatically downloaded
Stations obtained on request or on free access but not updated							
Atlantic Ocean	18	PIRATA	G	W/m ²	PT02M	UT	Free access on the NOAA website
Moldova	1	Academy of Sciences of Moldova	G, D, B	W/cm ²	1 min	UT	On request
Stations not updated anymore							
Romania	5	Nat. Meteo. Administration	G, D	KJ/m ²	10 min	UT	On request
Cyprus	1	CYMET	G, B	KJ/cm ²	10 min	TST	
Ireland	7	MET éireann	G, D	J/cm ²	1 hr	TST	



6.2 By provider

Table 6.2. Summary of data sets ordered by collection network. Shaded ones are either no more available or used punctually. The other ones are those currently used for the CRS-EQC validation quarterly reports.

Data set	Provider	Acquisition mode	Number of stations used for the CRS-EQC / Available (see Table 6.3)
Academy of Sciences of Moldova	Academy of Sciences of Moldova, Institute of Applied Physics, Atmospheric Research Group (ARG) Contact: Dr. Alexandr A. Aculinin	Dataset with 1 min resolution was sent by mail for years 2012-2018. Since 2018, the data with 1 hr resolution are downloaded from WRDC/GAW	0 / 1
BSRN	World Radiation Monitoring Center (WRMC)	Measurements from the central archive of the Baseline Surface Radiation Network (BSRN) may be accessed at the central archive managed by the Alfred-Wegener-Institute on free access: http://bsrn.awi.de/ The access can be automated. Only a limited number of stations are offering recent data. The PANGAEA site lists the availability of data: http://www.pangaea.de/PHP/BSRN_Status.php?q=LR0100	15 / 20
CYMET	Ministry of Agriculture, The Cyprus Department of Meteorology http://www.moa.gov.cy/moa/ms/ms.nsf/DMLforecast_en/DMLforecast_en Contact: Dr. Filippos S. Tyrnvios	Excel file deposited on dropbox	0 / 1
enerMENA	The contact point is the DLR, member of the CAMS-72 consortium. Contact: Dr. Natalie Hanrieder, Dr. Stefan Wilbert Schüler et al., 2016	Regular upload on ftp server every 3 months. An overview (table 6.5) of the good/malfunctions of the instruments and the good/bad quality of data is provided.	8 / 8
MET éireann	The Irish Meteorological Service: http://www.met.ie Contact: Noelle Gillespie	Excel file sent by mail on request One of the stations, Valentia, is available on WRDC/GAW	0 / 7
KNMI	The Dutch Meteorological Service: http://www.knmi.nl/over-het-knmi/about	Measurements are available with free access for long period until day -1 at: https://www.knmi.nl/nederland-nu/klimatologie/daggegevens	4 / 35
LEGMC	Latvian Environment, Geology and Meteorology Centre: http://www.meteo.lv/ Contact: Nadezda Dorogovceva	Regular monthly deposit on ftp site	6 / 6
LHMS	Lithuanian HydroMeteorological Service: http://www.meteo.lt/en Contact: Gintare Giliute	Regular monthly deposit on ftp site	2 / 2
PIRATA	The PIRATA project "Prediction and Research Moored Array in the Tropical Atlantic" is a joint effort between Brazil, France and the United States to collect oceanic and meteorological observations in the tropical Atlantic by the mean of mooring deployed during campaign cruises http://www.brest.ird.fr/pirata/index.php	Measurements can be accessed at the NOAA with free access for long period until day -1: https://www.pmel.noaa.gov/tao/drupal/disdell/ Not all stations are available all the time because of buoy adrift or not transmitting: https://www.pmel.noaa.gov/tao/global/status/buovstat-pirata.htm Stations metadata: https://www.pmel.noaa.gov/gtmba/historical-pirata-mooring-status	0 / 19
RNMA	Romania National Meteorological Administration: http://www.meteoromania.ro Contact: Gheorghe Stancalie	Excel file sent by mail on request	0 / 5



Data set	Provider	Acquisition mode	Number of stations used for the CRS-EQC / Available (see Table 6.3)
SHMI	Slovak Hydrometeorological Institute (SHMI): http://www.shmu.sk Contact : Pribullová Anna	Regular download on a ftp site, every 6 months	3 / 3
WRDC / GAW	World Meteorological Organization (WMO) / Global Atmosphere Watch (GAW) program.	Measurements from the GAW are available with free access on the World Radiation Data Centre (WRDC), a laboratory of the Voeikov Main Geophysical Observatory in Saint-Petersburg, Russia: http://wrdc.mgo.rssi.ru/ Data are not regularly updated. A visit to the website is needed to check new data set. Stations metadata: http://wrdc.mgo.rssi.ru/wwwroot/output/country_index.htm ↓	1 / 8

6.3 By station

Table 6.3. List of stations ordered by country in alphabetical order. Shaded ones are either no more available or used punctually. The other ones are those currently used for the CRS-EQC validation quarterly reports.

Country	Lat.	Lon.	Alt. (m)	Station	Time Resolution	Time Reference	Unit	Product	Date Begin	Date End	Provider (Table 6.2)	Comments		
Antarctica (Cosmonaut Sea)	-69.005	39.589	18	Syowa	1 min	UT	W/m ²	G, D, B	1994-01	2021-08	BSRN			
Algeria	27.878	-0.270	262	Adrar	1 min	UT+1	W/m ²	G, D, B	2015-01	2018-03	enerMENA	Table 6.5 Frequent data logger malfunction or insufficient maintenance. Stations will not be recovered due to missing collaboration of DLR Algerian partners.		
	32.386	3.780	463	Ghardaia					2015-01	2016-03				
	22.790	5.529	1385	Tamanrasset					2000-03	2021-10			BSRN	D and B stopped since March 2018
Argentina	-34.583	-58.483	25	Buenos-Aires	1 hr	Local time offset from GMT-3	J/cm ²	G, D	2014-01	2020-12	WRDC			
Atlantic Ocean	20.500	-23.000	0	21n23w	2 min	UT	W/m ²	G	2013-01	2017-03	PIRATA	Buoys north of 4°N with potentially less quality measurements due to current and contamination by African dust (Foltz et al., 2013, cited in Trollet et al., 2018)		
	20.000	-38.000	0	20n38w					2013-01	2017-03				
	15.000	-38.000	0	15n38w					2013-01	2015-11				
	11.500	-23.000	0	12n23w					2013-01	2015-11				
	12.000	-38.000	0	12n38w					2013-01	2018-02				
	8.000	-38.000	0	8n38w					2013-01	2015-10			2017-11	2018-02
	4.000	-23.000	0	4n23w					2013-01	2017-02				
	4.000	-38.000	0	4n38w					2013-01	2015-10				



Country	Lat.	Lon.	Alt. (m)	Station	Time Resolution	Time Reference	Unit	Product	Date Begin	Date End	Provider (Table 6.2)	Comments
Atlantic Ocean	0.000	0.000	0	0n0e					2012-01	2020-02		
	0.000	-10.000	0	0n10w					2012-01	2021-03		
	0.000	-23.000	0	0n23w					2012-03	2016-03		
	0.000	-35.000	0	0n35w					2013-01	2015-10		
	-6.000	8.000	0	6s8e					2013-06	2017-03		
	-6.000	-10.000	0	6s10w					2012-01	2019-03		
	-8.000	-30.000	0	8s30w					2013-01	2018-11		
	-10.000	-10.000	0	10s10w					2013-01	2016-03		
	-14.000	-32.000	0	14s32w					2013-01	2018-11		
	-19.000	-34.000	0	19s34w					2012-01	2018-11		
Atlantic Ocean	20.500	-23.000	0	21n23w	1 hr	UT	W/m ²	G	2017-03	2021-11	PIRATA	Buoys north of 4°N with potentially less quality measurements due to current and contamination by African dust (Foltz et al., 2013, cited by Trolliet et al., 2018)
	20.000	-38.000	0	20n38w					2017-03	2021-11		
	15.000	-38.000	0	15n38w					2017-12	2021-11		
	11.500	-23.000	0	12n23w					2015-11	2021-11		
	4.000	-23.000	0	4n23w					2017-03	2021-11		
	4.000	-38.000	0	4n38w					2017-12	2019-07		
	0.000	-23.000	0	0n23w					2017-01	2021-10		
	0.000	-35.000	0	0n35w					2017-11	2020-01		
	-6.000	8.000	0	6s8e					2017-03	2019-08		
	-6.000	-10.000	0	6s10w					2017-01	2021-11		
	-10.000	-10.000	0	10s10w	2017-01	2021-10						
Austria	47.054	12.958	3109	Sonnblick	1 min	UT	W/m ²	G, D, B	2013-01	2021-07	BSRN	
					1 hr	Local time offset from GMT+1		G		2021-06		
	48.200	16.567	157	Grossenzer-sdorf	1 hr		J/cm ²	G	1993-01	2021-06	WRDC	
48.250	16.350	203	Wien-Hohe-Warte	1 hr			G, D		2021-06			
Brazil	-27.605	-48.523	11	Florianopolis	1 min	UT	W/m ²	G, D, B	2013-09	2021-03	BSRN	
Cyprus	35.150	33.400	162	Athalassa	10 min	TST	kJ/m ²	G, D	2014-01	2014-12	CYMET	
Egypt	30.036	31.009	104	Cairo	1 min	UT+2	W/m ²	G, D, B	2015-01	2021-09	enerMENA	Table 6.5
Estonia	58.254	26.462	70	Toravere	1 min	UT	W/m ²	G, D, B	1999-01	2021-12	BSRN	
France	44.083	5.059	100	Carpentras	1 min	UT	W/m ²	G, D, B	1996-09	2018-12	BSRN	Closed in Dec. 2018
France (Indian Ocean)	-20.9014	55.4836	116	Reunion Island	1 min	UT	W/m ²	G, D, B	2019-08	2021-10	BSRN	
Germany	47.800	11.000	988	Hohenpeisenberg	1 hr	Local time offset from GMT+1	J/cm ²	G, D	1997-01	2020-12	WRDC	
Hungary	47.4291	19.1822	139	Budapest	1 min	UT	W/m ²	G, D, B	2019-06	2021-08	BSRN	



Country	Lat.	Lon.	Alt. (m)	Station	Time Resolution	Time Reference	Unit	Product	Date Begin	Date End	Provider (Table 6.2)	Comments
Iceland	64.133	-21.900	52	Reykjavik	1 hr	TST	J/cm ²	G	2014-01	2020-12	WRDC	At the extreme limit of the satellite field of view.
Ireland	51.930	-10.240	46	Valentia	1 hr	TST	J/cm ²	G, D	1996-01	2021-06	WRDC	
	52.300	-6.500	66	Johnstown								
	54.230	-10.000	13	Belmullet								
	53.430	-6.230	59	Dublin								
	53.030	-8.080	60	Gurteen								
	54.180	-7.230	58	Clones								
	55.370	-7.330	1	Malin-Head								
Japan	36.058	140.126	25	Tateno	1 min	UT	W/m ²	G, D, B	1996-02	2021-08	BSRN	
Jordan	30.172	35.818	1012	Ma'an	1 min	UT+2	W/m ²	G, D, B	2015-01	2021-09	enerMENA	Table 6.5
Latvia	57.439	27.035	197	Aluksne	1 hr	TST	W/m ²	G	2019-01	2021-11	LEGMC	New stations coming with the meteorological network modernization
	57.743	22.584	30	Kolka					2019-03	2021-11		
	55.870	26.617	97	Daugavpils					2017-01	2021-11		
	56.162	21.173	18	Rucava					2016-04	2018-10		
	56.951	24.116	6	Riga					2016-04	2021-11		
	56.475	21.021	3	Liepaja					2016-04	2021-11		
	57.135	25.906	187	Zoseni					2016-04	2021-11		
	56.620	23.320	42	Dobele					G, B	2016-04		
Lithuania	54.884	23.836	78	Kauno	1 hr	UT	kW/m ²	G, B	2016-11	2021-11	LHMS	B product frequently missing
	55.352	21.447	5	Silutes					2016-09	2021-11		
Moldova	47.000	28.817	205	Kishinev	1 min	UT	W/m ²	G, D, B	2012-01	2018-12	Academy of Sciences of Moldova	
					1 hr	Local time offset from GMT+2	J/cm ²		2003-10	2021-08	WRDC	
Morocco	28.498	-11.322	75	Tantan	1 min	UT	W/m ²	D, B	2015-01	2016-11	enerMENA	Station moved to Fki Ben Salah site
	34.650	-1.900	617	Oujda								
	30.272	-5.852	783	Zagora								
	31.491	-4.218	859	Erfoud								
	32.860	-4.107	1107	Missour								
	32.578	-6.622	485	Fki Ben Salah				G, D, B	2015-01	2021-09		Table 6.5
								2019-11				
Namibia	-23.561	15.042	407	Gobabeb	1 min	UT	W/m ²	G, D, B	2012-05	2021-06	BSRN	
The Netherlands	51.970	4.926	-1	Cabauw	1 min	UT	W/m ²	G D B	2005-11	Day -1	BSRN	May replace KNMI 1 hr
					1 hr		J/cm ²	G	1997-01		KNMI	
	52.750	6.574	16	Hoogeveen	1990-06							



Country	Lat.	Lon.	Alt. (m)	Station	Time Resolution	Time Reference	Unit	Product	Date Begin	Date End	Provider (Table 6.2)	Comments
	52.274	6.891	35	Twenthe					1951-01			
	50.906	5.762	114	Maastricht					1946-12			
	53.224	5.752	1	Leeuwarden					1951-01			
	53.392	5.346	1	Hoor					1994-06			
Norway (Spitzbergen)	78.925	11.930	11	Ny-Ålesund	1 min	UT	W/m ²	G, D, B	1992-08	2021-09	BSRN	
Romania	46.778	23.571	410	Cluj Napoca	10 min	UT	kJ/m ²	G, D	2014-11	2015-10	RNMA	
	45.473	28.032	69	Galati								
	44.310	23.867	192	Craiova								
	45.771	21.258	86	Timisoara								
	47.163	27.617	74	Iasa								
Slovakia	48.734	19.117	427	Banska-Bystrica	1 min	UT	W/m ²	G, D	2015-01	2021-06	SHMI	
	48.663	21.722	105	Milhostov	2015-01	2021-06						
	49.035	20.324	709	Poprad-Ganovce	1 min	UT	W/m ²	G, D, B	2015-01	2021-06		
Spain	37.091	-2.358	500	PSA	1 min	UT+1	W/m ²	G, D, B	2015-01	2019-12	enerMENA	
	42.816	-1.601	471	CENER		UT			2009-07	2021-05	BSRN	
	28.309	-16.499	2373	Izaña		UT			2009-03	2021-10	BSRN	
Switzerland	46.815	6.944	491	Payerne	1 min	UT	W/m ²	G, D, B	1992-10	2020-12	BSRN	Updating stopped in June 2013 but resumed in 2018 with 2011 to 2014 data. No data in 2021
Tunisia	32.974	10.485	210	Tataouine	1 min	UT+1	W/m ²	G, D, B	2015-01	2021-09	enerMENA	Table 6.5
United Kingdom	50.217	-5.317	88	Camborne	1 min	UT	W/m ²	G, D, B	2001-01	2017-07	BSRN	Stopped
United States	46.721	-87.411	208	Granite Island	1 min	UT	W/m ²	G, D, B	2018-10	2021-10	BSRN	
	37.104	-76.387	3	Langley					2014-12	2021-10		

6.4 Instruments

Table 6.4. List of stations ordered by country in alphabetical order, and their instruments when they are known. Shaded ones are either no more available or used punctually. The other ones are those currently used for the CRS-EQC validation quarterly reports.



Country	Provider (Table 6.2)	Station	Product	Instruments	Comments
Antarctica	BSRN	Syowa	G D B	Pyranometer, Kipp & Zonen, CMP21, SN 140466, WRMC No. 17041 Pyranometer, Kipp & Zonen, CMP21, SN 160649, WRMC No. 17042 Pyrheliometer, Kipp & Zonen, CHP 1, SN 140177, WRMC No. 17047	https://doi.org/10.5904/PANGAEA.927807
Algeria	BSRN	Tamanrasset	G	Pyranometer, Eppley, PSP, SN 30123 F3, WRMC No. 42001	https://doi.org/10.5904/PANGAEA.931419
			D	Tracker problem. Not available since 2018.	
			B		
Argentina	WRDC	Buenos-Aires	G	Pyranometer, Kipp & Zonen, CM11	
			D	Pyranometer, Kipp & Zonen, CM11 with shadowband	
Atlantic	PIRATA	0n0e 0n10w 0n23e 0n35w 4n23w 4n38w 6s10w 6s8e 8n38w 8s30w 10s10w 12n23w 12n38w 14s32w 15n38w 19s34w 20n38w 21n23w	G	Pyranometer, Eppley, PSP Nominal heights = 3.6 m above approximate buoy water line https://www.pmel.noaa.gov/ocs/sensors	Buoys north of 4°N with potentially less quality measurements due to current and contamination by African dust (Foltz et al., 2013, cited by Trolliet et al., 2018)
Austria	BSRN	Sonnblick	G D B	Pyranometer, Kipp & Zonen, CMP21, SN 090221, WRMC No. 75030 Pyranometer, Kipp & Zonen, CMP21, SN 090220, WRMC No. 75031 Pyrheliometer, Hukseflux, DR02-T2-10, SN 9119, WRMC No. 75029	https://doi.org/10.5904/PANGAEA.931487
			WRDC	Wien-Hohe-Warte	
					D
		Grossenzersdorf	G	Star pyranometer heated, manufacturer Schenk	
Brazil	BSRN	Florianopolis	G D B	Pyranometer, Kipp & Zonen, CM11, SN 892724, WRMC No. 3003 Pyranometer, Kipp & Zonen, CM11, SN 902820, WRMC No. 3001 Pyrheliometer, Eppley, NIP, SN 28024E6, WRMC No. 3004	https://doi.org/10.5904/PANGAEA.931344
Egypt	enerMENA	Cairo	G	2015-01-20 00:00:01, Kipp & Zonen, CMP21, SN 090290 2019-07-03 15:31:00, Kipp & Zonen, CMP21, SN 090293	Table 6.5
			D	2015-01-20 00:00:01, Kipp & Zonen, CMP21, SN 090293 2019-07-03 15:31:00, Kipp & Zonen, CMP21, SN 090290	
			B	2015-01-20 00:00:01, Kipp & Zonen, CHP1, SN 110656 2016-12-13 12:31:01, Kipp & Zonen, CHP1, SN 110742 2019-03-20 13:51:00, Kipp & Zonen, CHP1, SN 110779	
France (Indian ocean)	BSRN	Reunion Island	G D B	Pyranometer, Kipp & Zonen, CMP22, SN 140114, WRMC No. 82001 Pyranometer, Kipp & Zonen, CMP22, SN 120360, WRMC No. 82002 Pyrheliometer, Kipp & Zonen, CH1, SN 040374, WRMC No. 82003	https://doi.org/10.5904/PANGAEA.931193



Country	Provider (Table 6.2)	Station	Product	Instruments	Comments
Estonia	BSRN	Toravere	G D B	Kipp & Zonen, SMP21-V, SN 170011, WRMC No. 9043 Pyranometer, Kipp & Zonen, CMP21, SN 080074, WRMC No. 9041 Pyranometer, Kipp & Zonen, CMP21, SN 080074, WRMC No. 9041	https://doi.org/10.5904/PANGAEA.920195
Germany	WRDC	Hohenpeissenberg	G D	Pyranometer, Kipp & Zonen, CM-11 Pyranometer, Kipp & Zonen, CM-11 with tracking disk	
Hungary	BSRN	Budapest	G D B	Pyranometer, Kipp & Zonen, CMP11, SN 080466, WRMC No. 14001 Pyranometer, Kipp & Zonen, CMP6, SN 080519, WRMC No. 14003 Pyrheliometer, Kipp & Zonen, CH1, SN 980172, WRMC No. 14002	https://doi.org/10.5904/PANGAEA.931259
Iceland	WRDC	Reykjavik	G	Pyranometer, Kipp & Zonen CMP21	Since 2007
Ireland	WRDC	Valentia	G D	Pyranometer, Kipp & Zonen CM-11 Pyranometer, Kipp & Zonen, CM-11 with tracking disk	Since 2012
	Met éireann	Valentia Johnstown Belmullet Dublin Gurteen Clones Malin-Head	G, D	Kipp & Zonen, CM-11	
Japan	BSRN	Tateno	G D B	Pyranometer, Kipp & Zonen, CMP21, SN 090229, WRMC No. 16035 Pyranometer, Kipp & Zonen, CMP22, SN 090099, WRMC No. 16037 Pyrheliometer, Kipp & Zonen, CHP 1, SN 090140, WRMC No. 16034	https://doi.org/10.5904/PANGAEA.929208
Jordan	enerMENA	Ma'an	G D B	2014-10-27 00:00:01, Kipp & Zonen, CMP21, SN 090299 2014-10-27 00:00:01, Kipp & Zonen, CMP21, SN 090299 2017-01-17 00:00:01, Kipp & Zonen, CMP11, SN 100493 2019-10-18 00:00:01, Kipp & Zonen, CMP21, SN 100493 2014-10-27 00:00:01, Kipp & Zonen, CMP11, SN 100493 2017-01-17 00:00:01, Kipp & Zonen, CMP21, SN 090299 2019-10-18 00:00:01, Kipp & Zonen, CMP21, SN 090299 2014-10-27 00:00:01, Kipp & Zonen, CHP1, SN 090170 2017-01-17 00:00:01, Kipp & Zonen, CHP1, SN 090164 2019-03-27 00:00:00, Kipp & Zonen, CHP1, SN 090163	Table 6.5
Latvia	LEGMC	Daugavpils	G	Pyranometer, Kipp & Zonen, CMP21, 70115, calibration 01-04-2015	
		Riga		Pyranometer, Kipp & Zonen, CMP21, 61670, calibration 19-06-2013	
		Liepaja		Pyranometer, Kipp & Zonen, CMP21, 61670, calibration 01-04-2014	
		Zoseni		Pyranometer, Kipp & Zonen, CMP21, 61670, calibration 13-04-2015	
		Aluksne		Mail sent	
		Kolka		Mail sent	
Lithuania	LHMS	Kauno	G	2016, Kipp & Zonen, CMP6B, 994112, calibration 1999, last checkup 2019-05-03 2020, Kipp & Zonen, CMP6, 19337, calibration 2019, last check-up 2020-05-07	
			B	2016, Kipp & Zonen, CH1, 070602, calibration 2007, last checkup 2016-03-25 2020, Kipp & Zonen, CHP1, 190700, calibration 2019, last check-up 2020-05-07	
		Silutes	G	2016, Kipp & Zonen, CMP6, 101307, calibration 2010, last checkup 2018-08-27 2020, Kipp & Zonen, CMP6, 193346, calibration 2019, last check-up 2020-09-02	
			B	2016, Kipp & Zonen, CH1, 990208, calibration 1999, last checkup 2017-04-11 2020, Kipp & Zonen, CHP1, 190702, calibration 2019, last check-up 2020-09-02	



Country	Provider (Table 6.2)	Station	Product	Instruments	Comments
Moldova	WRDC	Kishinev	G D B	Pyranometer, Kipp & Zonen, CM-11 (305-2800 nm) Pyranometer, Kipp & Zonen, CM-11 (305-2800 nm) with Kipp & Zonen, CH-1 (200-4000 nm) on active solar tracking 2AP BD unit	shadowband on active solar tracking 2AP BD unit
Morocco	enerMENA	Oujda	G	2014-05-15 09:05:01, Kipp & Zonen, CMP21, SN 090279 2016-04-08 08:46:00, Kipp & Zonen, CMP21, SN 110868 2019-08-06 09:49:00, Kipp & Zonen, CMP21, SN 110876	Table 6.5
			D	2014-05-15 09:05:01, Kipp & Zonen, CMP21, SN 090280 2016-04-08 08:46:00, Kipp & Zonen, CMP21, SN 110876 2019-08-06 09:49:00, Kipp & Zonen, CMP21, SN 110868	
			B	2014-05-15 09:05:01, Kipp & Zonen, CHP1, SN 090164 2016-04-08 08:46:00, Kipp & Zonen, CHP1, SN 090167 2019-07-16 12:01:00, Kipp & Zonen, CHP1, SN 080028 2019-07-16 12:01:00, Kipp & Zonen, CHP1, SN 110657	
		Fki Ben Salah	G	In repair	Table 6.5
			D	2019-10-25 00:00:01, Kipp & Zonen, CMP21, SN 133168	
			B	2019-10-25 00:00:01, Kipp & Zonen, CHP1, SN 080028	
		Erfoud	G	2013-06-01 12:00:00, RSP1018-1, RSP Sensor, SN PY67982 2016-03-31 12:01:00, RSI Twin PU, SN PY87339 2018-01-10 11:51:00, RSI Twin PU, SN PY90702 2020-01-14 14:00:01, RSI Twin PU, SN PY87339	Table 6.5
			D	2013-06-01 12:00:00, RSP1018-1, RSP Sensor, SN PY67982 2016-03-31 12:01:00, RSI Twin PU, SN PY87339 2018-01-10 11:51:00, RSI Twin PU, SN PY90702 2020-01-14 14:00:01, RSI Twin PU, SN PY87339	
			B	2013-06-01 12:00:00, RSP1018-1, RSP Sensor, SN PY67982 2016-03-31 12:01:00, RSI , Twin PU, SN PY87339 2018-01-10 11:51:00, RSI Twin PU, SN PY90702 2020-01-14 14:00:01, RSI , Twin PU, SN PY87339	
		Missour	G	2013-05-27 00:00:00, Kipp & Zonen, CMP21, SN 110845 2016-03-30 12:31:00, Kipp & Zonen, CMP21, SN 090291 2020-01-13 15:00:02, Kipp & Zonen, CMP21, SN 090300	Table 6.5
			D	2013-05-27 00:00:00, Kipp & Zonen, CMP21, SN 110846 2016-03-30 12:31:00, Kipp & Zonen, CMP21, SN 090300 2019-10-24 00:00:02, Kipp & Zonen, CMP21, SN 110864	
			B	2013-05-27 00:00:00, Kipp & Zonen, CHP1, SN 110742 2016-03-30 12:31:00, Kipp & Zonen, CHP1, SN 110780 2019-07-10 14:01:00, Kipp & Zonen, CHP1, SN 110656	
		Zagora	G	2013-06-01 12:00:00, RSP1201-1, RSP Sensor, SN PY75722 2016-04-01 12:01:00, RSI Twin PU, SN PY87337 2018-01-11 15:01:00, RSI Twin PU, SN PY90700 2020-01-14 18:00:01, RSI Twin PU, SN PY87337	Table 6.5
			D	2013-06-01 12:00:00, RSP1201-1, RSP Sensor, SN PY75722 2016-04-01 12:01:00, RSI , Twin PU, SN PY87337 2018-01-11 15:01:00, RSI Twin PU, SN PY90700 2020-01-14 18:00:01RSI Twin PU, SN PY87337	
			B	2013-06-01 12:00:00, RSP1201-1, RSP Sensor, SN PY75722 2016-04-01 12:01:00, RSI Twin PU, SN PY87337 2018-01-11 15:01:00, RSI , Twin PU, SN PY90700 2020-01-14 18:00:01, RSI, Twin PU, SN PY87337	



Country	Provider (Table 6.2)	Station	Product	Instruments	Comments
Namibia	BSRN	Gobabeb	G D B	Pyranometer, Kipp & Zonen, CMP22, SN 110315, WRMC No. 20100 Pyranometer, Kipp & Zonen, CMP 22, SN 110316, WRMC No. 20101 Pyrheliometer, Kipp & Zonen, CHP 1, SN 110764, WRMC No. 20000	https://doi.org/10.5904/ANGA-EA.931713
The Netherlands	BSRN	Cabauw	G D B	Pyranometer, Kipp & Zonen, CM22, SN 010032, WRMC No. 53002 Pyranometer, Kipp & Zonen, CMP22, SN 130475, WRMC No. 53016 Pyrheliometer, Kipp & Zonen, CH1, SN 020283, WRMC No. 53003	https://doi.org/10.5904/ANGA-EA.931490
The Netherlands	KNMI	32 stations	G	Pyranometer, CM-11	http://projects.knmi.nl/klimatologie/metadatas/index.html
Norway (Spitzbergen)	BSRN	Ny-Ålesund	G D B	Pyranometer, Kipp & Zonen, CM22, SN 100219, WRMC No. 11023 Pyranometer, Kipp & Zonen, CM22, SN 100216, WRMC No. 11021 Pyrheliometer, Kipp & Zonen, CHP 1, SN 100440, WRMC No. 11018	https://doi.org/10.5904/ANGA-EA.938520
Romania	RNMA	Cluj Napoca Galati Craiova Timisoara Iasi	G, D	Thermoelectric pyranometers type CM6 – Kipp & Zonen, ISO first class, (double glass dome, Spectral range 285-2800 nm)	
Slovakia	SHMI	Banska-Bystrica Milhostov	G	Pyranometer, Kipp & Zonen, CMP21	ventilation unit, sampling interval 5 s, calibration interval 2 years
			D	Pyranometer, Kipp & Zonen, CMP21 on shadow ring CM121	
		Poprad-Ganovce	G	Pyranometer, Kipp & Zonen, CMP21	
			D	Pyranometer, Kipp & Zonen, CMP21 on tracker 2AP with shadow assembly	
B	Pyrheliometer, Kipp & Zonen, CHP1, on tracker 2AP				
Spain	BSRN	Izaña	G	Pyranometer, EKO, MS-802F, SN F15508FR, WRMC No. 61010	https://doi.org/10.5904/ANGA-EA.931359
			D	Pyranometer, EKO, MS-802F, SN F15509FR, WRMC No. 61011	
			B	Pyrheliometer, EKO, MS-56, SN P15048, WRMC No. 61012	
	enerMENA	PSA	G	2014-09-05 15:33:01, Kipp & Zonen, CMP21, SN 090281	https://doi.org/10.5904/ANGA-EA.931712
				2016-03-10 00:00:01, Kipp & Zonen, CMP21, SN 110875	
				2019-03-25 13:00:00, Kipp & Zonen, CMP21, SN 090279	
enerMENA	PSA	D	2014-09-05 15:33:01, Kipp & Zonen, CMP21, SN 090292	https://doi.org/10.5904/ANGA-EA.931712	
			2016-03-10 00:00:01, Kipp & Zonen, CMP21, SN 110869		
			2019-03-25 13:00:00, Kipp & Zonen, CMP21, SN 090292		
enerMENA	PSA	B	2014-09-05 15:33:01, Kipp & Zonen, CHP1, SN 090163	https://doi.org/10.5904/ANGA-EA.931712	
			2015-03-17 00:00:01, Kipp & Zonen, CH1, SN 70574		
			2016-03-10 00:00:01, Kipp & Zonen, CHP1, SN 110779		
2018-07-04 00:00:00, Hukseflux, SN 10025					
Switzerland	BSRN	Payerne	G D B	Pyranometer, Kipp & Zonen, CM22, SN 080002, WRMC No. 21060 Pyranometer, Kipp & Zonen, CM22, SN 080001, WRMC No. 21061 Pyrheliometer, Kipp & Zonen, CHP 1, SN 110740, WRMC No. 21062	https://doi.org/10.5904/ANGA-EA.913967



Country	Provider (Table 6.2)	Station	Product	Instruments	Comments
Tunisia	enerMENA	Tataouine	G	2012-11-30 00:00:01, Kipp & Zonen, CMP21, SN 110869 2015-04-10 00:00:01, Kipp & Zonen, CMP21, SN 110789 2018-12-14 00:01:01, Kipp & Zonen, CMP21, SN 110790 2019-03-16 00:00:01, Kipp & Zonen, CMP21, SN 110789	Table 6.5
			D	2012-11-30 00:00:01, Kipp & Zonen, CMP21, SN 110875 2015-04-10 00:00:01, Kipp & Zonen, CMP21, SN 110790 2018-12-14 00:01:01, Kipp & Zonen, CMP21, SN 110789 2019-03-16 00:00:01, Kipp & Zonen, CMP21, SN 110790	
			B	2012-11-30 00:00:01, Kipp & Zonen, CHP1, SN 110779 2015-04-10 00:00:01, Kipp & Zonen, CHP1, SN 110686 2019-03-25 00:00:01, Kipp & Zonen, CHP1, SN 110686	
United States	BSRN	Langley Research Center	G D B	Pyranometer, Kipp & Zonen, CM22, SN 040100, WRMC No. 39039 Pyranometer, Kipp & Zonen, CM31, SN 000507, WRMC No. 39032 Pyrheliometer, Kipp & Zonen, CH1, SN 960133, WRMC No. 39017	https://doi.org/10.5904/ANGAEA-2019-1594/PANGAEA.926562
		Granite Island	G D B	Pyranometer, Kipp & Zonen, CM21, SN 041282, WRMC No. 78003 Pyranometer, Kipp & Zonen, CM21, SN 051417, WRMC No. 78004 Pyrheliometer, Kipp & Zonen, CH1, SN 010254, WRMC No. 39038	https://doi.org/10.5904/ANGAEA-2019-1594/PANGAEA.926543

Table 6.5. Status of the enerMENA stations provided by the DLR team at Almeria for the period June 2020 to May 2021 covered by the CRS-EQC reports delivered in 2021.

Color code months	Missing	doubtfully maintained	Good
Color code station	No priority	Effort to make station work again	Priority

2020	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Cairo, Egypt	Tracker failure until 18. of June. GHI data ok, but no cleaning during tracker failure period. Power outage between 3 and 7 June. RH and temperature sensor failure between 10. and 14. June. Shadow on the sensor for a short period in the morning, data is flagged accordingly.	Good quality. Week-daily cleaning	Good quality. Week-daily cleaning	Good quality. Week-daily cleaning	tracker broken --> Only GHI data accurate. No cleaning in October 2020.	tracker broken --> Only GHI data accurate.	tracker broken --> Only GHI data accurate.
Erfoud, Morocco	Good quality	Good quality	Good quality	Good quality	Good quality	Good quality	Good quality
Maan, Jordan	Quality ok. Almost no cleaning due to COVID-19. Anemometer broken.	Quality ok. Tracker unaligned at first hour during the day. Cleaning every ~4 days. Anemometer broken.	Quality ok. Tracker unaligned at first hour during the day. Cleaning every ~4 days. Anemometer broken.	Quality ok. Tracker unaligned at first hour during the day. Cleaning every ~4 days. Anemometer broken.	Quality ok. Tracker unaligned at first hour during the day. Data gap between Oct. 15th and Nov. 1st 2020.	Quality ok. Tracker unaligned at first hour during the day. Anemometer broken.	Quality ok. Tracker unaligned at first hour during the day. Anemometer exchanged on Dec. 12th, 2020.



2020	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
					Anemometer broken.		
Missour, Morocco	Small but regular data gaps due to low logger voltage. Week-daily cleaning.	Good quality, but many short data gaps due to power failures of the logger. Cleaning every ~1-2 days.	Longer data gaps due to power failures of the logger.	Good quality, but many short data gaps due to power failures of the logger. Cleaning every ~1-2 days.	Good quality, but many short data gaps due to power failures of the logger. Cleaning every ~1-2 days.	Data gap between Nov. 14th and end of Nov. 2020 due to logger failure.	Data gap between Dec. 1 and 17th, 2020 due to logger failure. Maintenance visit on Dec. 17th, 2020 and logger repair.
Oujda, Morocco	Good quality. Cleaning every ~3 days. Tracker failure between 8 and 16 of June.	Good quality. Cleaning every ~3 days	Good quality. Cleaning every ~3 days	Good quality. Cleaning every ~3 days	Good quality, but several tracker outages. Cleaning every ~3 days	Good quality, but several tracker outages. Cleaning every ~3 days	Good quality, but several tracker outages. Cleaning every ~3 days
Fki Ben Salah, Morocco	DHI data good quality. GHI data not available due to broken sensor. Pyrliometer sometimes in the afternoon misaligned due to erroneous mounting. Broken anemometer. Cleaning button broken.	DHI data good quality. GHI data not available due to broken sensor. Pyrliometer sometimes in the afternoon misaligned due to erroneous mounting. Broken anemometer. Cleaning button broken.	DHI data good quality. GHI data not available due to broken sensor. Pyrliometer sometimes in the afternoon misaligned due to erroneous mounting. Broken anemometer. Cleaning button broken.	DHI data good quality. GHI data not available due to broken sensor. Pyrliometer sometimes in the afternoon misaligned due to erroneous mounting. Broken anemometer. Cleaning button broken.	DHI data good quality. GHI data not available due to broken sensor. Pyrliometer sometimes in the afternoon misaligned due to erroneous mounting. Broken anemometer. Cleaning button broken.	DHI data good quality. GHI data not available due to broken sensor. Pyrliometer sometimes in the afternoon misaligned due to erroneous mounting. DNI mounting enhanced and anemometer repaired during maintenance visit on Nov 19th,2020. Cleaning button broken.	DHI data good quality. GHI data not available due to broken sensor. DNI pyrliometer still sometimes misaligned. Cleaning button broken.
Tatouine, Tunisia	Medium quality, week- daily cleaning. Data gap between 18 and 22 of June. Station visit on 22 June, anemometer replaced.	Good quality, cleaning every ~3days	Good quality, cleaning every ~3days, data gap between 11 and 24 August due to corrupt logger program	Good quality, cleaning every ~3days	Good quality, cleaning every ~3days	Good quality, cleaning every ~3days	Good quality, cleaning every ~3days
Zagora, Morocco	Good quality	Good quality	Good quality	Good quality	Good quality	Good quality	Good quality

2021	Jan.	Feb.	March	April	May
Cairo, Egypt	Only GHI available. Week-daily cleaning	Only GHI available. Week-daily cleaning	Only GHI available. Week-daily cleaning	Only GHI available. Week-daily cleaning. RH and Tamb sensor not working until 19 April, data gap from April 19 to end of April	Only GHI available. Week-daily cleaning. RH and Tamb sensor not working, data gap from May 1 to May 17
Erfoud, Morocco	Good quality	Good quality	Good quality	Good quality	Good quality



2021	Jan.	Feb.	March	April	May
Maan, Jordan	Quality ok. Tracker unaligned in the morning.	Quality ok. Tracker unaligned in the morning.	Quality ok. Tracker unaligned in the morning.	Quality ok. Tracker unaligned in the morning.	Quality ok. Tracker unaligned in the morning.
Missour, Morocco	Good quality. Week-daily cleaning.	Good quality. Week-daily cleaning.	Good quality. Week-daily cleaning.	Good quality. Week-daily cleaning. Tracker off until April 14	Good quality. Week-daily cleaning.
Oujda, Morocco	Good quality. Cleaning every ~3 days.	Good quality. Cleaning every ~3 days.	Good quality. Cleaning every ~3 days.	Tracker off. Only GHI available. Cleaning every ~3 days.	Tracker off. Only GHI available. Cleaning every ~3 days.
Fki Ben Salah, Morocco	DHI data good quality. DNI pyrhelimeter sometimes misaligned in the morning. GHI data not available.	DHI data good quality. DNI pyrhelimeter sometimes misaligned in the morning. GHI data not available. Maintenance visit and installation of new wind vane.	DHI data good quality. DNI pyrhelimeter sometimes misaligned in the morning. GHI data not available.	DHI data good quality. DNI pyrhelimeter sometimes misaligned in the morning. GHI data not available. Pb sensor blocked by wasps.	DHI data good quality. DNI pyrhelimeter sometimes misaligned in the morning. GHI data not available. Pb sensor blocked by wasps.
Tatouine, Tunisia	Good quality, cleaning every ~3days.	Good quality, cleaning every ~3days.	Good quality, cleaning every ~3days.	Good quality, cleaning every ~3days.	Good quality, cleaning every ~3days.
Zagora, Morocco	Good quality	Good quality	Good quality	Good quality, wind data missing	Good quality, wind data missing



6.5 By climate

The selected stations for the quarterly validation are located in several different climates as reported in Table 6.6. The description of climates is taken from the updated world map of the Köppen-Geiger climate classification by Peel et al. (2007).

Table 6.6. List of climates and corresponding stations used in validation reports

Climate (Köppen-Geiger classification)	Stations
As: Tropical savanna climate, dry summer	Reunion island
Dfa: Continental wet. Cold climate without dry season and hot summer	Poprad-Ganovce, Banska-Bystrica, Milhostov
Dfb: Continental wet. Cold climate without dry season and warm summer	Toravere, Zoseni, Riga, Dobeles, Daugavpils, Liepaja, Aluksne, Kolka, Rucava, Silutes, Kauno, Kishinev, Budapest, Granite Island
Cfa: Temperate climate without dry season and hot summer	Florianopolis, Tateno
Cfb: Temperate climate without dry season and warm summer	Hoorn, Hoogeveen, Twenthe, Cabauw, Leeuwarden, Maastricht, Vlissingen, Camborne, Payerne, CENER
Csa: Temperate climate with dry and hot summer	Oujda, Missouri
Csb: Temperate climate with dry and warm summer	Carpentras, PSA, Langley
BWh: Arid and hot climate of desert type	Tataouine, Erfoud, Cairo, Zagora, Ma'an, Tamanrasset, Fki Ben Salah
BWk: Arid and cold climate of desert type	Gobabeb
ET: Polar tundra climate with no true summer	Ny-Ålesund
EF: Ice cap climate	Syowa



7. Reference

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8. APPENDIX A. Methodology for identifying and collecting measurements

A thorough survey of various sources of data in solar irradiation was performed in previous projects and is on-going. It is not the objective of this report to fully document the sources; only outlines are given here remembering that the current situation described below is prone to quick changes. It was found that measurements of the three components of the irradiation: global (G), diffuse (D) and direct at normal incidence (B), or even two components: G and B , exist and can be accessed sometimes in an automated way.

The most known source is certainly the Baseline Surface Radiation Network (BSRN). These data are of high quality and are very often used to validate methods, such as the McClear model and the Heliosat-4 method used in CAMS-RAD. They can be accessed via a website and are thus of easy access. The format is standard so that an automated processing of these measurements is possible. This automation is facilitated by the provision of quality flags that are given for each measurement. Measurements are made every 1 min, allowing for the construction of 15 min and hourly sums expressed in a different time system, e.g. UT.

The PIRATA project “Prediction and Research Moored Array in the Tropical Atlantic” is a joint effort between Brazil, France and the United States to collect oceanic and meteorological observations in the tropical Atlantic by the mean of mooring deployed during campaign cruises (<http://www.brest.ird.fr/pirata/index.php>). The NOAA/PMEL offers in real-time global solar radiation data at 2 min resolution and hourly resolution. Not all stations are available all the time because of buoy adrift or not transmitting (<https://www.pmel.noaa.gov/tao/global/status/buoystat-pirata.html>).

National meteorological and hydrological services (NMHS) usually measure global solar irradiation at a few sites on hourly or daily time steps. Diffuse irradiation is rarely measured and measurements of the direct irradiation at normal incidence (B) are even more seldom. Daily data are sent to the World Radiation Data Center (WRDC: wrdc.mgo.rssi.ru), a laboratory of the Voeikov Main Geophysical Observatory in Saint-Petersburg, Russia, under the control of the World Meteorological Organization (WMO). There, the data are archived and published. Quality of measurement is difficult to assess from the WRDC archives. All data are scrutinized at WRDC and quality-flagged before entering archives. No information on uncertainty other than the flag is provided with the radiation data. Given the available sources, the wishes and the various constraints, the GAW data available at the WRDC was believed to be a very good candidate. Despite the difficulty in deciphering the format, it offers a single web site to access hourly measurements from several stations. There are approximately 20 stations listed for Europe and two in Africa. However, a deeper look reveals that:

- There is no fresh data for many sites,
- Three European sites are located on top of mountains or in areas with complex orography,
- Most European sites have measurements for global radiation only,



- Among the remaining stations having measurements of at least global and diffuse radiation, only a few stations offer fresh data, i.e. less than 6 months old,
- The data are not in a convenient format and must be converted into a more standard one.

This situation is not satisfactory enough and it was decided to approach each NMHS in Europe to get data for more stations and fresher data. The list of recipients was further extended to other NMHS outside Europe and to other institutes.

The approach was made by the means of e-mail. Several NMHS have web sites on which requests must be made. The text of the request was similar to each recipient. Details were adjusted on an *ad hoc* basis. In many cases, a second mail was necessary to get a first answer.

Below is an example of the mail sent to each recipient at the initial stage:

To the attention of Director General, Dr. XXX

Dear Madam

MINES ParisTech is an education and research institution in France. One of the main goals of our Research Center within MINES ParisTech is to assess the solar radiation received at ground level for any place and any time.

The Copernicus Atmosphere Monitoring Service (CAMS) has been developed to meet needs relating to the composition of the atmosphere, aiming at supporting policymakers, business and citizens with enhanced atmospheric environmental information (atmosphere.copernicus.eu/).

It is a European Union programme implemented by ECMWF. Within CAMS, we are in charge of delivering products in solar radiation (atmosphere.copernicus.eu/services/solar-radiation) in conjunction with the German aerospace center DLR, the Finnish Meteorological Institute FMI and the company Transvalor managing the SoDa portal for professionals in solar energy (www.soda-pro.com).

The CAMS project includes a periodic validation of its products and publicly reporting on the results of this validation.

MINES ParisTech is in charge of this validation for total solar radiation and as such, we are seeking for a periodic access to recent data from pyranometers and pyrroheliometers.

I would like to know if your institute may help us in that matter.

Please, would you mind acknowledging the receipt of the request?

Best regards

Lucien Wald

Appendix on data requirements (our wishlist, we may adjust)

Data from pyranometers and pyrroheliometers if possible.

Data should be hourly irradiation or more frequent.

Calibration of instruments must be traceable to WRR.

Instruments must be preferably "second standard".

Access by Internet, FTP protocol or SWE from OGC.



*Access should be established in an automated way. One access to data per month.
Data should be available for download a few weeks after they have been acquired.
Data will be used for the sole purpose of the CAMS validation. They will not be disseminated nor
redistributed to a third party, unless stated otherwise by the owner of data.*



9. APPENDIX B. List of approached meteorological offices and other institutes

National meteorological and hydrological services (NMHS) in Europe

Austria	Belgium	Bulgaria
Croatia	Cyprus	Czech Republic
Denmark	France	Germany
Greece	Hungary	Ireland
Italy	Latvia	Lithuania
Luxemburg	The Netherlands	Poland
Portugal	Romania	Slovakia
Spain	Switzerland	

Several NMHS were not contacted because access to another source (e.g., BSRN) was available. Estonia, France or United Kingdom are such countries.

National meteorological and hydrological services (NMHS) outside Europe

Mozambique	Qatar
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Several NMHS were not contacted because access to another source (e.g., BSRN) was available. Algeria is such a country.

Many NMHS in Africa, Middle-East or Arabian Peninsula were not contacted because the authors know that these NMHS do not measure solar radiation by experience and by the available documentation on each station in the WMO network.

An exception may be the Egyptian Meteorological Authority (EMA) in Egypt which devotes great care to several stations measuring the global irradiation and its diffuse and direct components on hourly basis (Aswan, Cairo, El Farafra). The master pyrreheliometer has been calibrated recently at Davos. Contact could be easily taken if necessary.

Other institutes and networks

The IDMP (International Daylight Monitoring Programme) is a network comprising approximately 15 sites in Europe. There is no central archiving; contact should be established individually. Connections to two IDMP stations (ENTPE in Vaulx-en-Velin, France, and University of Geneva, Switzerland) have been established in the framework of the ConnectinGEO, another H2020-funded project. Data were fetched and were stored in a database at Armines. They can be accessed on the web using the sensor web enablement standard (<http://insitu.webservice-energy.org>).

