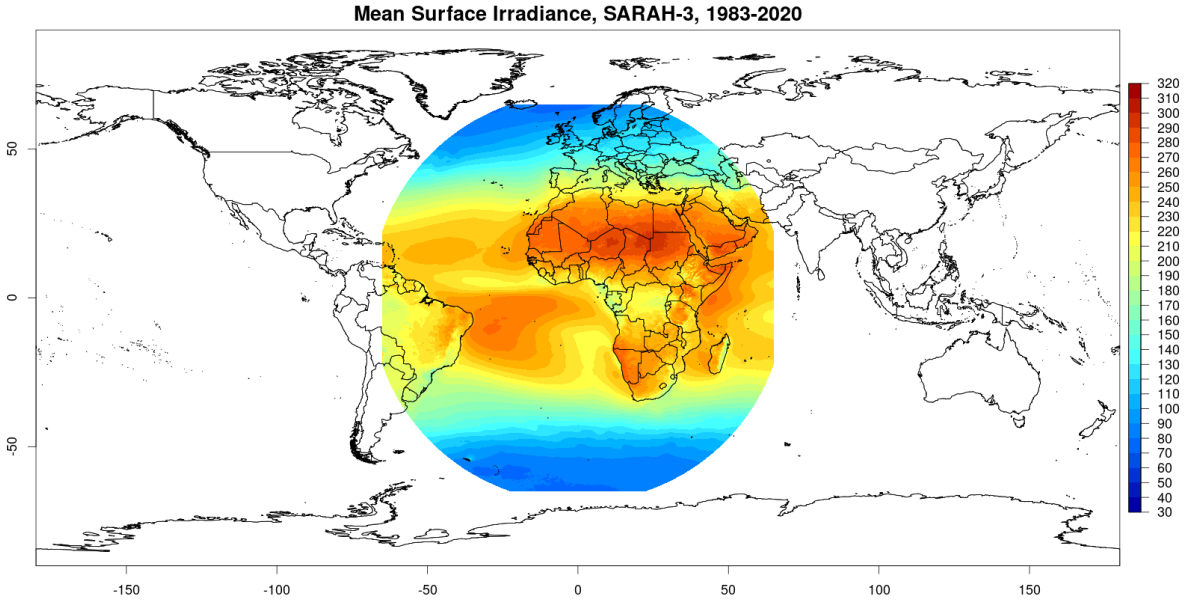
Surface Solar Radiation based on Satellite Observations – the new SARAH-3 Climate Data Record

Uwe Pfeifroth, Jaqueline Drücke, Steffen Kothe, Jörg Trentmann, Marc Schröder, Rainer Hollmann and the CM SAF Team

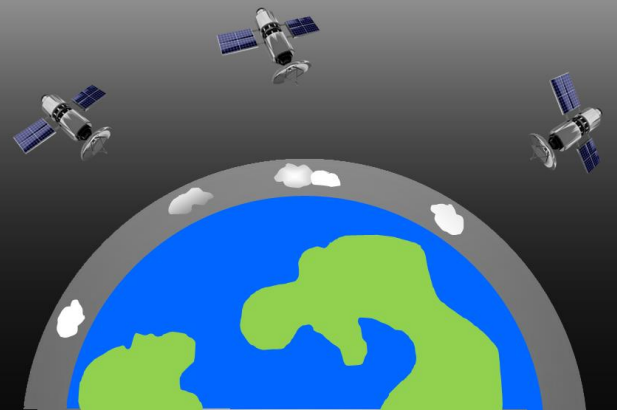


Satellite Application Facility on Climate Monitoring

EUMETSAT CM SAF

What we do → **Satellite-derived Products of Energy & Water Cycle** → **Why we do it**

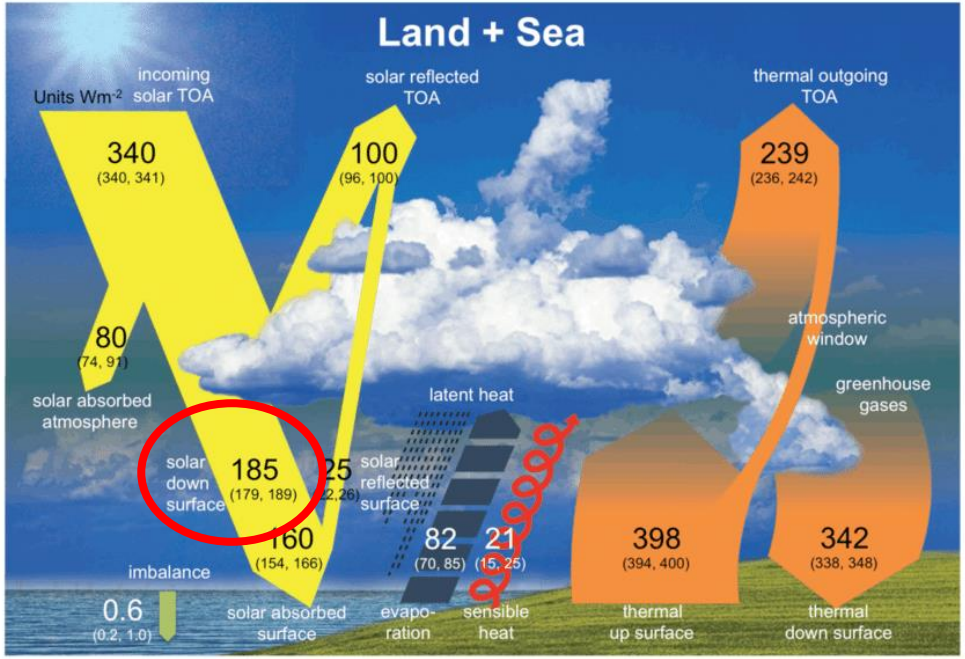
Develop
Generate
Archive
Distribute



Monitor
Understand
Adapt

Climate Variability
&
Climate Change

Energy Fluxes control the Earth‘s climate

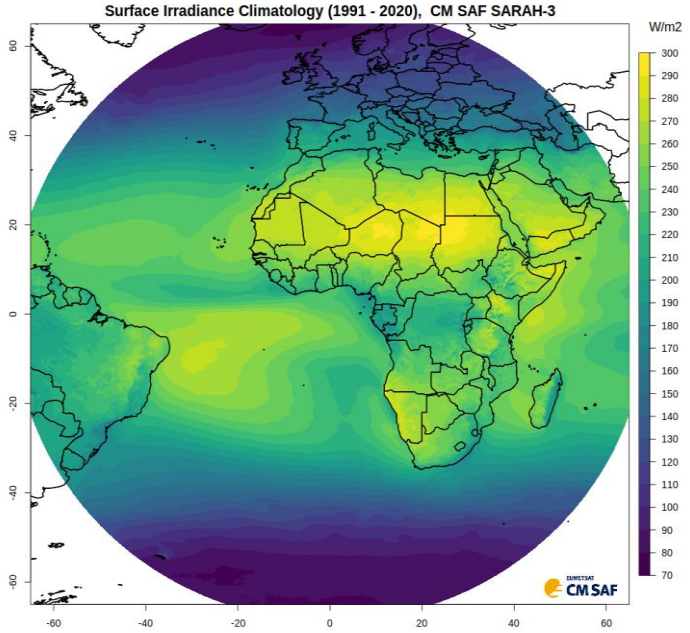


Source: Wild et al., 2017

CM SAF SARAH-3

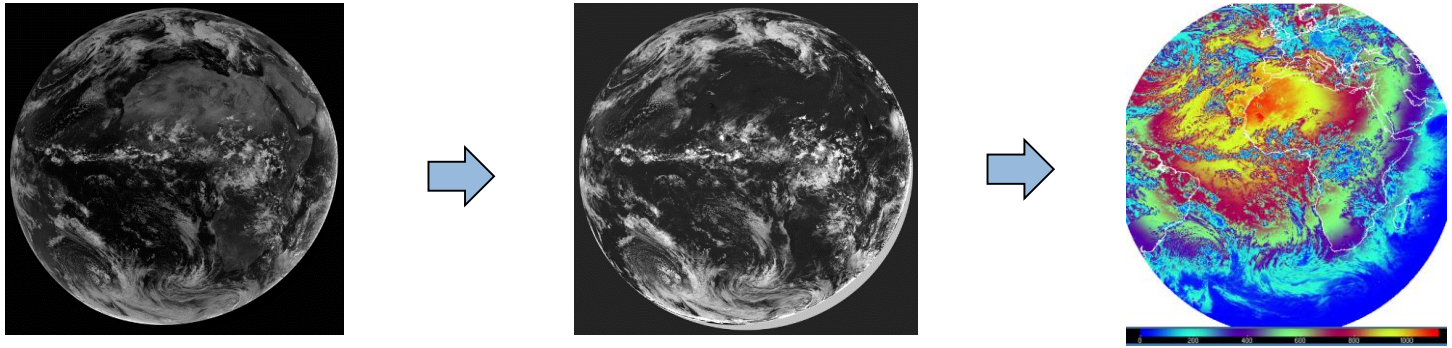
Surface Solar Radiation Dataset – Heliosat

- **Variables**
  - Surface Solar Irradiance (SIS)
  - Surface Direct Irradiance (SID, DNI)
  - Sunshine Duration (SDU)
  - Photosynthetic Active Radiation (PAR)
  - Daylight (DAL)
  - Effective Cloud Albedo (CAL)
- **Resolution**
  - Spatial: 0.05° × 0.05°
  - Temporal: 30-min, daily-, monthly mean
- **Coverage**
  - Spatial: regional (±65°)
  - Temporal: 1983 to 2020 (CDR)
    2021 to date (ICDR)
  - Available now at www.cmsaf.eu



Pfeifroth, Uwe; Kothe, Steffen; Drücke, Jaqueline; Trentmann, Jörg; Schröder, Marc; Selbach, Nathalie; Hollmann, Rainer (2023): Surface Radiation Data Set - Heliosat (SARAH) - Edition 3, Satellite Application Facility on Climate Monitoring, **DOI:10.5676/EUM_SAF_CM/SARAH/V003**.

SARAH Algorithm Basics



Raw data (visible channel(s)) → Effective Cloud Albedo (CAL) → Surface radiation parameter (SIS)

$$\frac{R - Rmin}{Rmax - Rmin}$$

$$CAL\text{-}1 \sim SIS / SISclear$$

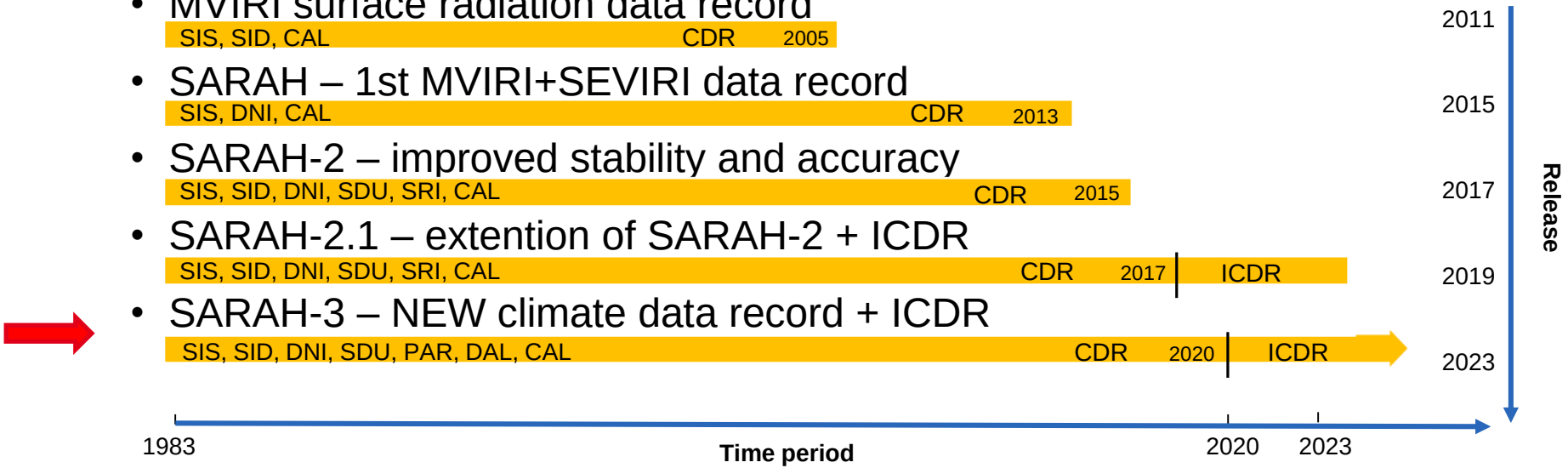
R =	Reflection observed by satellite
Rmin =	Minimum reflection per month, timeslot, pixel
Rmax =	Maximum reflection per month
CAL=	Effective Cloud Albedo
SIS =	Surface Incoming Solar Radiation
SISclear =	SIS assuming clear-sky (spectral clear-sky model SPECMAGIC)

Basic Algorithm Desctription:

- Müller, R. et al. (2015) *Remote Sens., 7*, 8067-8101, doi:10.3390/rs70608067
- CM SAF Documention: SARAH-3 Algorithm Theoretical Baseline Document at cmsaf.eu

SARAH History

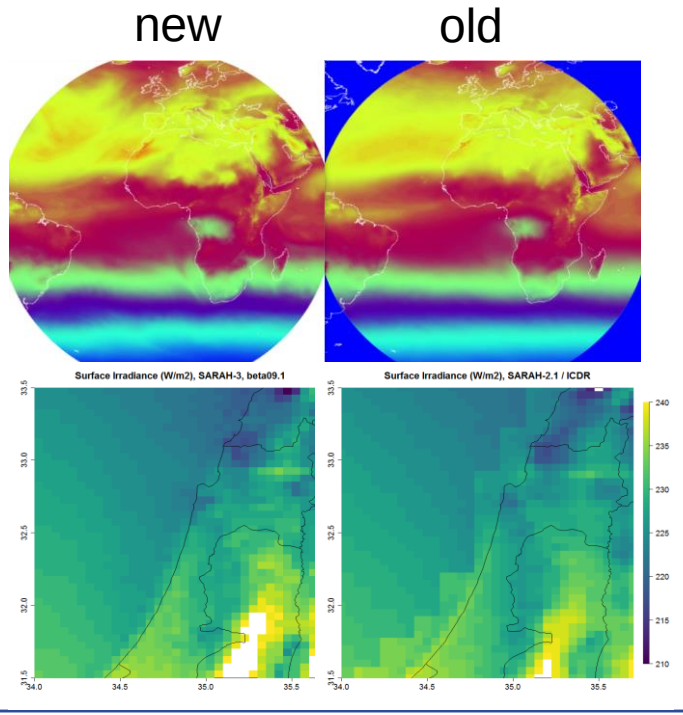
- MVIRI surface radiation data record
  SIS, SID, CAL — CDR 2005
- SARAH – 1st MVIRI+SEVIRI data record
  SIS, DNI, CAL — CDR 2013
- SARAH-2 – improved stability and accuracy
  SIS, SID, DNI, SDU, SRI, CAL — CDR 2015
- SARAH-2.1 – extention of SARAH-2 + ICDR
  SIS, SID, DNI, SDU, SRI, CAL — CDR 2017 | ICDR
- SARAH-3 – NEW climate data record + ICDR
  SIS, SID, DNI, SDU, PAR, DAL, CAL — CDR 2020 | ICDR



SARAH-3 – What‘s new ? (1) -> Updated and improved **auxilliary data**

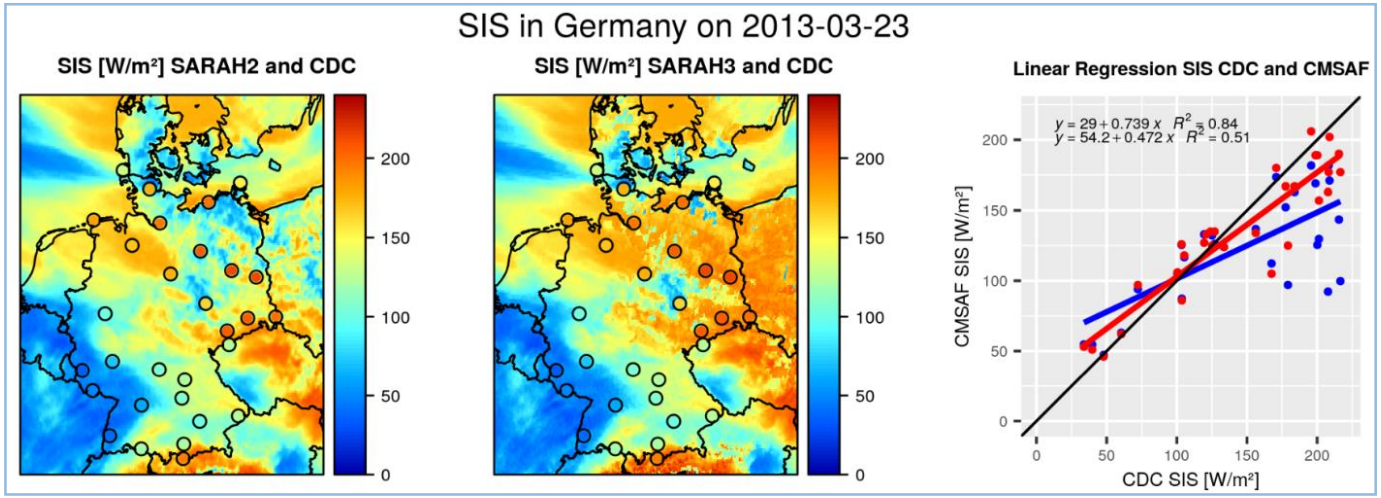
- Daily ERA-5 Ozone and Total Column Water Vapour (before: monthly ERA-Interim)

- New spectrally resolved Surface Albedo data based on MODIS (Blanc et al.) with higher resolution (before: land-use classes)



SARAH-3 – What‘s new ? (2) -> Improved **surface irradiance over snow**

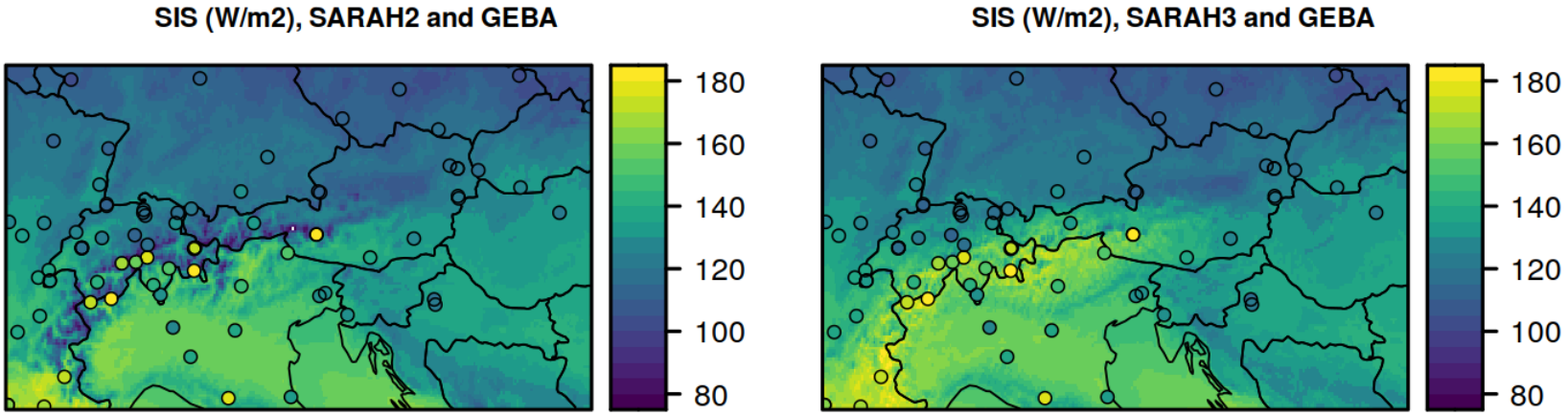
- internal daily snow information (HELSNOW-Algorithm)



old new

SARAH-3 – What‘s new ? (2) -> Improved **surface irradiance over snow**

- SARAH-3 shows higher surface irradiance in **alpine** regions



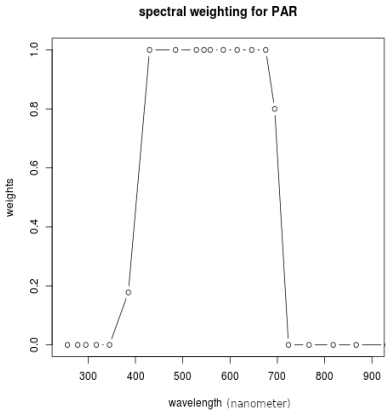
GEBA: Global Energy Budget Archive (monthly surface radiation station data)

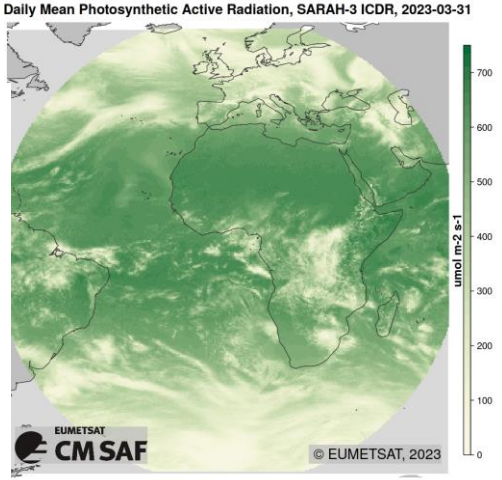
SARAH-3 – What‘s new ? (3) -> New Parameters PAR and DAL

- Photosynthetic Active Radiation (PAR)

provided as

$[\mu mol \cdot m^{-2} \cdot s^{-1}]$



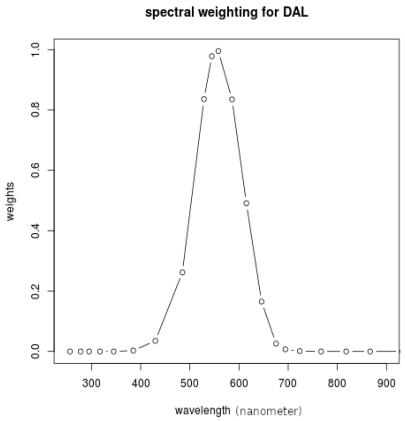


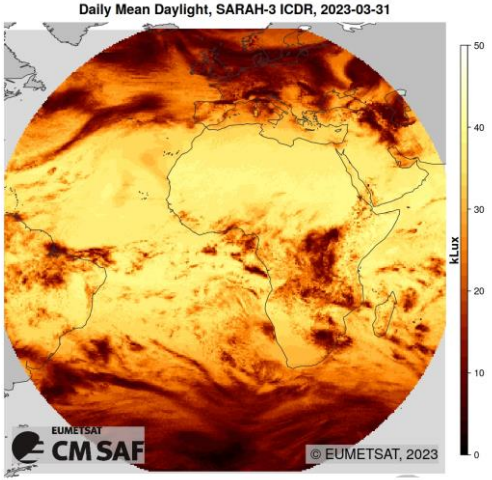
e.g. for biological application

- Daylight (DAL)

provided as

$[kLux]$

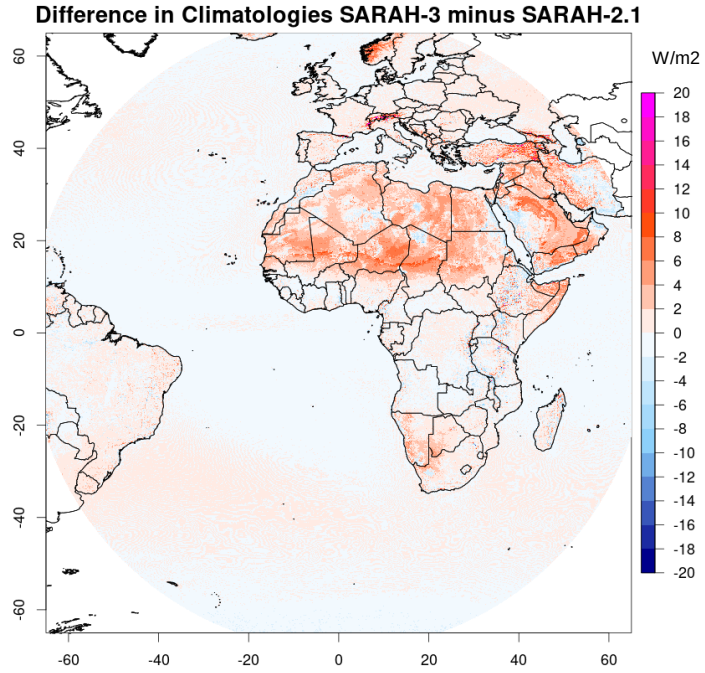




e.g. for infrastructure planing

SARAH-3 – Validation

-> Comparison vs. SARAH-2.1



- Changes in subtropics due to **new surface albedo** auxillary data
- Changes in alpine regions due to **improved treatment of snow**

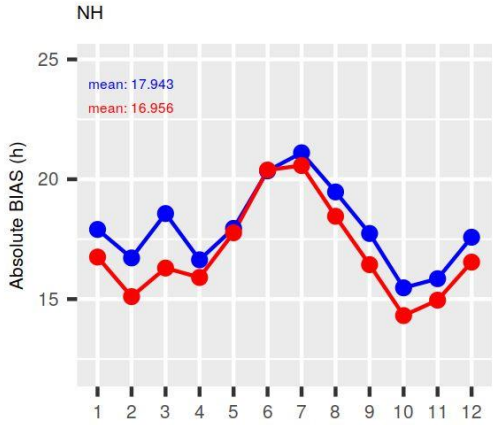
SARAH-3 – Validation

- daily mean global radiation vs BSRN stations

SIS	N_{day}	Bias [W/m²]	MAD [W/m²]	SD [W/m²]	StMAD [W/m²]	AC	$Frac_{day}$ > threshold accuracy [%]
SARAH-3	84789	2.18	10.9	15.8	11.32	0.96	19.6 (>17 W/m²)
SARAH-2.1	84815	1.52	11.5	16.8	11.99	0.95	21.4 (>17 W/m²)
+ ICDR							
SARAH-2.1	72087	1.51	11.70	17.2	11.92	0.95	16.8 (>20 W/m²)
SARAH-2	57128	1.74	11.78	17.2	11.96	0.95	16.9 (>20 W/m²)
SARAH	48605	1.12	12.1	17.9	/	0.95	11.3 (>25 W/m²)
MVIRI	29790	4.41	15.05	23.36	/	0.92	16.3 (>25 W/m²)

Source: SARAH-3 Validation report, www.cmsaf.eu

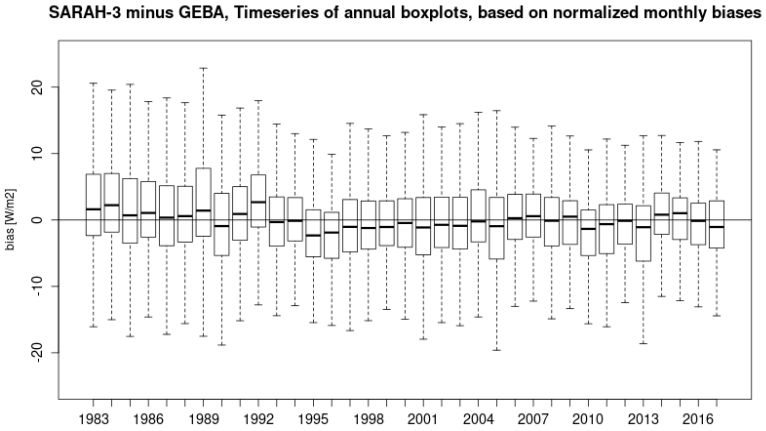
- monthly sunshine duration vs CLIMAT stations

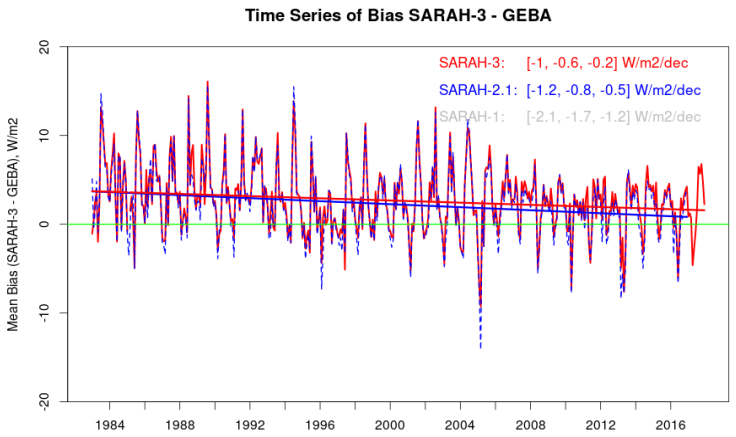


- High quality of SARAH-3
- Continuous improvement of SARAH data records

BSRN: Baseline Surface Radiation Network
CLIMAT: Collection of monthly meteorological data from stations

SARAH-3 – Validation -> monthly global radiation vs GEBA stations in Europe





- Data slighty improving over time
- Small underestimation of the linear trend as given by GEBA stations

Application of the CM SAF radiation data records

- Climate analysis, Trend Analysis (e.g. Pfeifroth et al., 2018)
- Solar energy assessments and modelling / Solar Atlases (e.g. Druecke et al., 2021)
- Climate Monitoring (e.g. Copernicus European State of the Climate 2022)
- Evaluation of (climate) model simulations (e.g. Katragkou et al., 2015)
- Combination with station data (best of both worlds) (e.g. Zak et al., 2015)
- Quality control of surface measurements (e.g. Urraca et al., 2017)
- Agrometeorology and Biology (e.g. Pelosi et al., 2022)
- …….

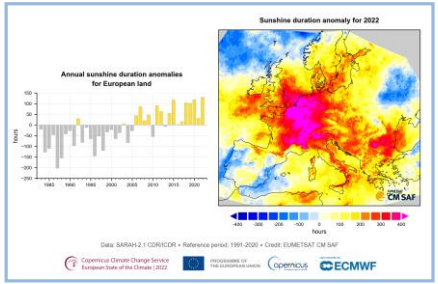
- See www.cmsaf.eu → Outreach → Applications
- List of peer-reviewed publications
  https://public.cmsaf.dwd.de/data/jtrentma/CMSAF_RadiationPublications_April2021.pdf

SARAH enables a wide range of **applications**

-> METEOSAT-based CM SAF surface radiation data records used in >200 scientific publications

e.g. Climate Monitoring

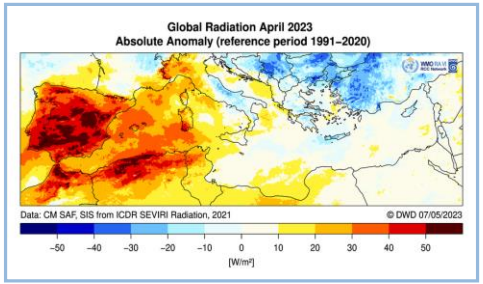
ESOTC 2022



-> Sunny Central Europe

Source:
https://climate.copernicus.eu/esotc/2022/clouds-and-sunshine-duration

WMO RCC RA6

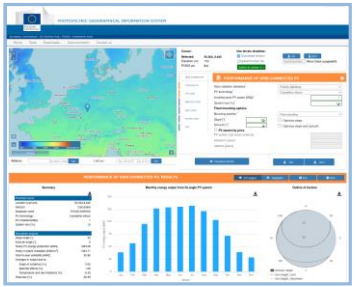


-> Heatwave in Spain, 04-2023

Source:
https://rcccm.dwd.de/DWD-RCCCM/EN/products/europe/europe_node.html

e.g. Renewable Energy

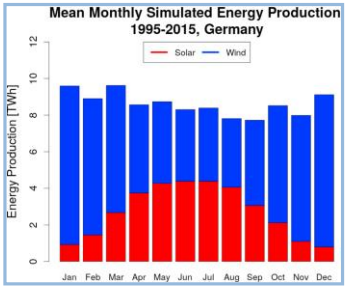
PV GIS



-> PV Potential *(Millions of accesses !)*

Source:
https://re.jrc.ec.europa.eu/pvg_tools/en/

Wind and Solar



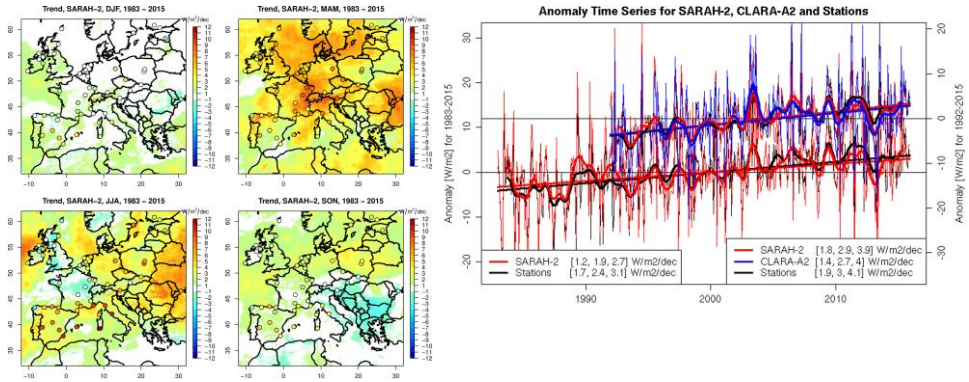
Source:
Climatological analysis of solar and wind energy in Germany using the Grosswetterlagen classification, Drücke et al., 2021, Renewable Energy 164

SARAH enables a wide range of **applications**

-> METEOSAT-based CM SAF surface radiation data records used in >200 scientific publications

e.g. Climate Analysis / Validation

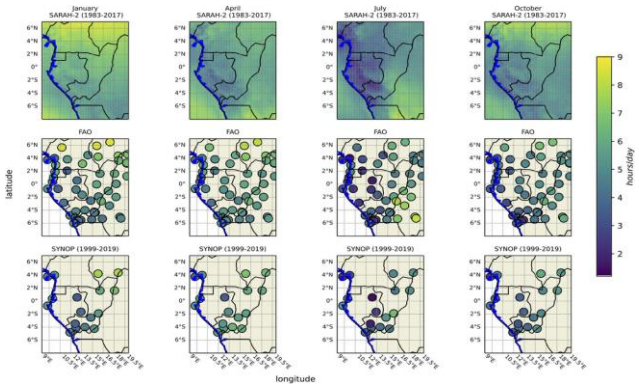
European Trends of surface irradiance



-> positive trends in solar radiation (strongest in spring)

See Pfeifroth, et al. (2018). Journal of Geophysical Research: Atmospheres,123, 1735–1754.https://doi.org/10.1002/2017JD027418

Comparison to stations in Western Equ. Africa



-> good agrement between SARAH-2 and stations

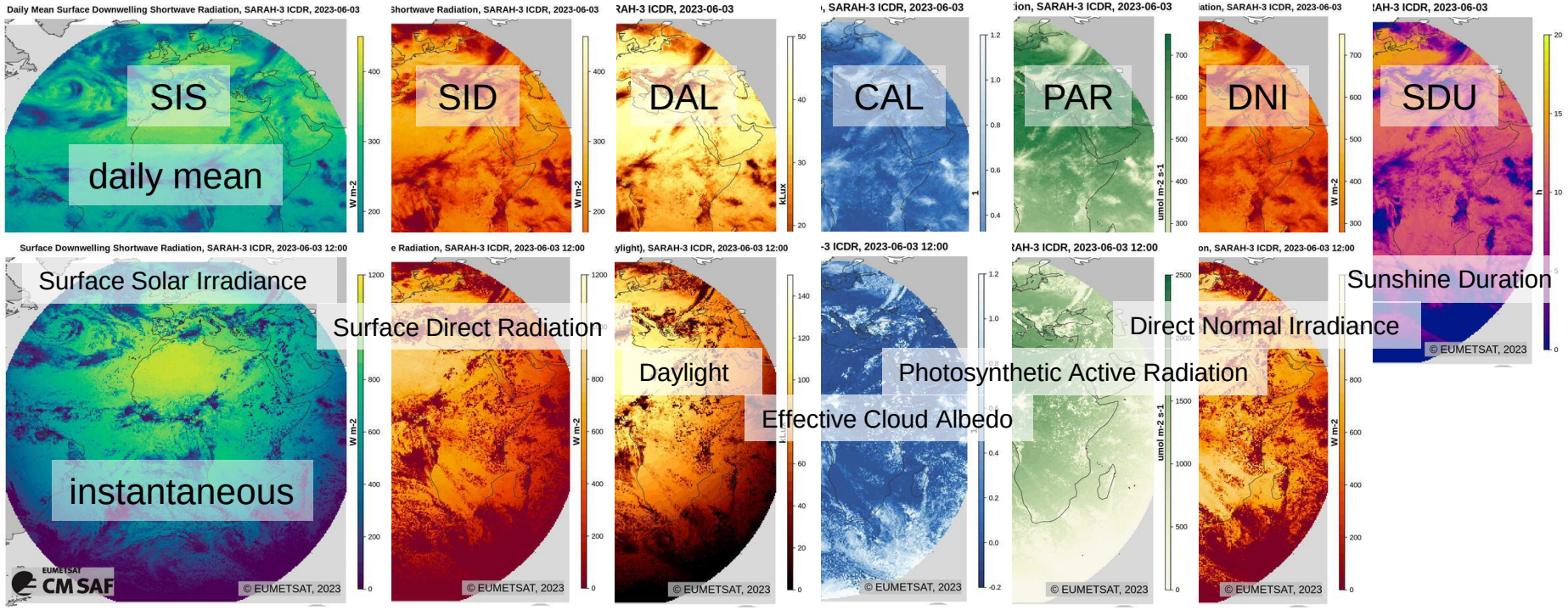
See Philippon, et al., 2022, J. Appl. Meteor. Climatol., 61, 185–201, https://doi.org/10.1175/JAMC-D-21-0072.1.

EUMETSAT CM SAF
CLIMATE MONITORING

Deutscher Wetterdienst
Wetter und Klima aus einer Hand

SARAH-3 - Latest Images from the ICDR

https://public.cmsaf.dwd.de/data/perm/quicklooks/



Summary

- **SARAH-3** provides various surface radiation parameters and enables a wide range of applications
- SARAH-3 offers **high quality** data (improvements over snow covered surfaces)
- SARAH-3 provides **more than 40 years** of data and covers the current climate normal period
- SARAH-3 provides **consistent near-realtime** processing of all parameters (ICDR)
- SARAH-3 data **freely available** via wui.cmsaf.eu