A climate data record of "sunshine": SARAH

28 October 2020

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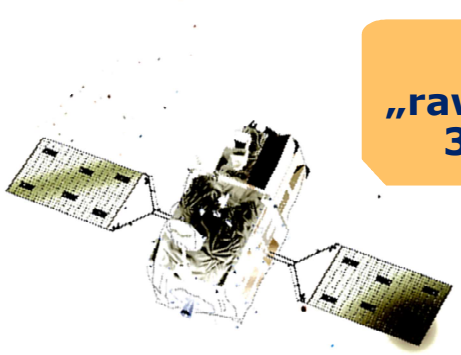
DWD / CM SAF

… may we introduce to you: SARAH and CLARA

Surface Radiation Climate Data Records from CM SAF

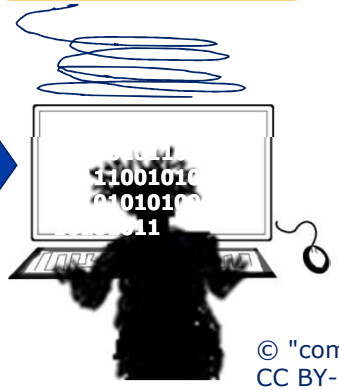
- **SARAH**
  - ➔Born on 1 Jan 1983
  - ➔Multi-national
  - ➔Very sunny attitude, counts every sunny hour
- **CLARA**
  - ➔Born on 1 Jan 1982
  - ➔Truly global
  - ➔Grounded on her feet, sunny mind, enjoying clouds

Climate Data Satellite Retrieval System



Big Data I:
„raw" satellite data,
30 yrs or more

Smart people / algorithms + computing power



© "computor" by Nick See:
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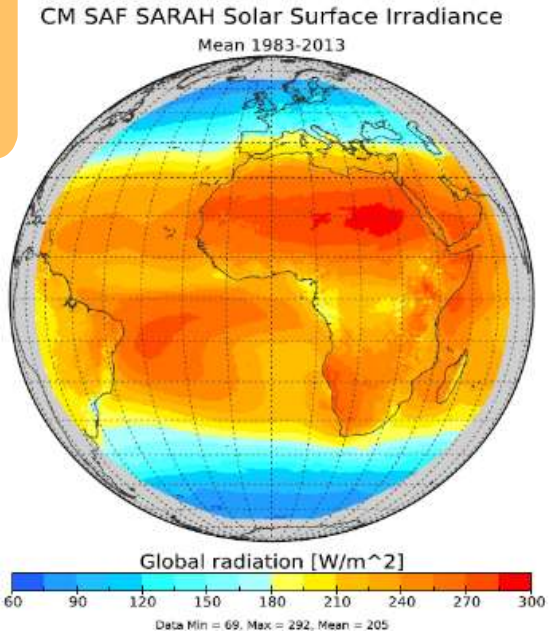
Big Data II:
ready-to-use data record, geophysical parameter



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Surface Irradiance

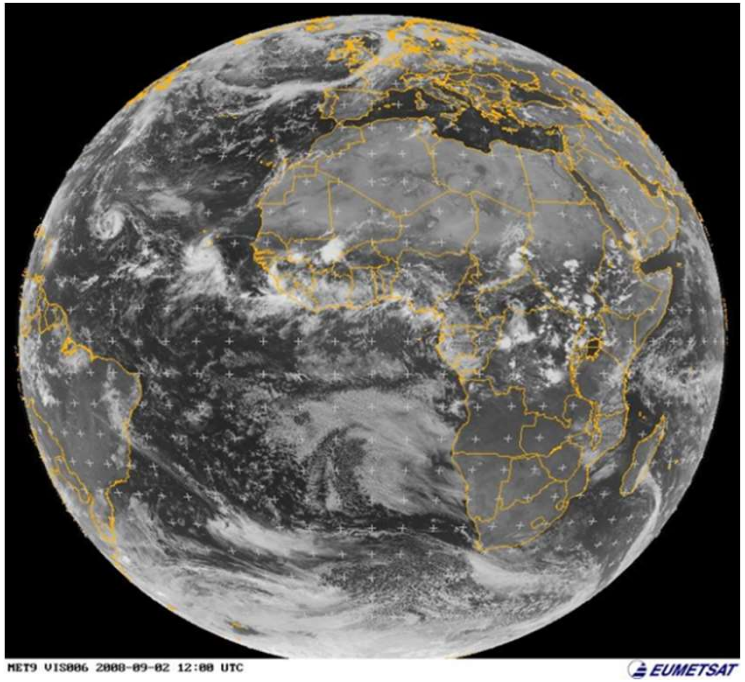
- Surface Solar Radiation / Surface Irradiance is determined by….

    1. Astronomy (solar zenith angle)
    2. Cloud coverage / optical depth
    3. Vertically integrated water vapor
    4. Surface albedo
    5. Aerosol content and their optical properties

- Most factors are well known (e.g., solar zenith angle), can be es estimated well from satellite measurements (cloud coverage during daytime) or reanalysis / other sources (water vapor, albedo, aerosol).

Surface Irradiance from satellite (1 / 3)

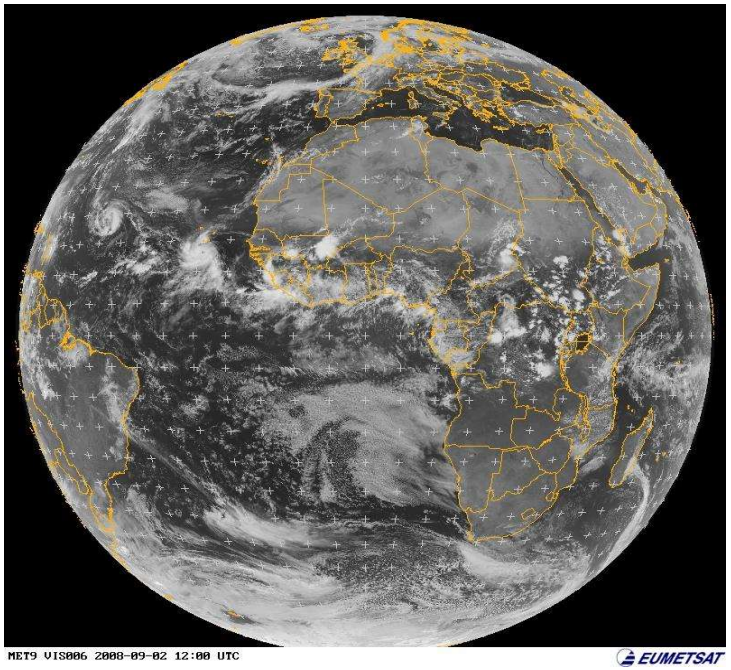
- Spatial and temporal information of ***surface solar radiation*** can accurately be derived from satellite observations, because…
  - ✓ … satellites can well detect **clouds** (= bright regions) during daytime
  - ✓ … **clear-sky solar radiative transfer** is well simulated assuming auxiliary data (e.g., water vapor, aerosol) is available



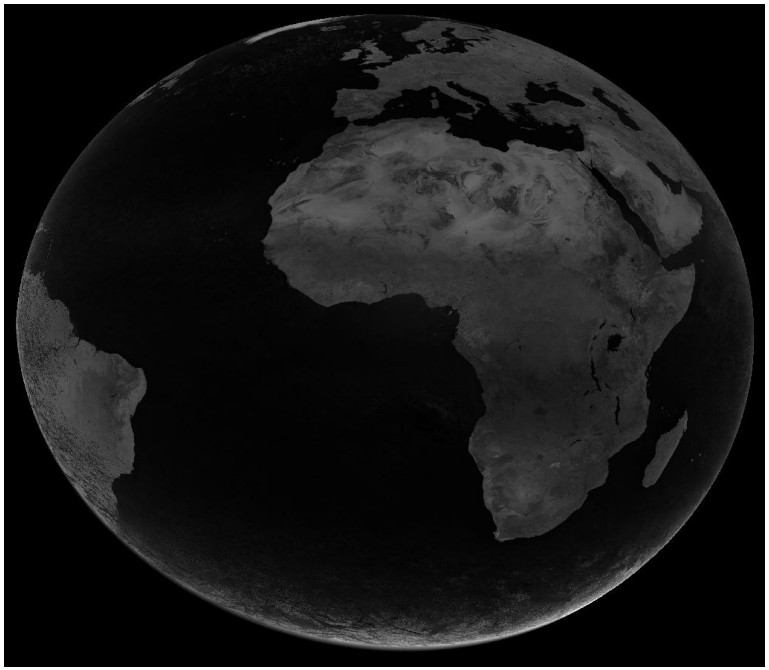
Surface Irradiance from satellite (2 / 3)

The „Heliosat“ algorithm

Reflectivity, 12 UTC, 2 Sept 2008



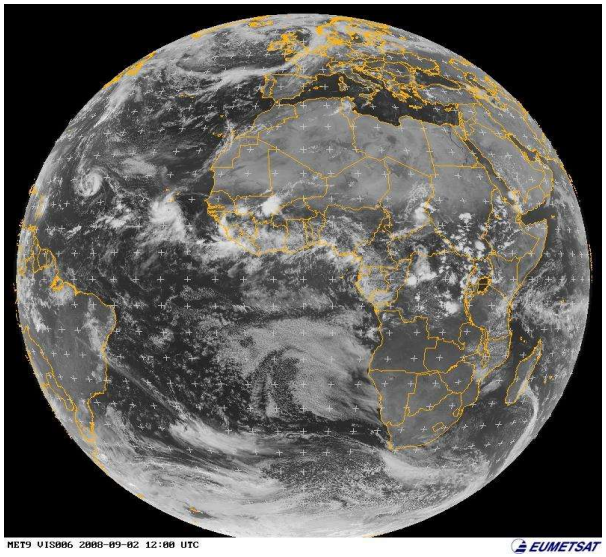
Min. Reflectivity, R_{min}, 12 UTC, Sept 2008



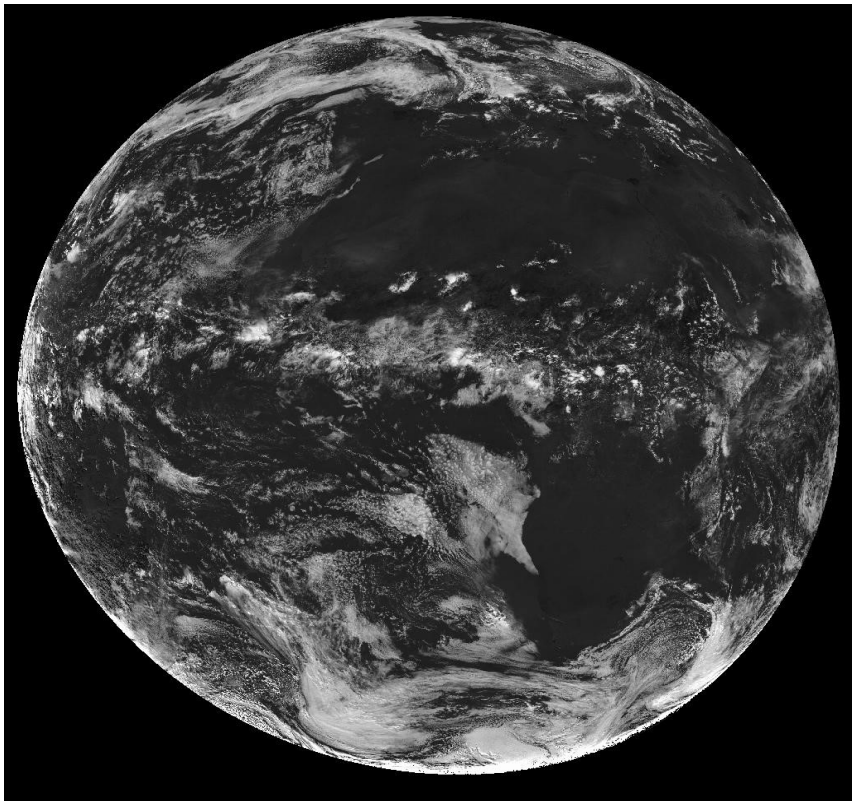
Surface Irradiance from satellite (3 / 3)

The Cloud Index n:

$$n = \frac{R - R_{min}}{R_{max} - R_{min}}$$



Cloud Index, 11 UTC, 1 July 2005



Surface Irradiance from satellite (3 / 3)

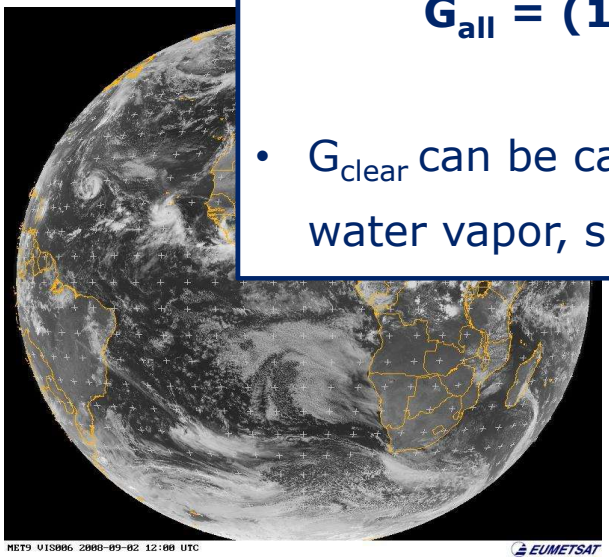
The Cloud Index n:

$$n = \frac{R - R_{min}}{R_{max}}$$

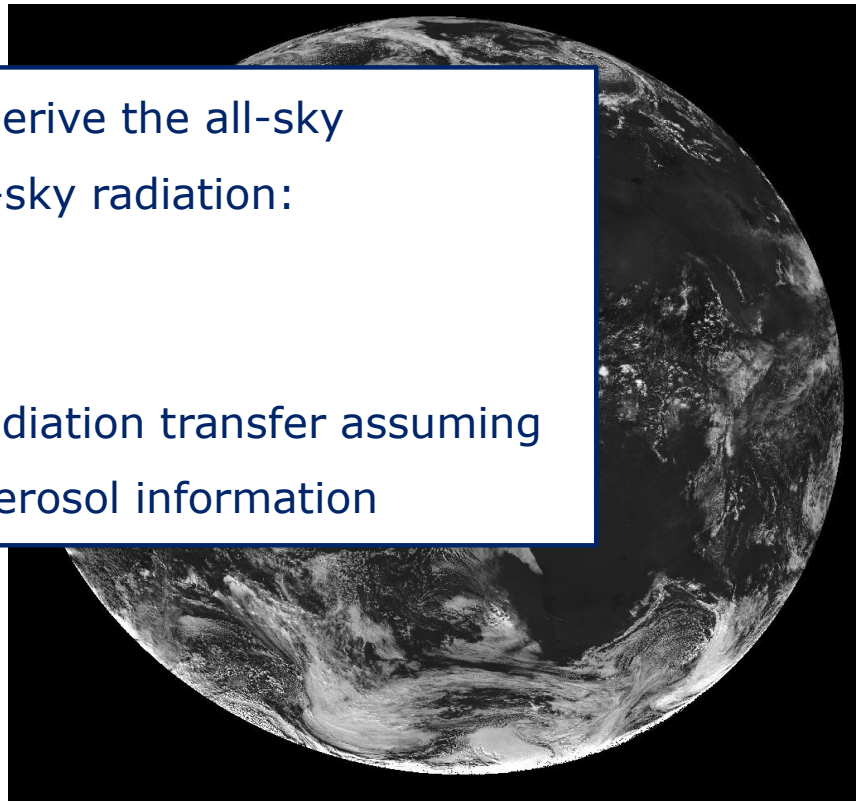
- The cloud index, n, allows to derive the all-sky irradiance, G_{all}, from the clear-sky radiation:

  $$\mathbf{G_{all} = (1 - n)\, G_{clear}}$$

- G_{clear} can be calculated from radiation transfer assuming water vapor, surface albedo, aerosol information

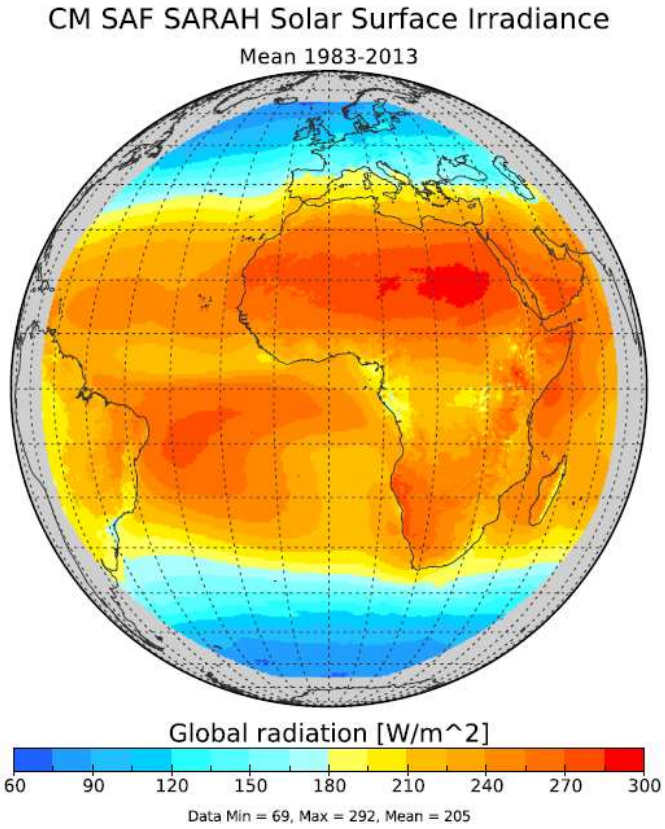


Cloud Index, 11 UTC, 1 July 2005



Surface Solar Radiation Data Set - Heliosat (SARAH-2.1)

- **Variables**
  - Global radiation / irradiance (SIS)
  - Sunshine duration (SDU)
  - Surface direct irradiance (SID, DNI)
  - Spectral resolved irradiance (SRI)
  - Effective cloud albedo (CAL)
- **Resolution**
  - Spatial: 0.05° × 0.05°
  - Temporal: 30 min, daily-, monthly means
- **Coverage**
  - Spatial: Meteosat disc
    (circle with center at 0°N / 0°E and radius 65°)
  - Temporal: 1983 to 2017



DOI:10.5676/EUM_SAF_CM/SARAH/V002_01

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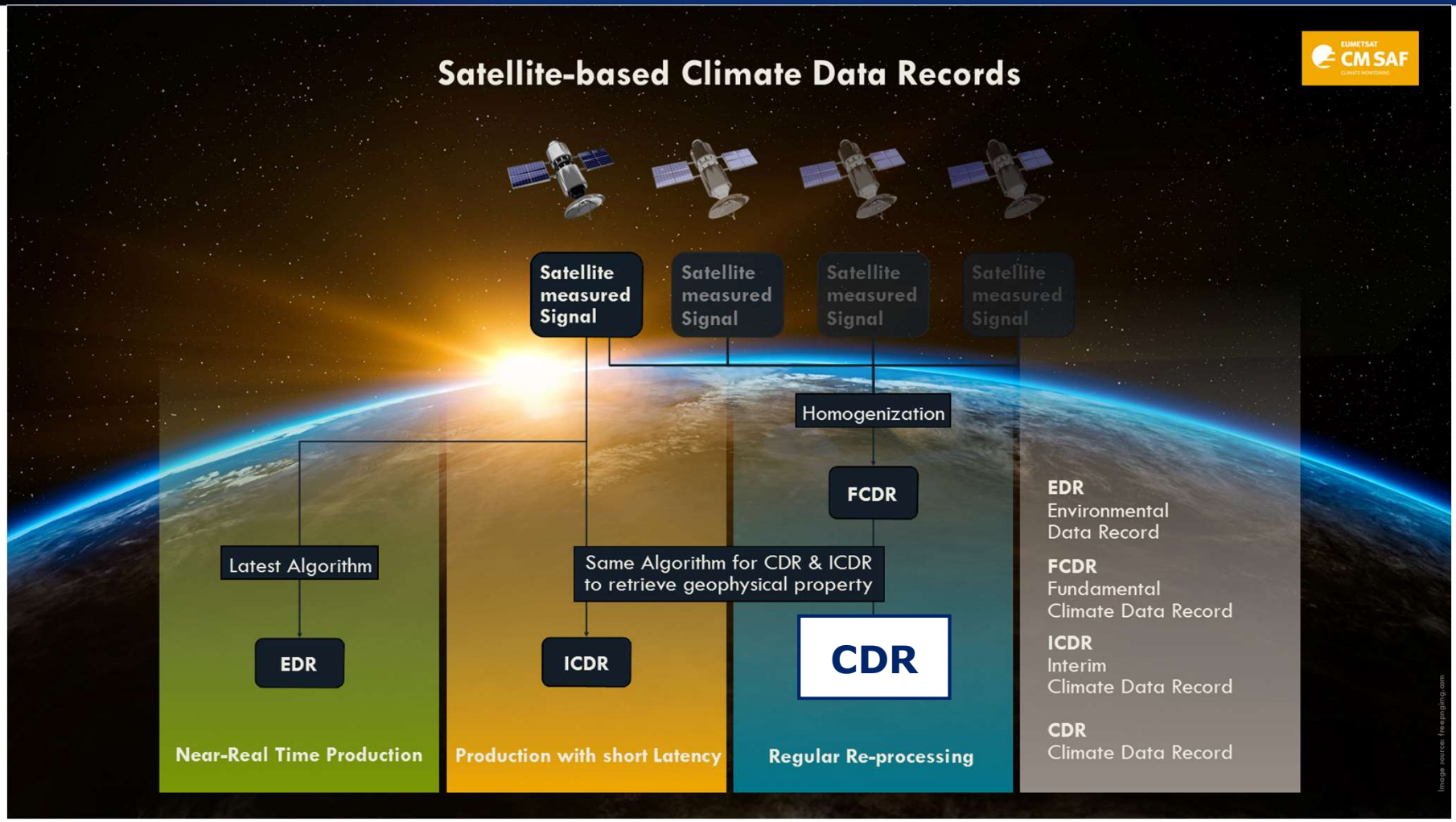
Thematic vs Interim Climate Data Record



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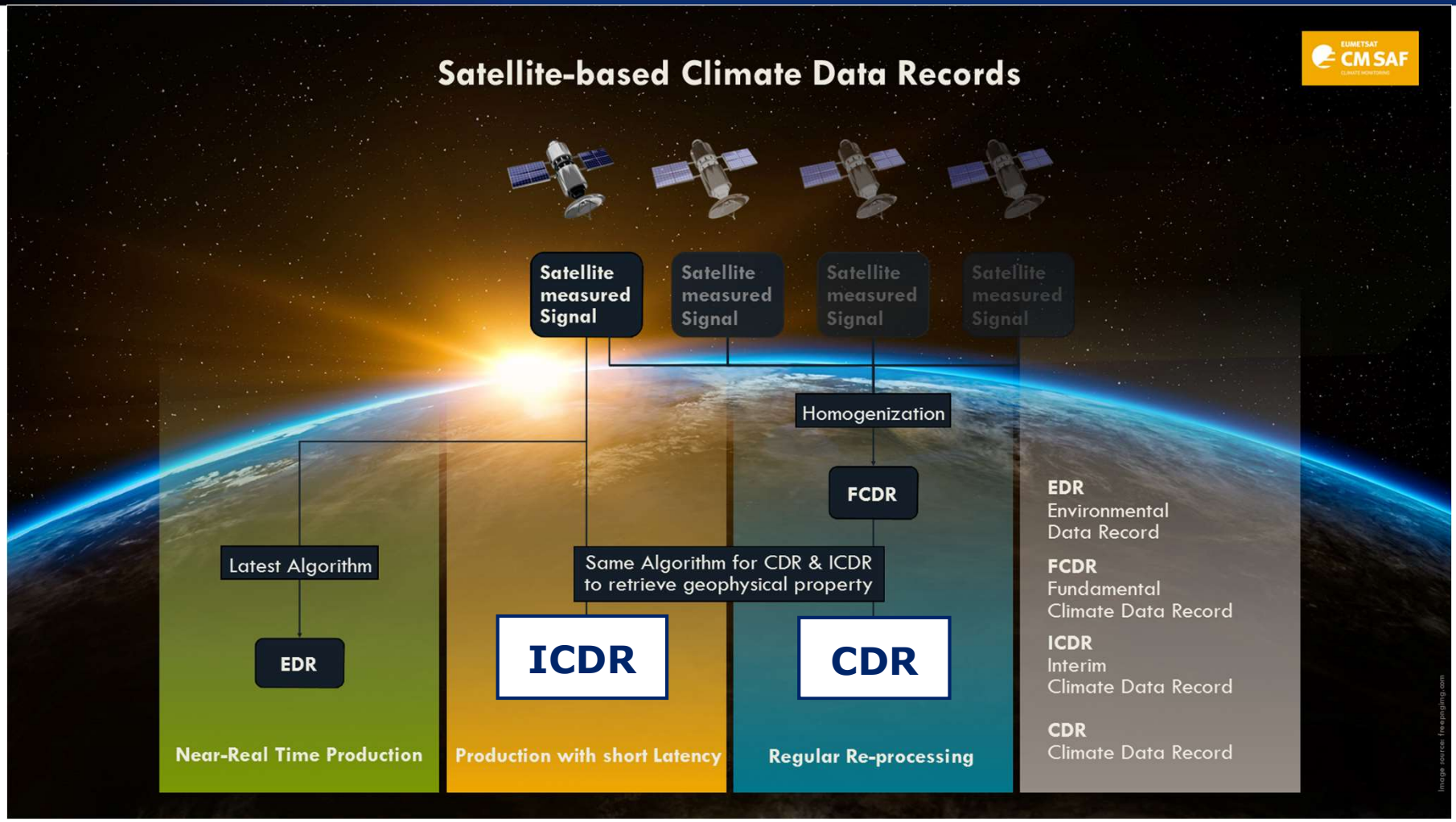

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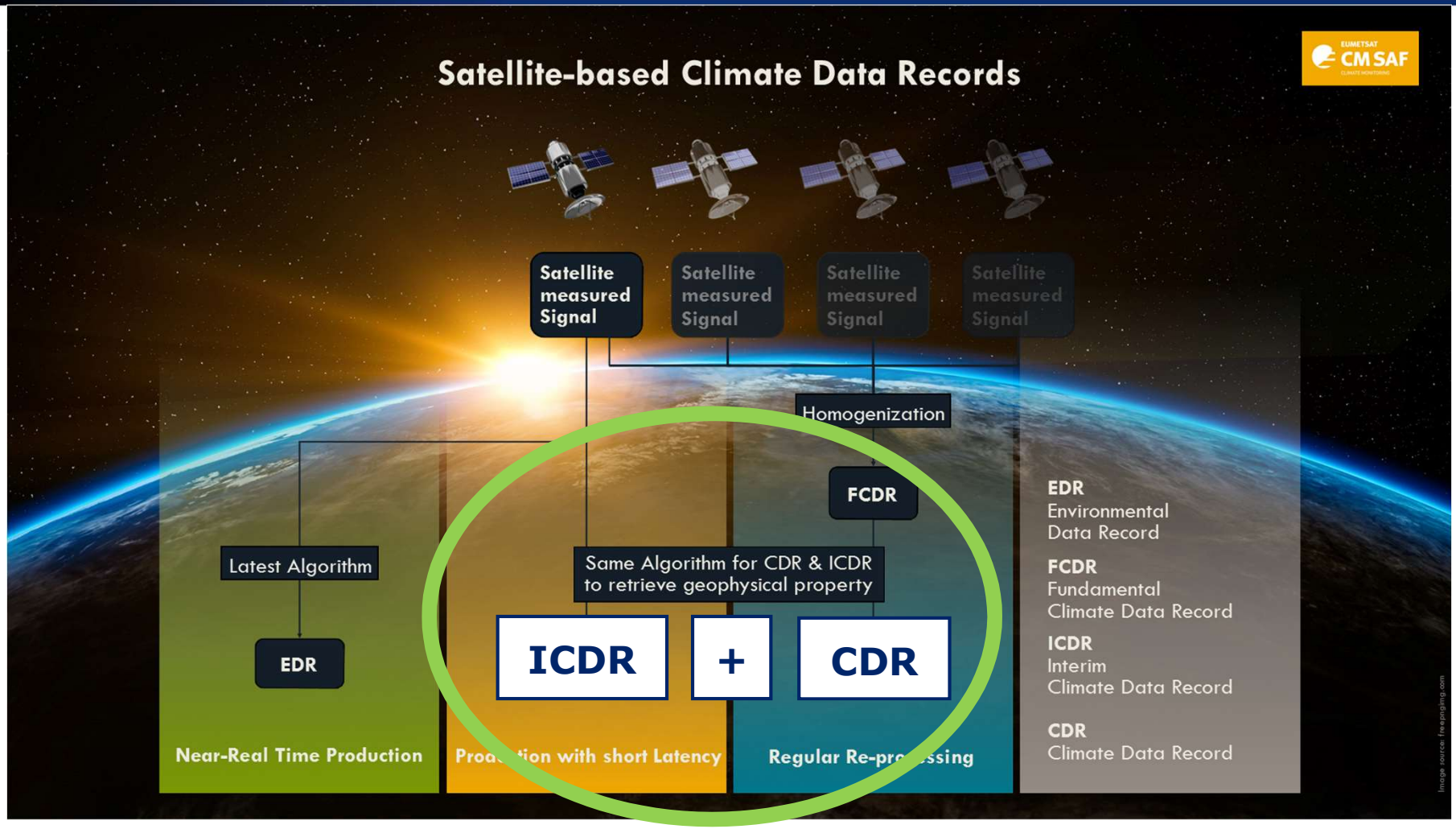

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SARAH-2.1 + SARAH ICDR

- **Variables**
  - **Global radiation / irradiance (SIS)**
  - **Sunshine duration (SDU)**
  - **Surface direct irradiance (SID, DNI)**
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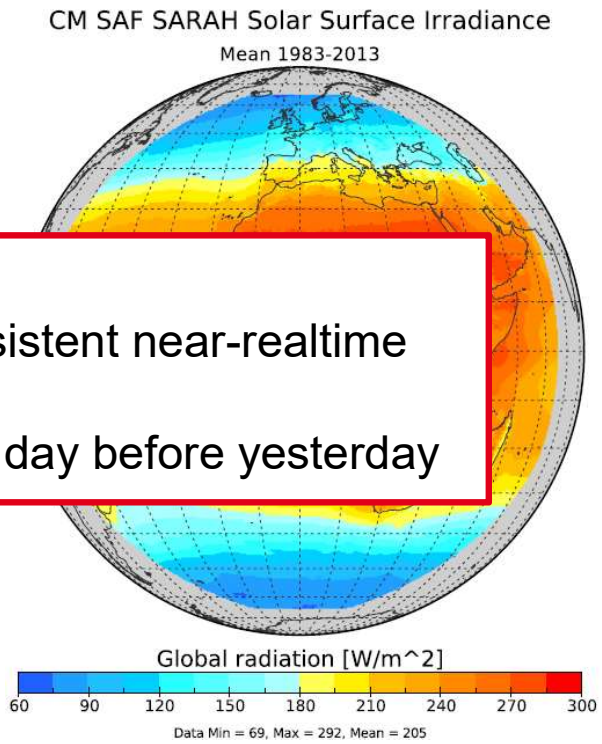
  - Temporal: 1983 to 2017

SARAH ICDR
Available as consistent near-realtime data:
1 Jan 2018 – the day before yesterday



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What can you do with these data…..

SARAH data are used for…..

- ➔ Climate analysis / monitoring
- ➔ (Climate) Model evaluation
- ➔ Solar energy assessment
- ➔ Agrometeorology
- ➔ ….

What would you like to do with SARAH data?

How can SARAH help you ?

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- ➔ Agrometeorology
- ➔ ….

What would you like to do with SARAH data?

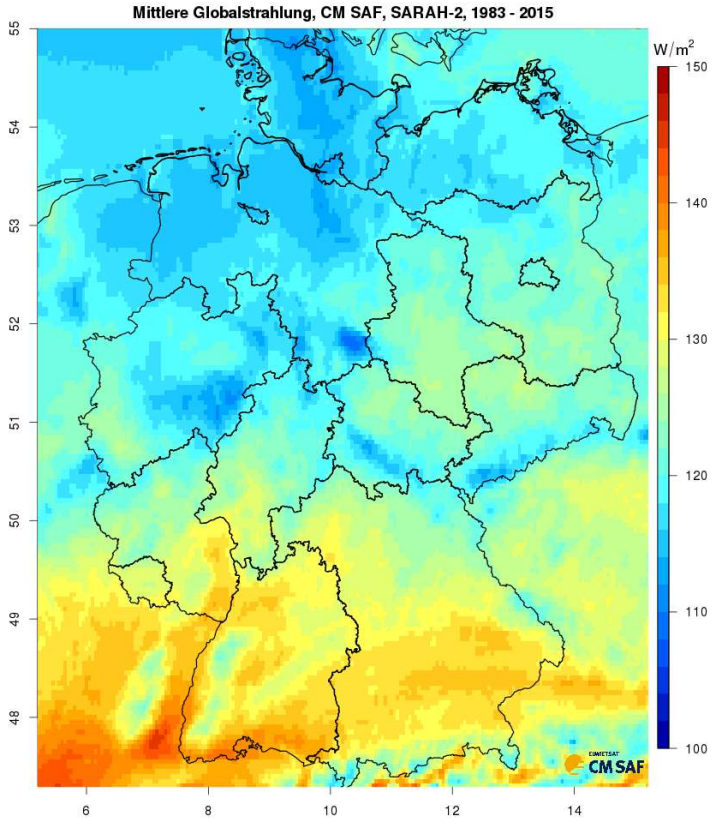
How can SARAH help you ?

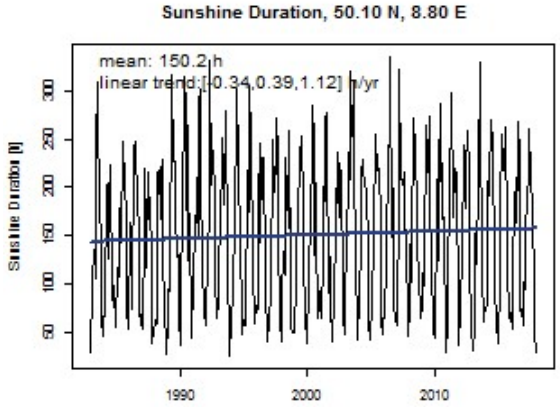
.. but are these data good enough?

- ➔ Data evaluation is really important before using any data
- ➔ What exactly is ‘good enough’ in your specific case?
- ➔ Have a look at the data!
- ➔ Use available information and / or make your own assessment.

1.) A first look at the data….

SIS Climatology, Germany

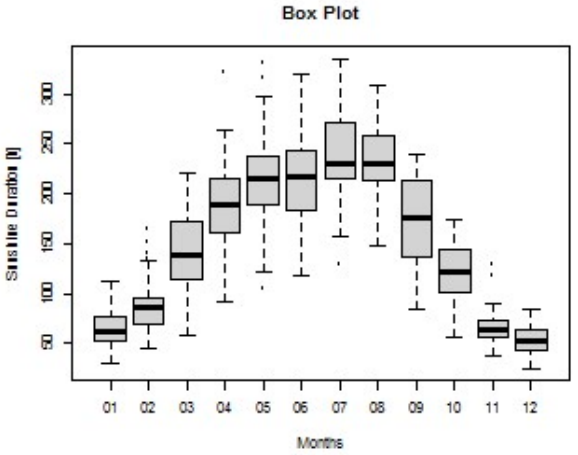


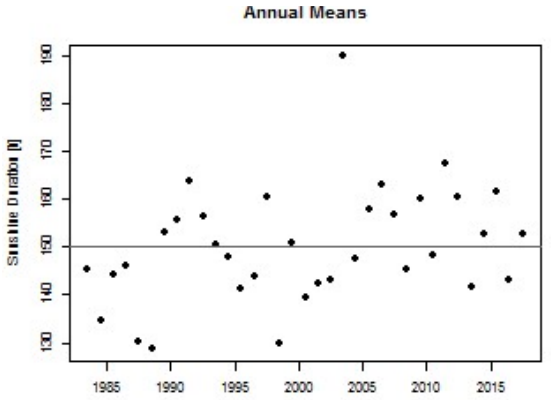


My conclusion:

The data looks realistic

SDU Time Series, Offenbach





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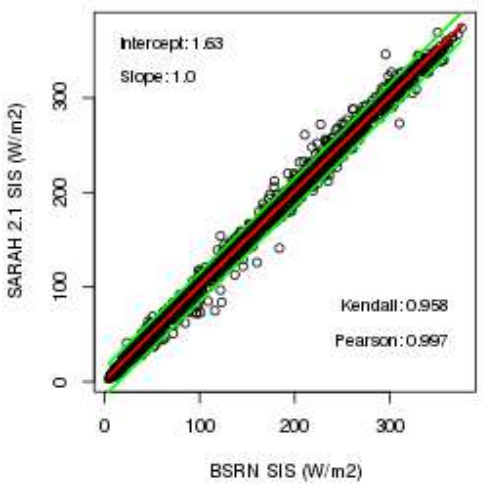
2.) Check out CM SAF documentation

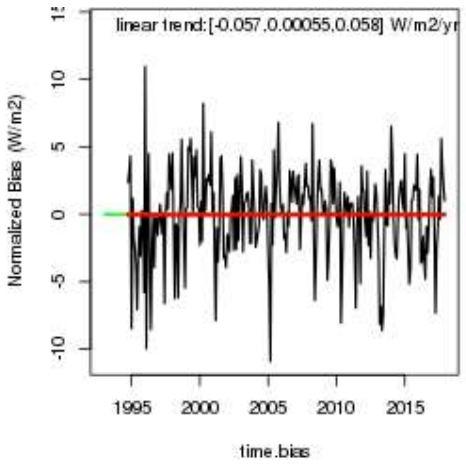
Comparison with reference data (CM SAF Validation Report)

SIS (SARAH) vs SIS(BSRN), monthly, all stations

Correlation



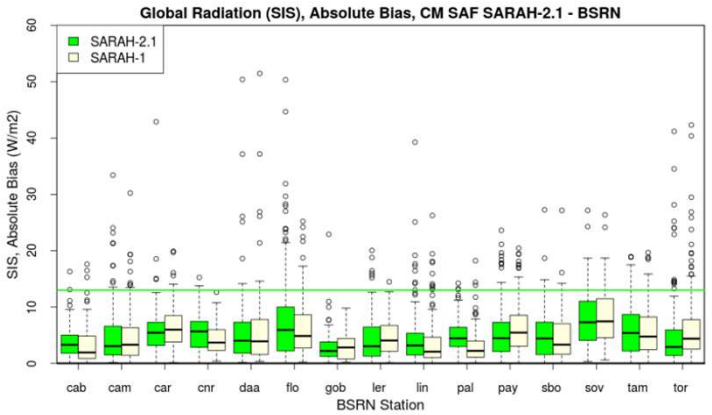
Time Series of the bias



Accuracy: 5 W/m^2 (mm) / 12 W/m^2 (dm)

Stability: ~ 1 W/m^2/dec

Abs. difference for many stations



Our conclusion:

The data is accurate and has a high stability at 15 BSRN stations

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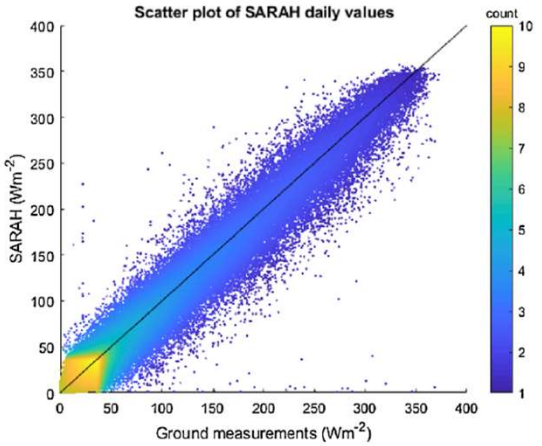
3.) Check out peer-reviewed literature

Comparison with reference data (e.g., peer-reviewed literature)

➔ Many published studies about comparing the SARAH data record with surface reference data are available (see the reference list)

Norway



SARAH	RMSD (Wm^{-2})	MAD (Wm^{-2})	MBD (Wm^{-2})
Clear-sky	20.4	12.8	-5.5
Intermediate-cloudiness	20.1	13.4	-2.9
Overcast	13.2	8.7	4.5

Babar et al., 2019

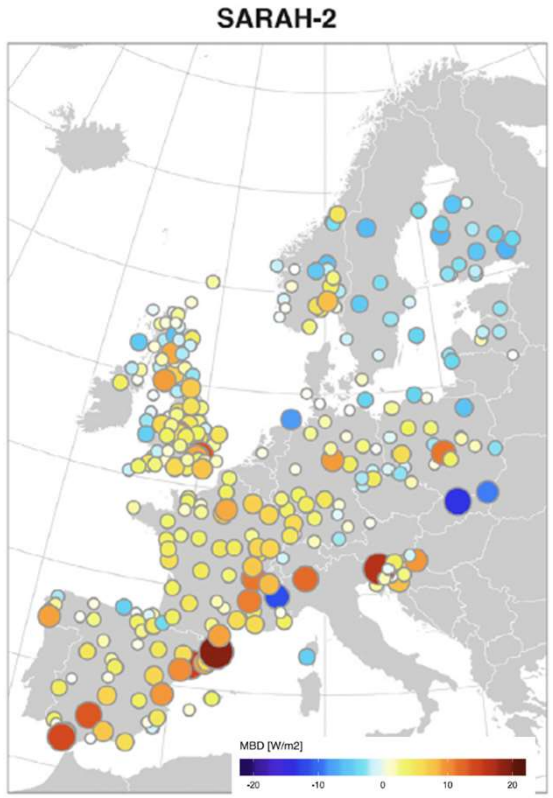
Poland

TABLE 2 Results of the statistical verification of SIS data (SARAH-2) over the period 1986–2015, in relation to the average monthly global solar irradiance

Station	ME ($W \cdot m^{-2}$)	MAE ($W \cdot m^{-2}$)	λ
Belsk	0.90	5.62	0.59
Bielsko-Biała	2.16	9.15	0.66
Gdynia	−0.88	4.57	0.59
Jelenia Góra	−1.23	6.11	0.64
Kasprowy Wierch	−14.65	18.70	**1.92**
Kłodzko	5.59	9.36	0.94
Koło	2.97	7.45	0.76
Kołobrzeg	−0.72	4.62	0.60
Legnica	1.42	5.53	0.60
Lesko	0.36	7.44	0.59
Mikołajki	−3.38	6.89	0.65
Piła	1.09	4.85	0.65
Radzyń ląd	5.77	7.25	0.91
Sulejów	1.41	5.78	0.59
Toruń	3.08	7.56	0.70
Warszawa	2.43	5.35	0.63
Zakopane	−2.02	9.50	0.65
Total	0.26	7.39	0.59

Kulesza, 2020

Europe



Urraca et al., 2020

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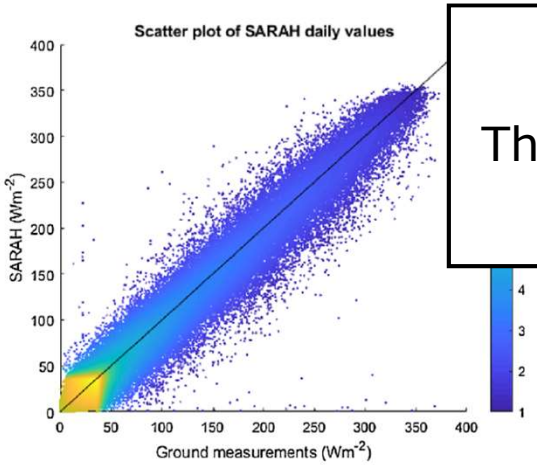

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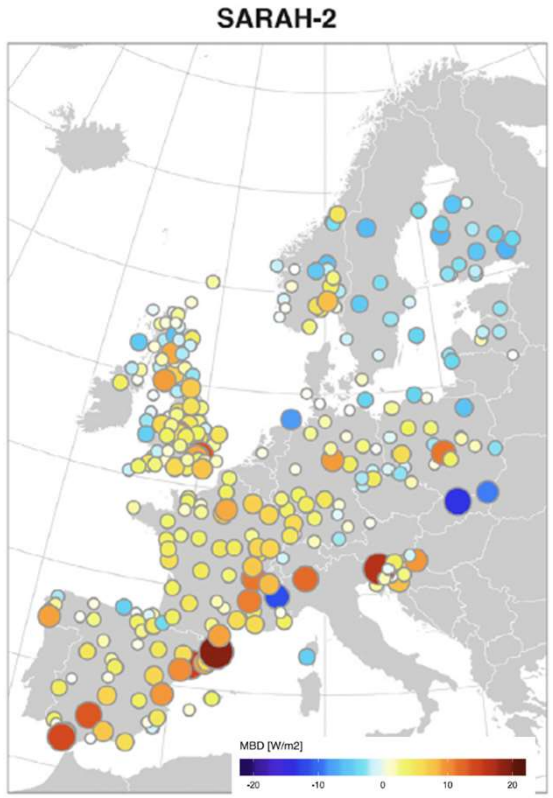
Kulesza, 2020

Main conclusion:

The SARAH data is of high quality and suitable for many applications.

Europe



Urraca et al., 2020

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4.) Assess the data by yourself

Comparison of the SARAH data record with your own reference data

- Use high quality surface reference measurements
- Ensure the reference data is representative for the local area (Remember: SARAH data represents an area of 5 km x 5 km)
- Make sure the units of the data match: SARAH provides averages for solar radiation and sums for sunshine duration
- Be open for surprises in the reference data

Your conclusion:

???

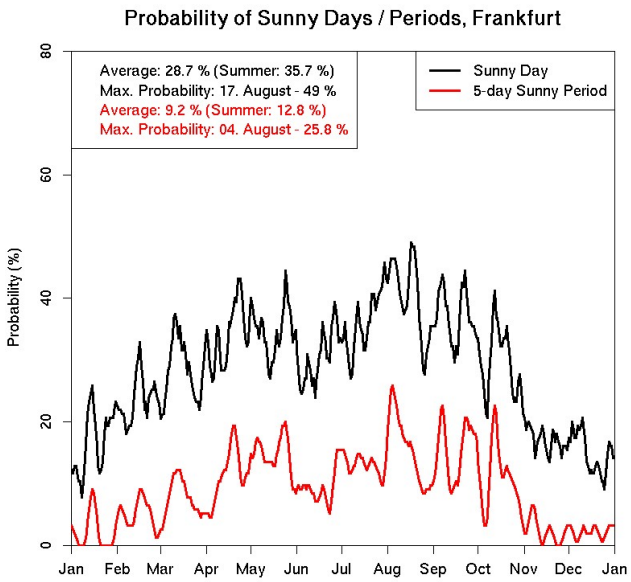
Application areas of the SARAH data record

- Climate analysis, Trend Analysis
- Solar energy assessment / Solar Atlas
- Quality control of surface measurements
- Climate Monitoring
- Evaluation of (climate) model simulations
- Agrometeorology
- …….

  - See www.cmsaf.eu → Outreach → Applications

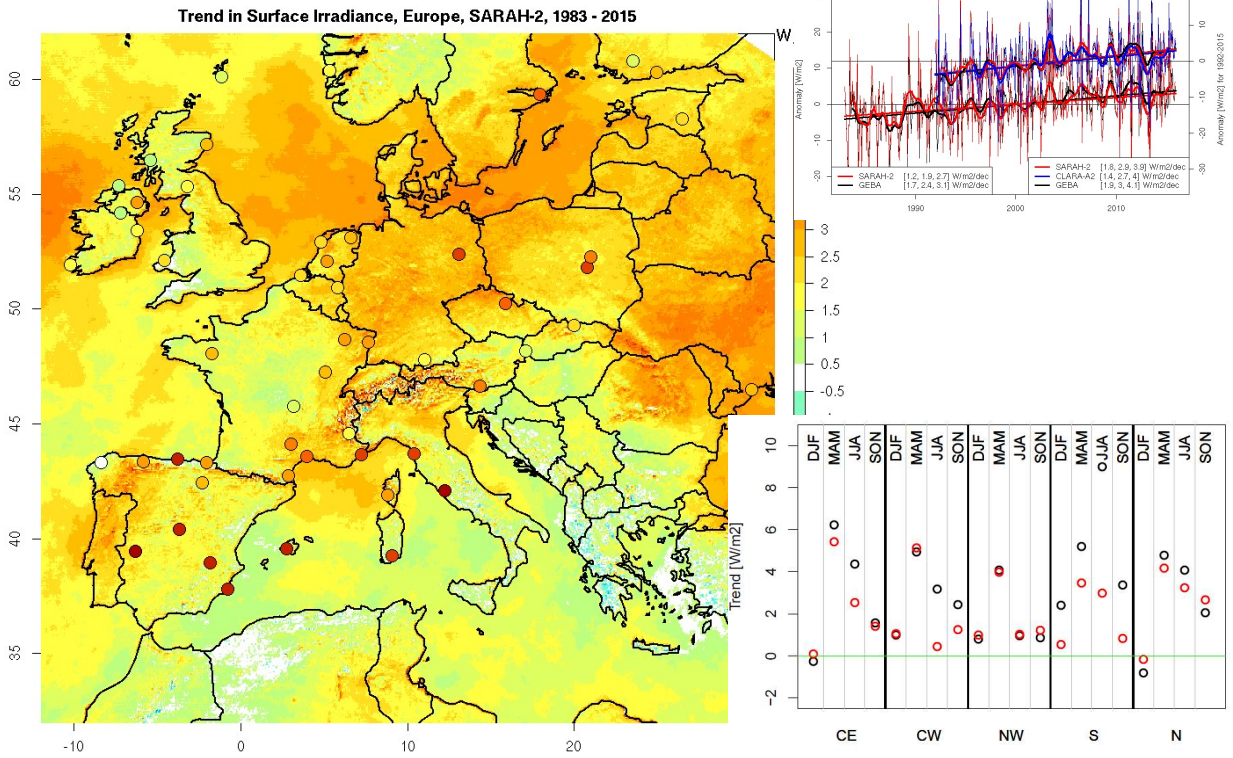
Climate Analysis, Trend Analysis

„Sunny Days“, Frankfurt



https://www.cmsaf.eu/SunnyDays

Decadal Trend SARAH-2



Pfeifroth et al., 2018

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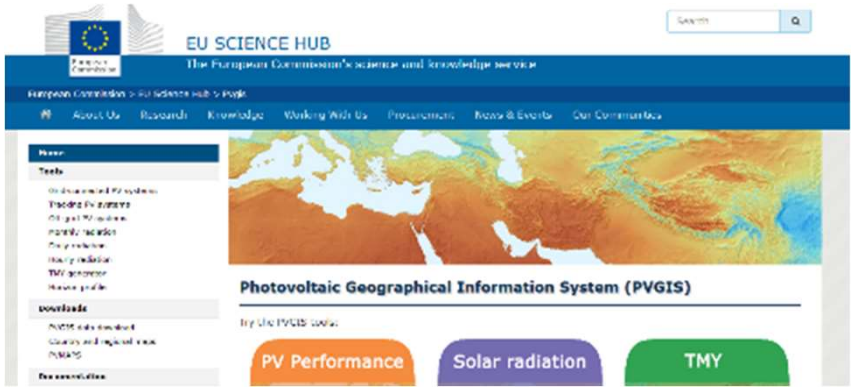
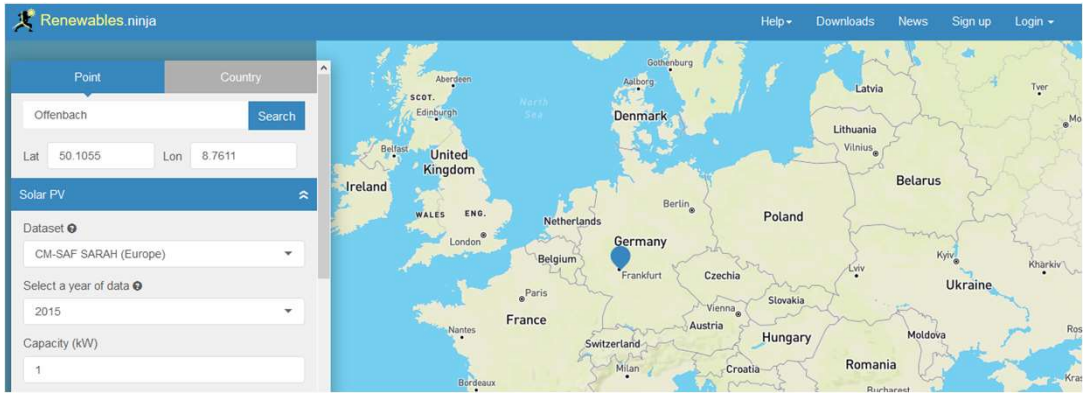
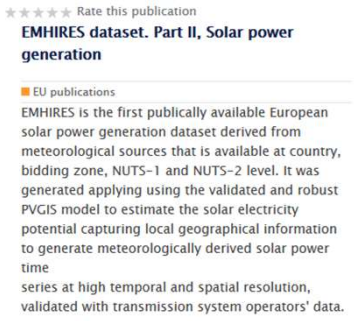
Solar Energy Modeling

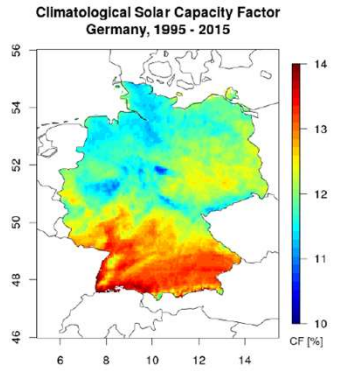


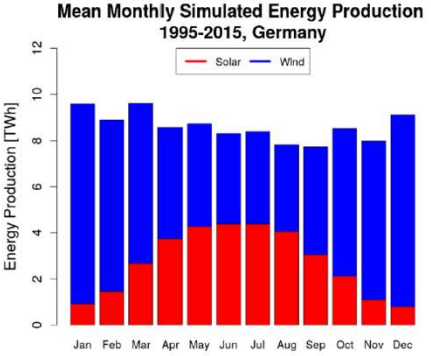


https://www.renewables.ninja/



https://ec.europa.eu/jrc/en/pvgis





Drücke et al., 2020

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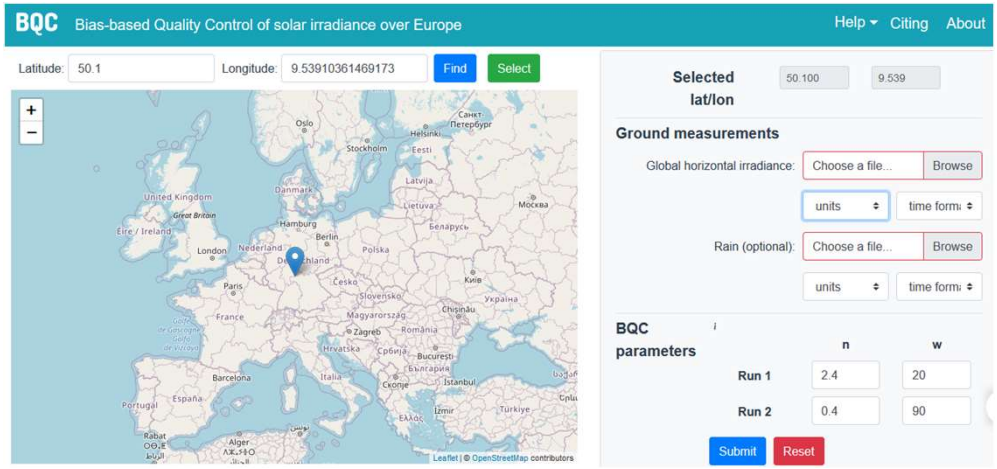
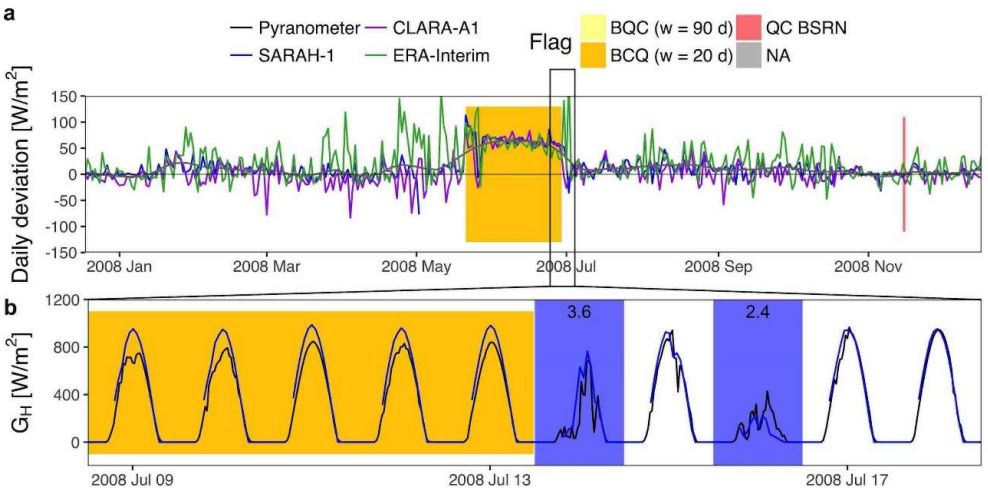
Quality control of surface measurements





http://www.bqcmethod.com/

Urraca et al., 2017, 2020

➔ Using satellite (SARAH, CLARA) and reanalysis data to detect problems in surface measurements, e.g., soiling

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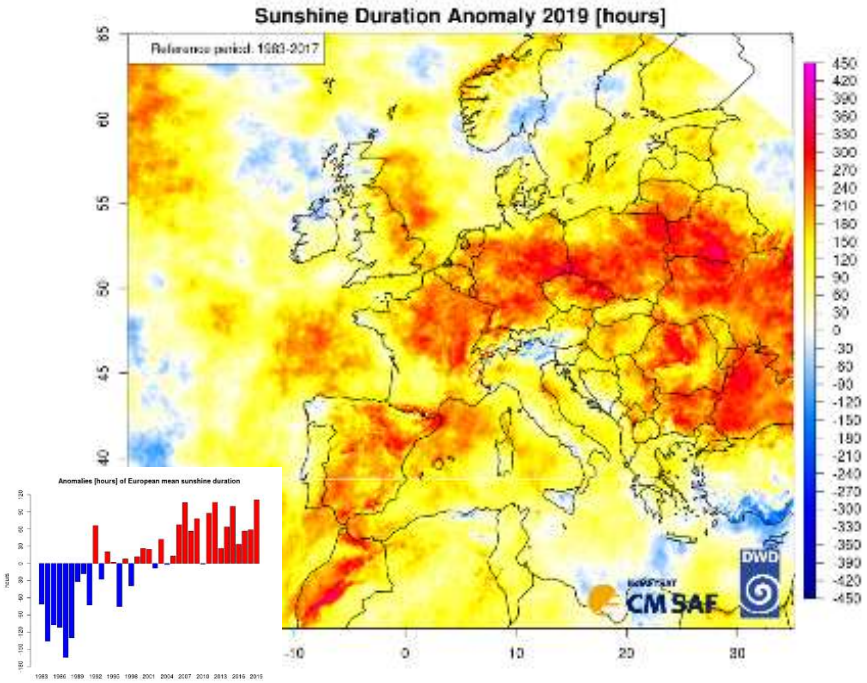
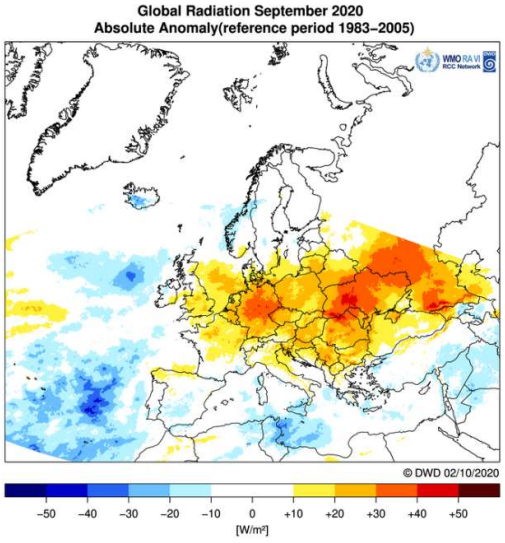
Climate Monitoring

Sunshine Duration in 2019

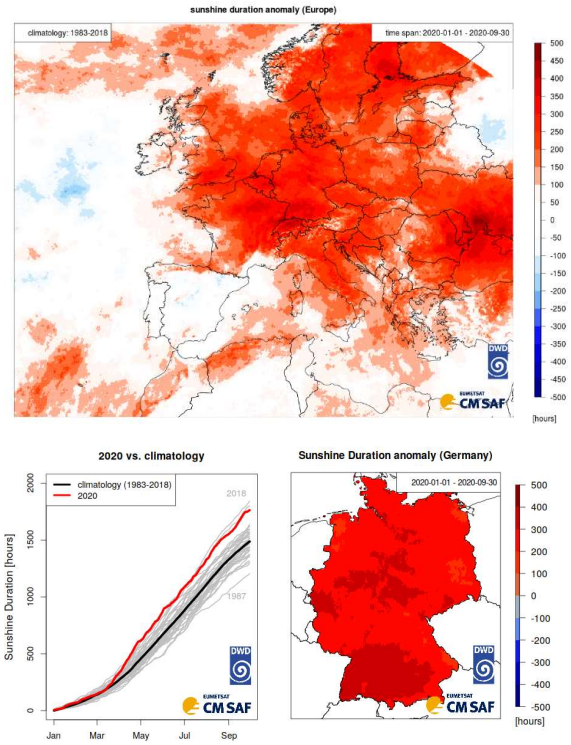


Blunden and Arndt, 2020, BAMS State of the Climate 2019

Sunshine Duration in 2020 (so far)



https://www.dwd.de/EN/ourservices/rcccm/int/rcccm_int_sun.html



Prepared with the CM SAF R Toolbox!

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Getting started / Known limitations

Getting started

- Make sure to minimize the size of your order / download, e.g., by specifying a certain region
- Start with monthly averages for an overview
- Read the documentation / references, in particular on the data evaluation
- Make sure to use the proper unit
- Use the CM SAF R-Toolbox, in particular in case you are not familiar with netcdf-files

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Known limitations

- SARAH data tends to overestimate surface irradiance / sunshine duration in West Africa
- Trends in surface irradiance due to aerosol changes are not fully described in SARAH; trends estimated using SARAH are dominated by changes in cloudiness
- SARAH-2 underestimates surface radiation over snow-covered surfaces

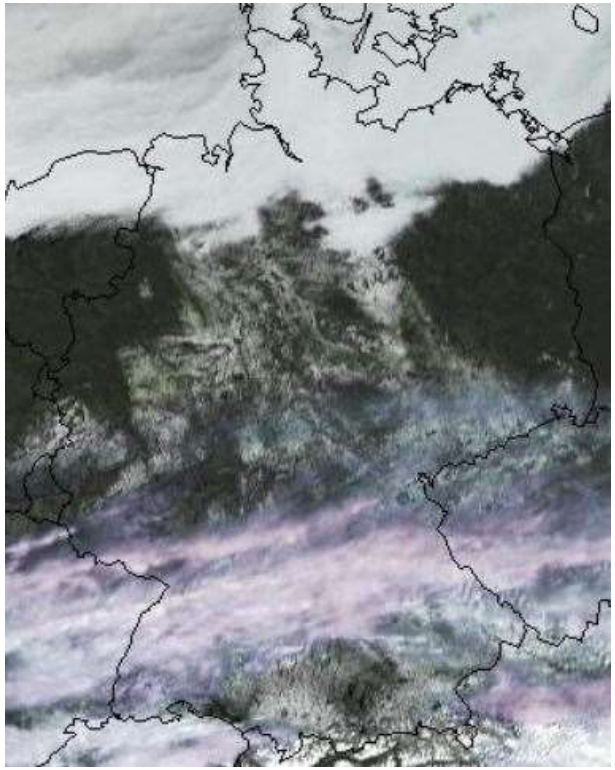
Changes in SARAH-3 (available in 2021)

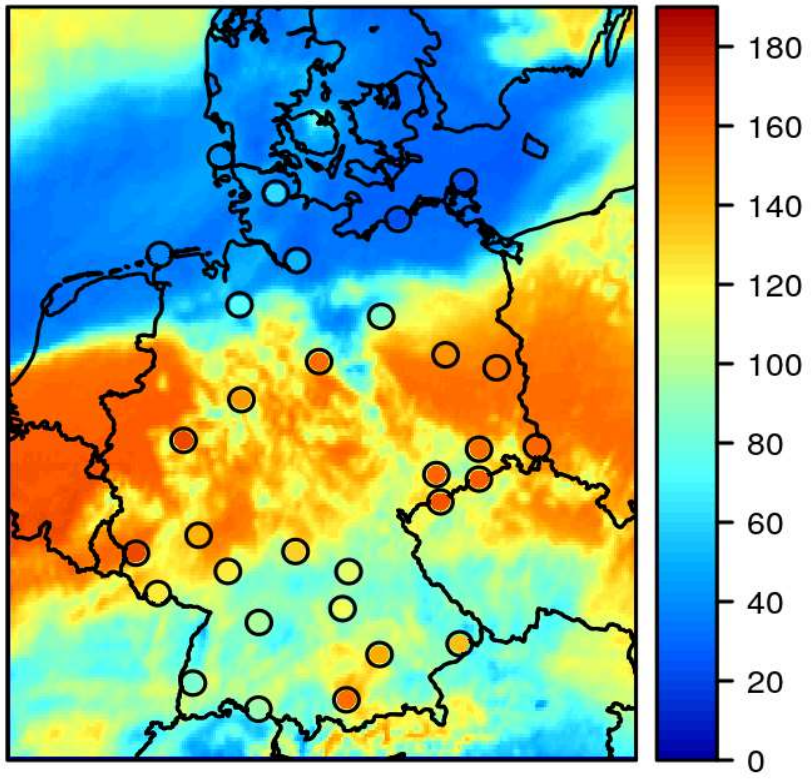
- ✓ Covering 1983 to 2020 (i.e., including new WMO climate reference period)
- ✓ New spectral parameters:
  - ✓ Photosynthetic active radiation: PAR
  - ✓ Daylight: DAL
- ✓ Improved retrieval over snow-covered surfaces

Example, Snow Coverage 10 March 2010 (1/2)

Surface Radiation (SARAH-2)

10 March 2010





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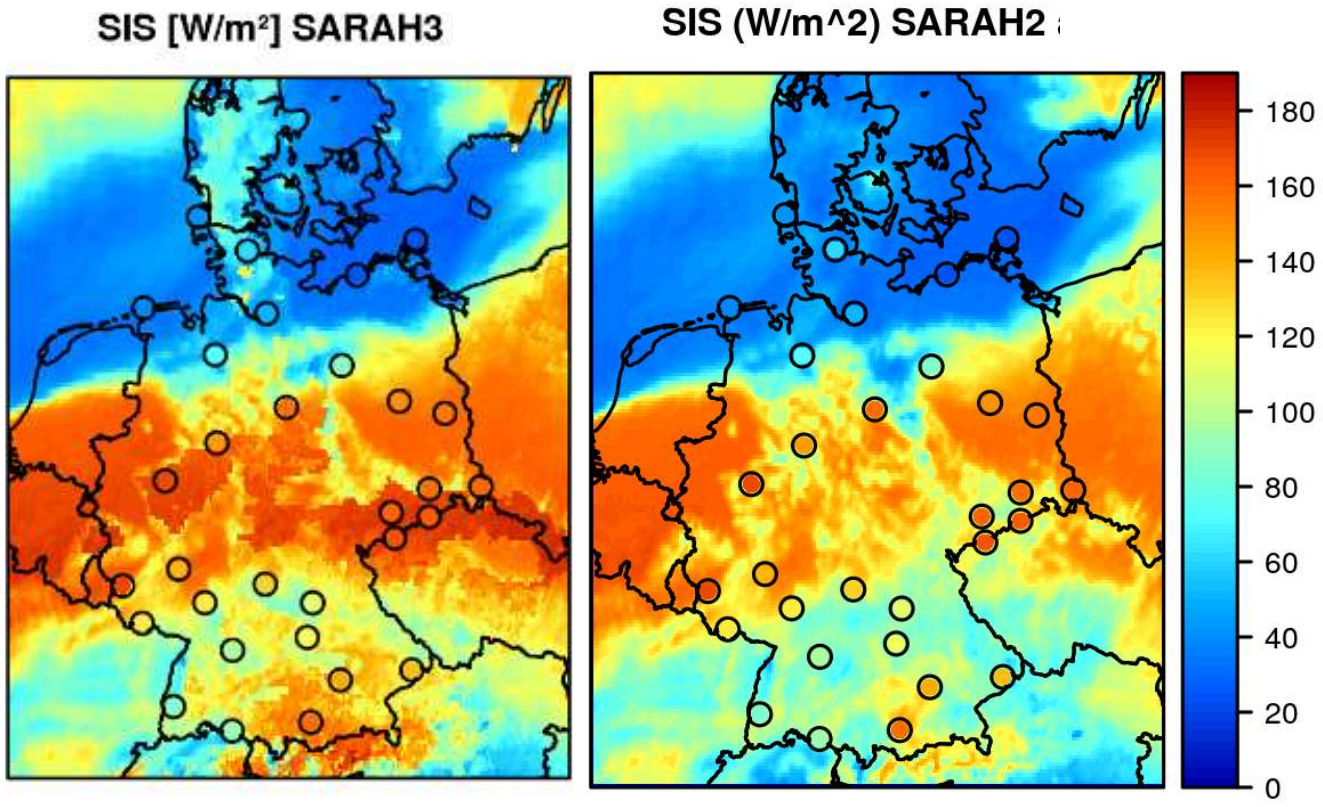
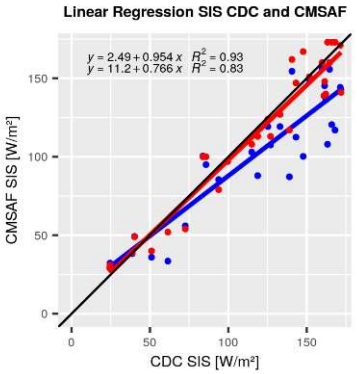
Example, Snow Coverage 10 March 2010 (2/2)

Surface Radiation (SARAH-3, beta06.1)





10 March 2010

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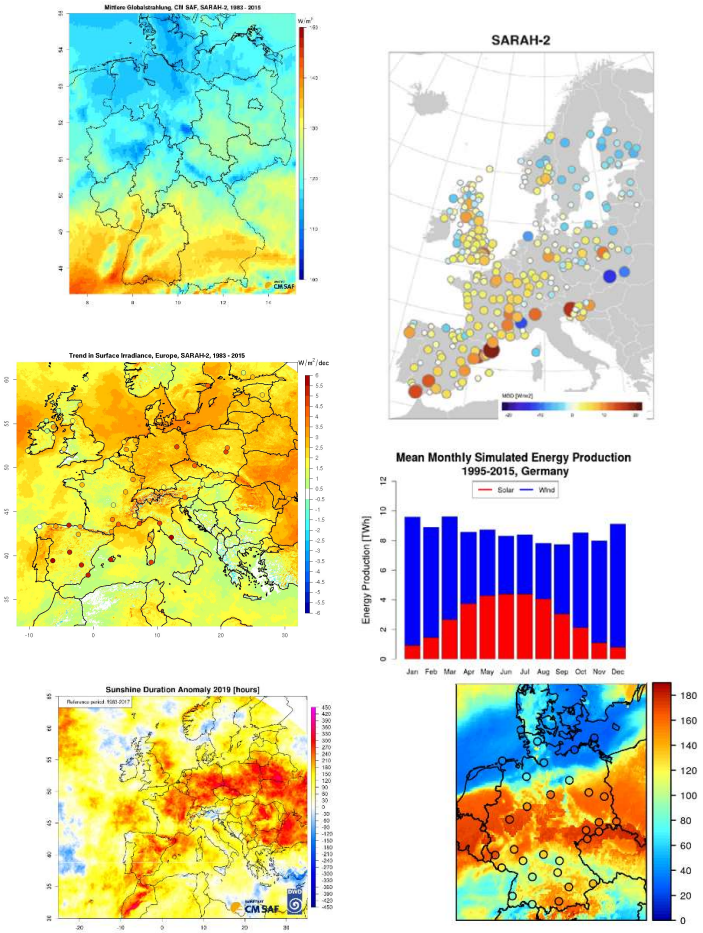
Summary

- The SARAH climate data records (CDR + ICDR) provides surface solar radiation data with high accuracy and stability for Europe and Africa
- Numerous examples document the suitability of the SARAH data for a variety of applications.
- Combined use of CDR and ICDR allows local / regional climate monitoring
- The upcoming SARAH-3 data record will have an improved data quality over snow-covered surfaces
- CM SAF R-Toolbox provides an easy start for data exploration
- CM SAF SARAH data are freely available via **www.cmsaf.eu**



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