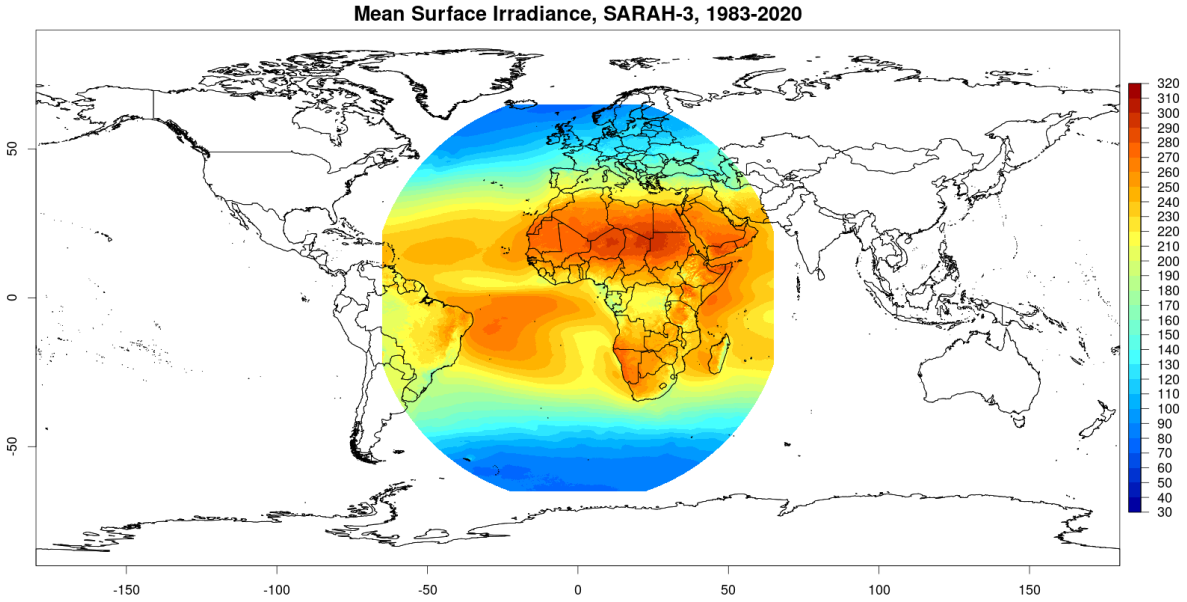
# Surface Solar Radiation based on Satellite Observations – the new SARAH-3 Climate Data Record

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

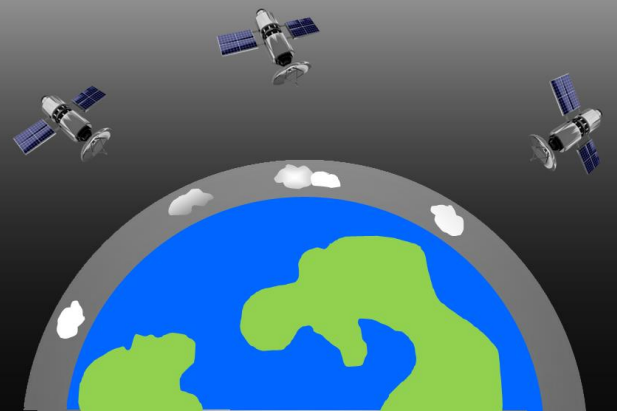


# Satellite Application Facility on Climate Monitoring

EUMETSAT CM SAF

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

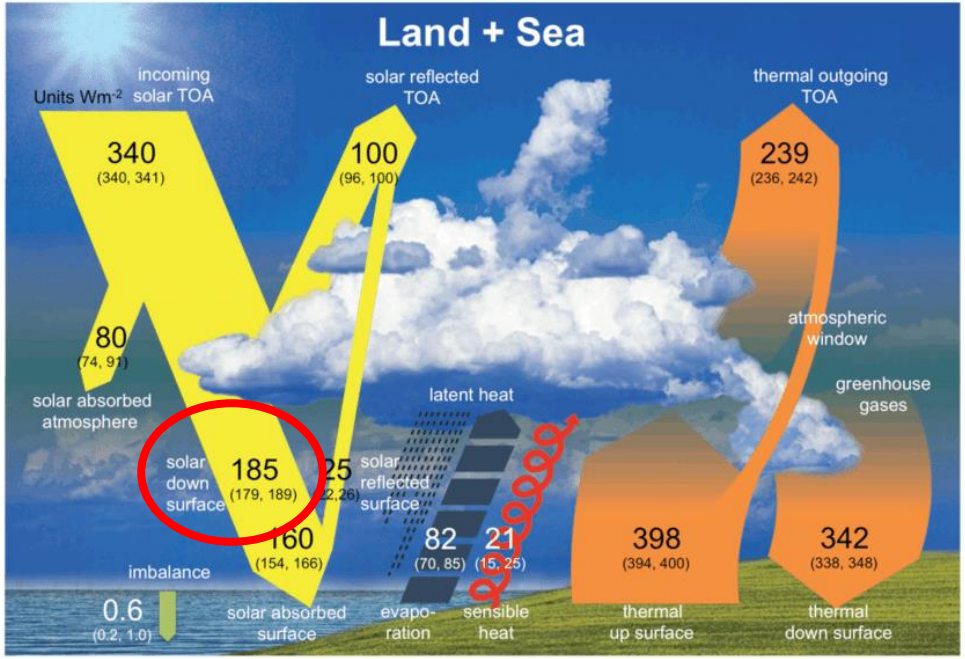
Develop
Generate
Archive
Distribute



Monitor
Understand
Adapt

Climate Variability
&
Climate Change

## Energy Fluxes control the Earth‘s climate

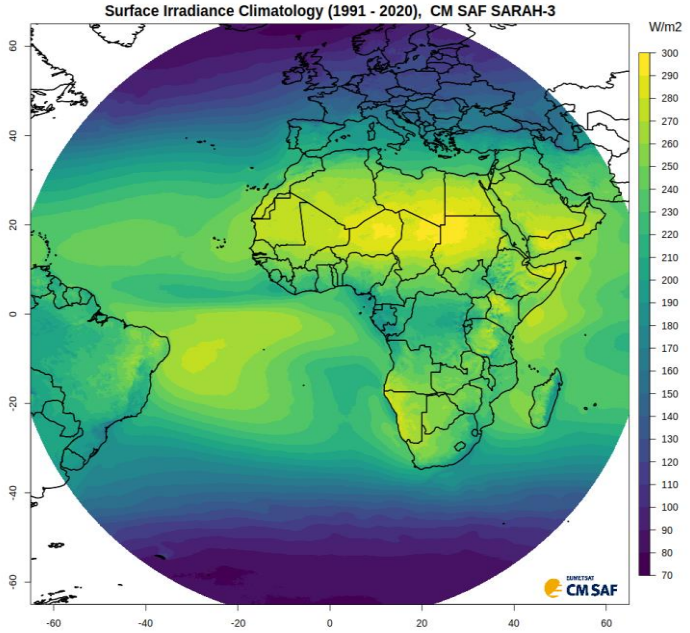



Source: Wild et al., 2017

# CM SAF SARAH-3

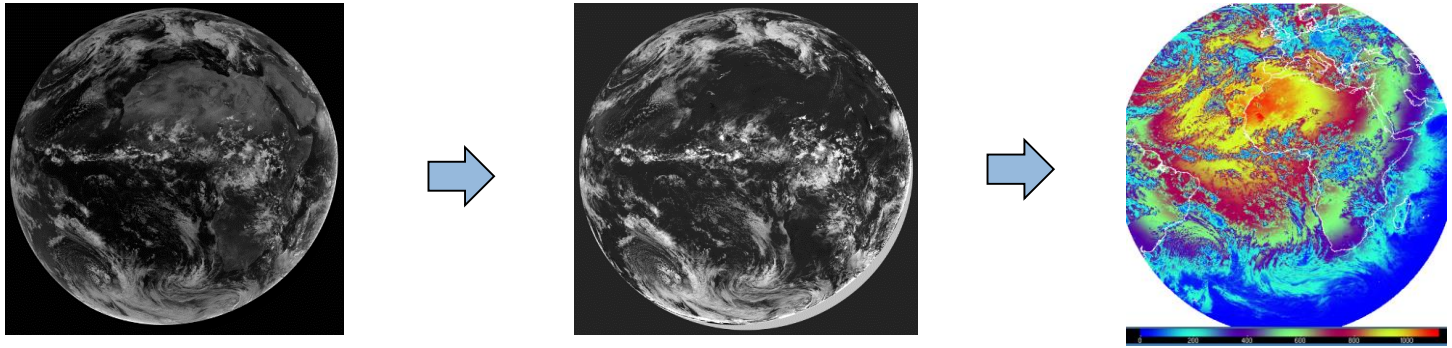
**Surface Solar Radiation Dataset – Heliosat**

- **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)

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

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

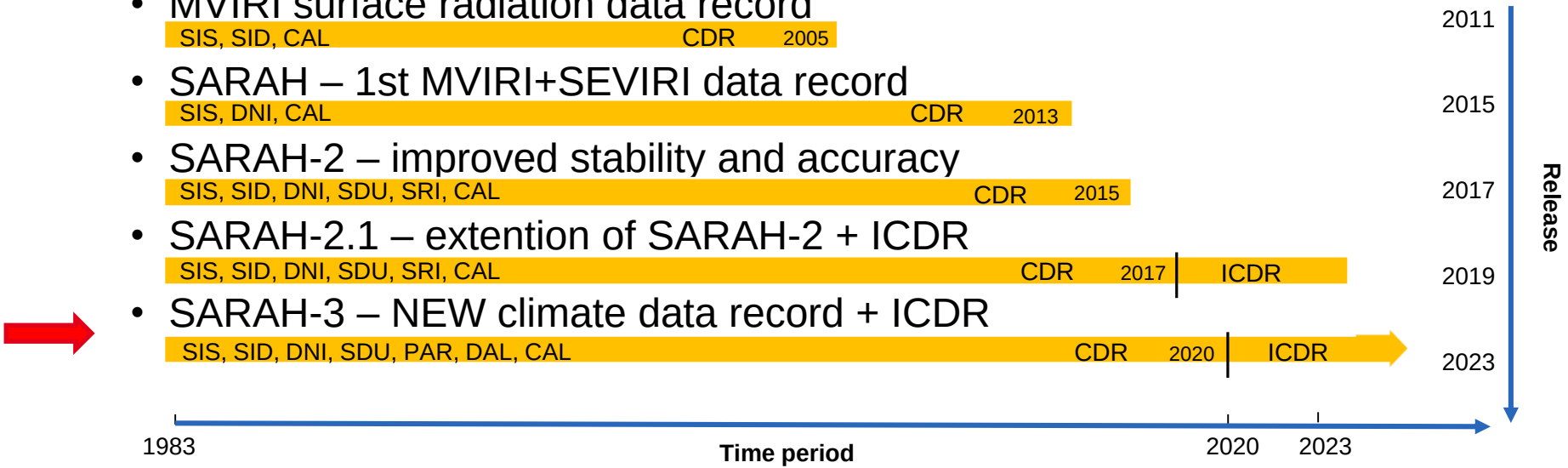
| | |
|---|---|
| R = | Reflection observed by satellite |
| Rmin = | Minimum reflection per month, timeslot, pixel |
| Rmax = | Maximum reflection per month |
| CAL= | Effective Cloud Albedo |
| SIS = | Surface Incoming Solar Radiation |
| SISclear = | SIS assuming clear-sky (spectral clear-sky model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

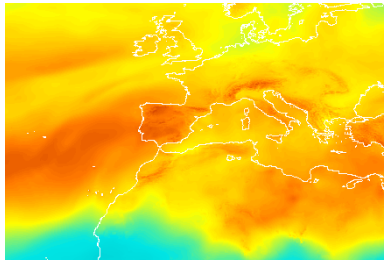
- MVIRI surface radiation data record
  SIS, SID, CAL — CDR 2005
- SARAH – 1st MVIRI+SEVIRI data record
  SIS, DNI, CAL — CDR 2013
- SARAH-2 – improved stability and accuracy
  SIS, SID, DNI, SDU, SRI, CAL — CDR 2015
- SARAH-2.1 – extention of SARAH-2 + ICDR
  SIS, SID, DNI, SDU, SRI, CAL — CDR 2017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



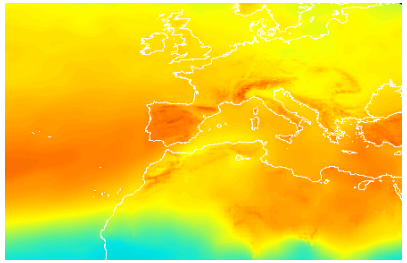
# SARAH-3 – What‘s new ? (1) -> Updated and improved **auxilliary data**

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

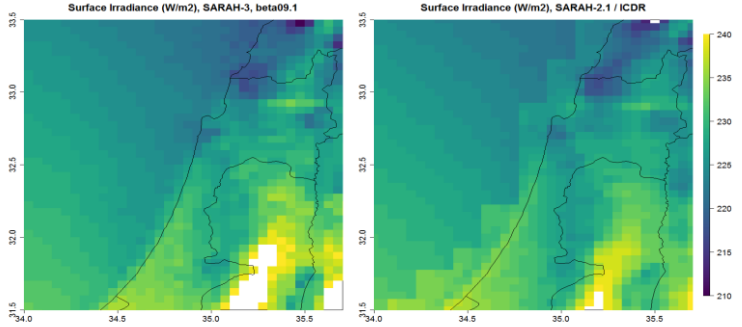
new



old

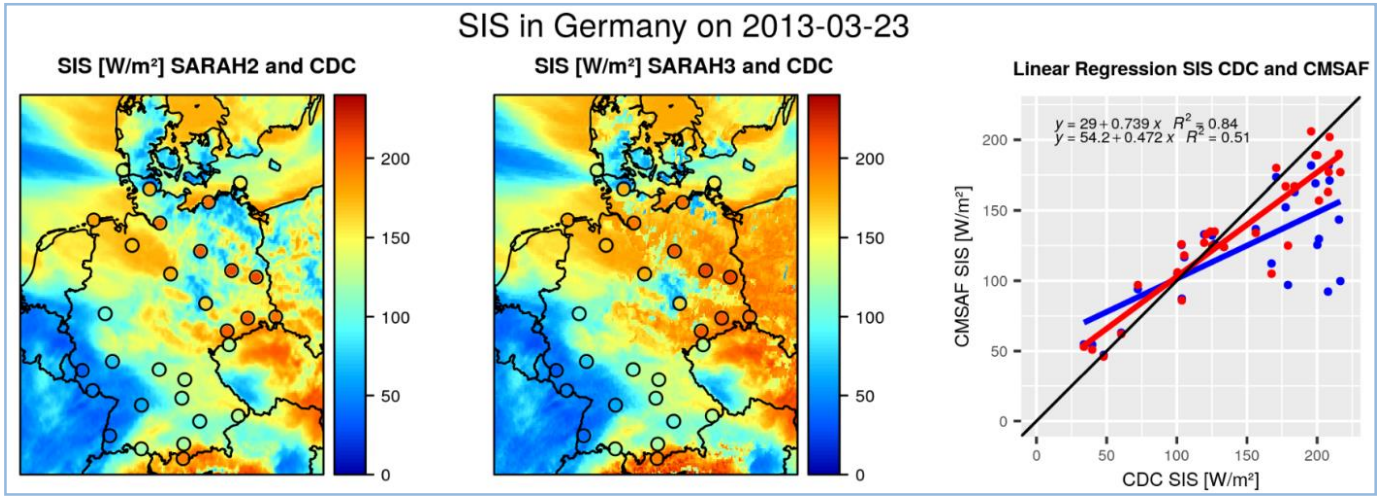


- New spectrally resolved Surface Albedo data based on MODIS (Blanc et al.) with higher resolution (before: land-use classes)



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

- internal daily snow information (HELSNOW-Algorithm)

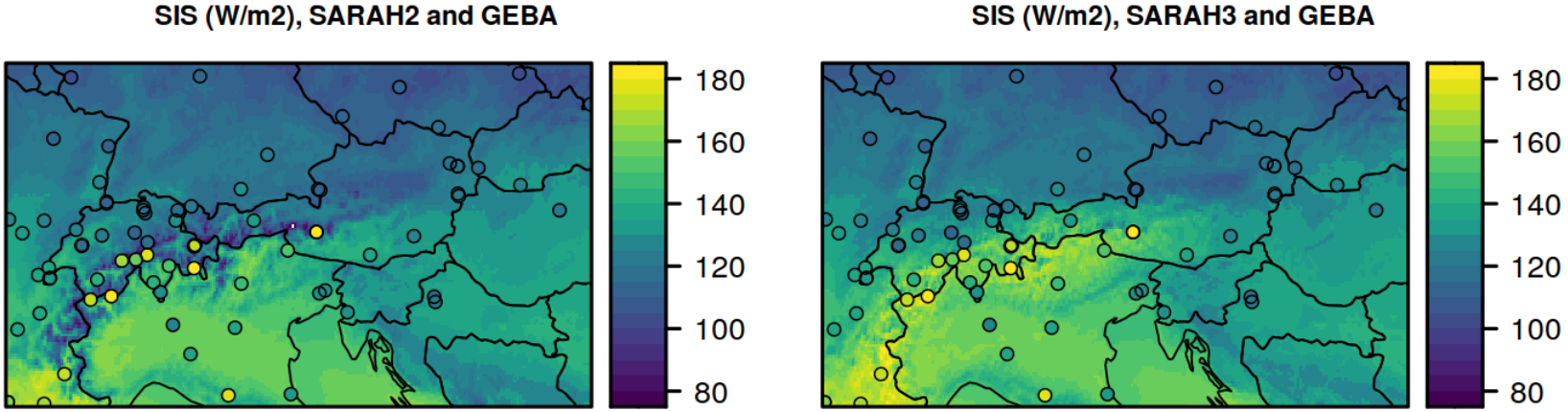



old new

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

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

March Climatologies



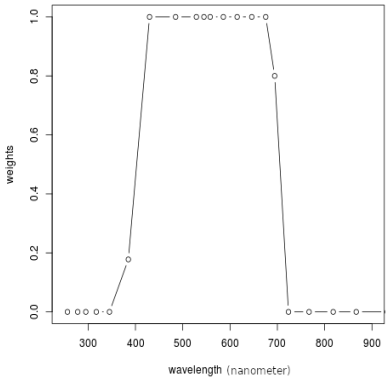

GEBA: Global Energy Budget Archive (monthly surface radiation station data)

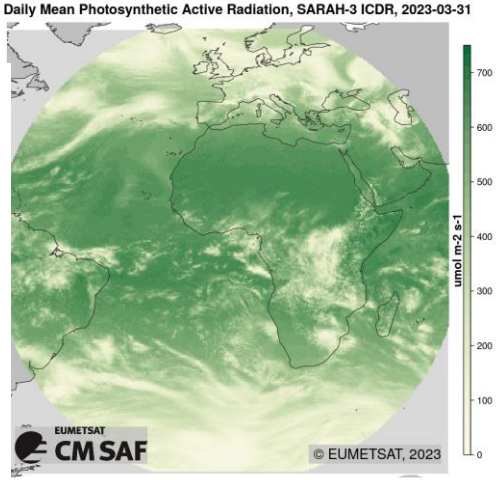
# SARAH-3 – What‘s new ? (3) -> New Parameters PAR and DAL

- Photosynthetic Active Radiation (PAR)

provided as

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



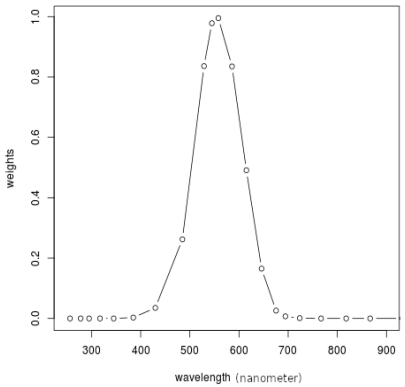



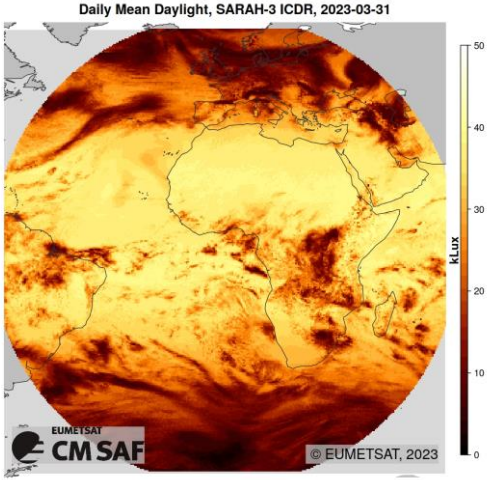

e.g. for biological application

- Daylight (DAL)

provided as

$[kLux]$



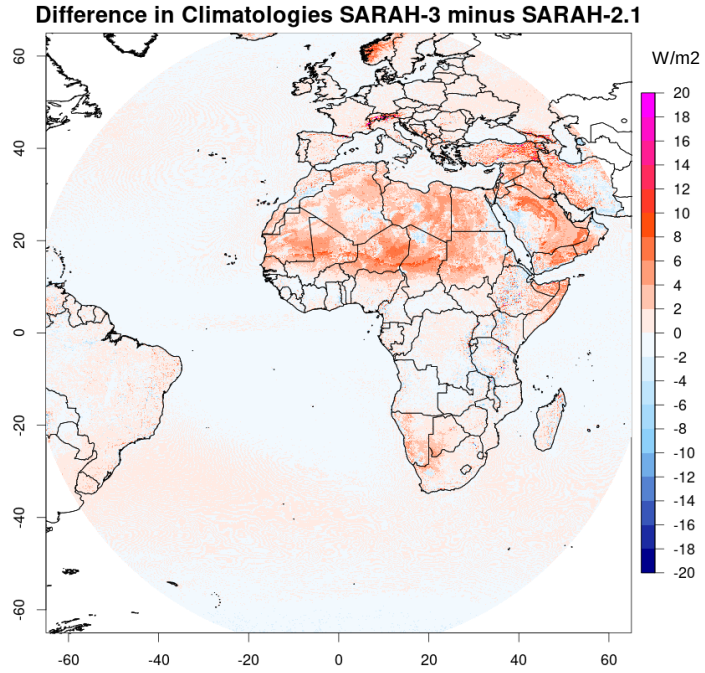




e.g. for infrastructure planing

See also Thomas et al., 2023, https://doi.org/10.3390/atmos14081259

# 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**

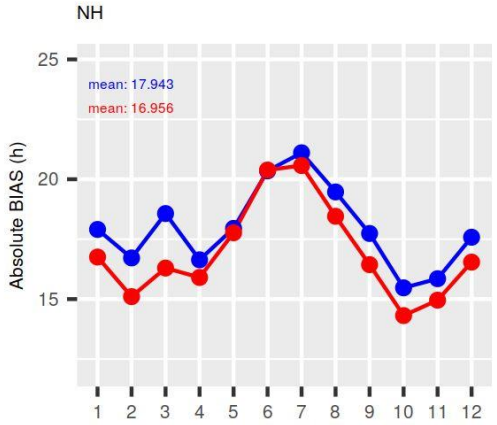
# SARAH-3 – Validation

- 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

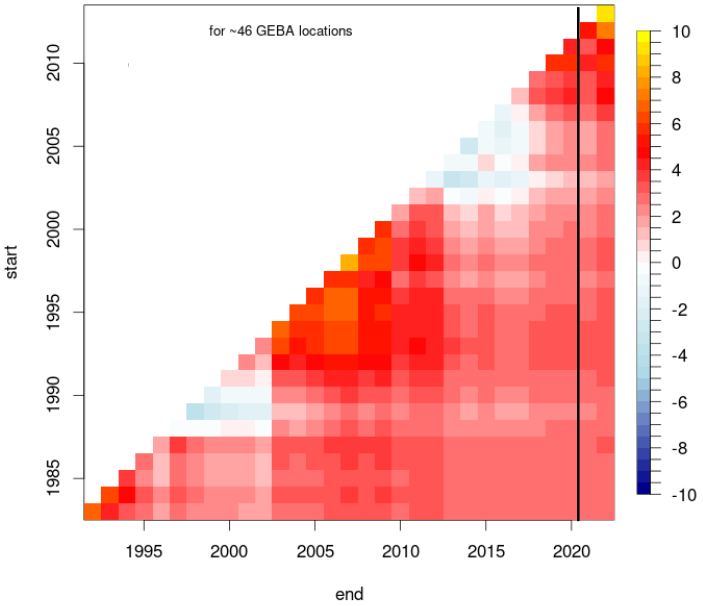



- High quality of SARAH-3
- Continuous improvement of SARAH data records

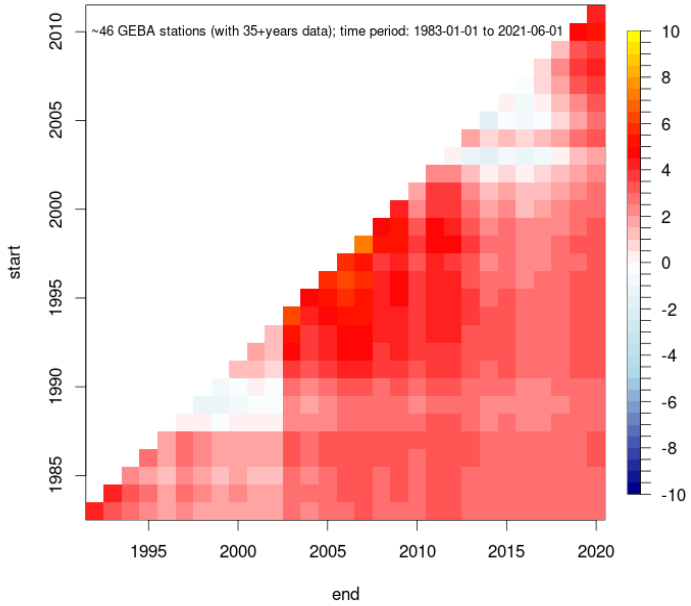
BSRN: Baseline Surface Radiation Network
CLIMAT: Collection of monthly meteorological data from stations

# Trends and variability of global radiation in Europe: Comparison with GEBA*

SARAH-3 SIS Trendraster-Plot [W/m2/decade], Europe, 1983-2022




GEBA SIS Trendraster-Plot [W/m2/decade], Europe, 1983-2020




GEBA-stations used for Trendraster-Plots

➢ **Good agreement !**

* GEBA: Global Energy Budget Archive, https://geba.ethz.ch

# 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 report 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)
- …….

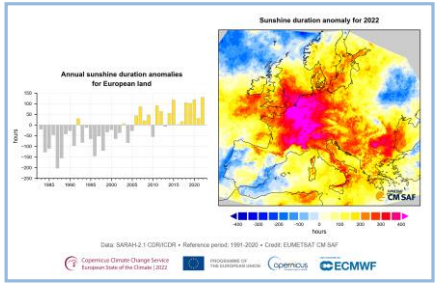
- See www.cmsaf.eu → Outreach → Applications
- List of peer-reviewed publications
  https://public.cmsaf.dwd.de/data/jtrentma/CMSAF_RadiationPublications_April2021.pdf

# **SARAH** enables a wide range of **applications**

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

## e.g. Climate Monitoring

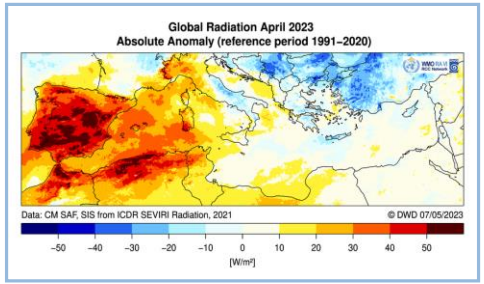
### ESOTC 2022




-> Sunny Central Europe

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

### WMO RCC RA6

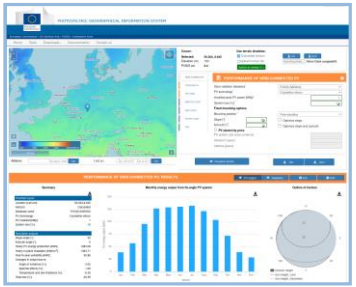



-> Heatwave in Spain, 04-2023

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

## e.g. Renewable Energy

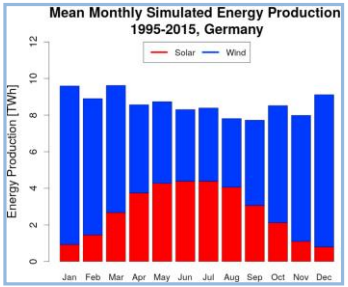
### PV GIS



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

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

### Wind and Solar



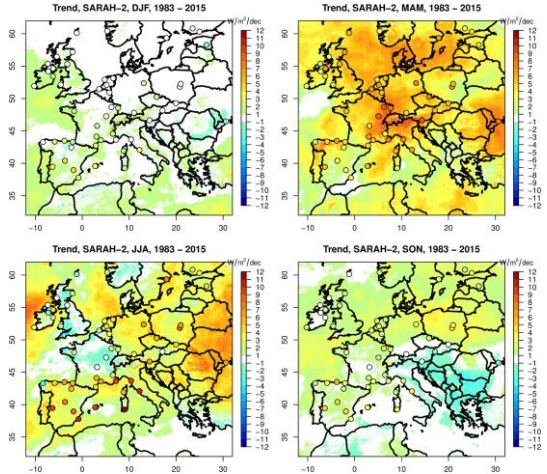

Source:
Climatological analysis of solar and wind energy in Germany using the Grosswetterlagen classification, Drücke et al., 2021, Renewable Energy 164

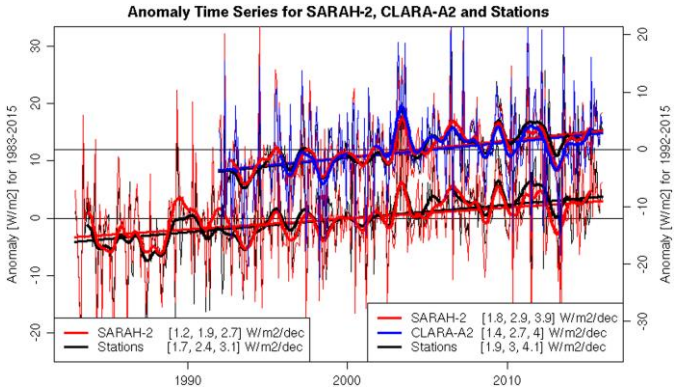
# **SARAH** enables a wide range of **applications**

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

## e.g. Climate Analysis / Validation

European trends of surface irradiance




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

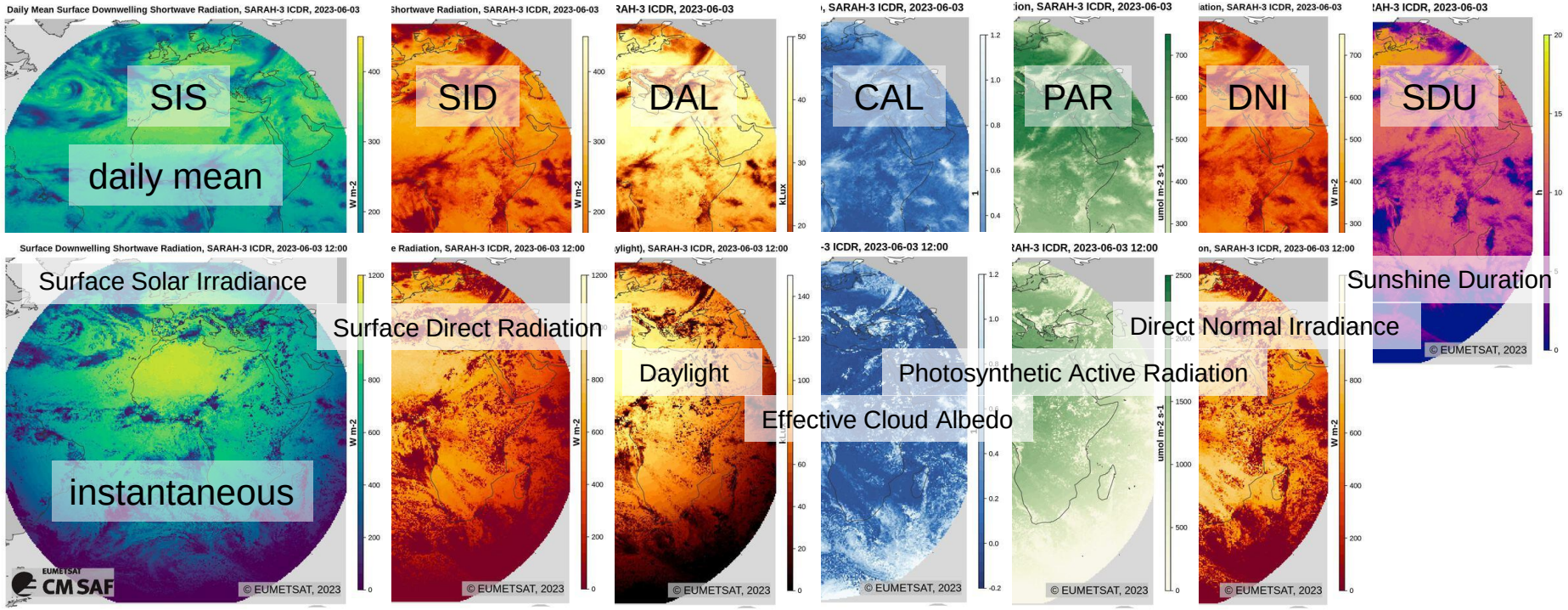
See Pfeifroth, et al. (2018). Journal of Geophysical Research: Atmospheres,123, 1735–1754.https://doi.org/10.1002/2017JD027418

EUMETSAT CM SAF
CLIMATE MONITORING

Deutscher Wetterdienst
Wetter und Klima aus einer Hand

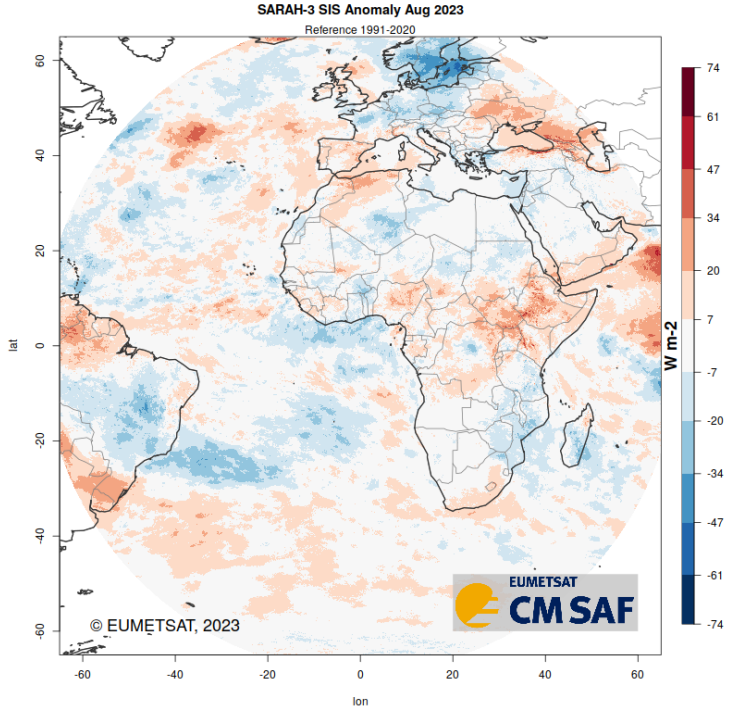
# SARAH-3 - Latest Images from the ICDR

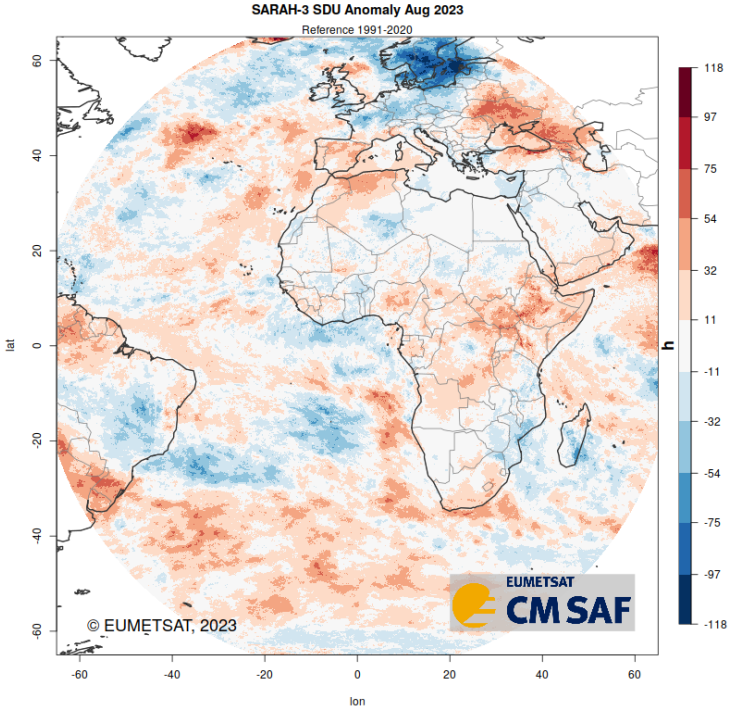
https://public.cmsaf.dwd.de/data/perm/quicklooks/

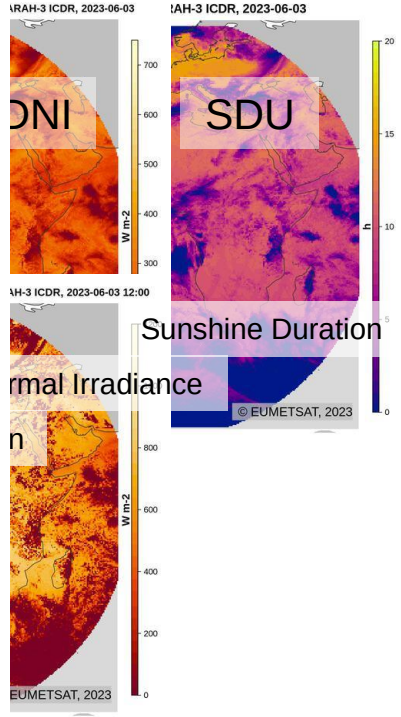


# SARAH-3 - Latest Images from the ICDR

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



# CLARA – A new Climate Data Record on Earth Radiation Budget

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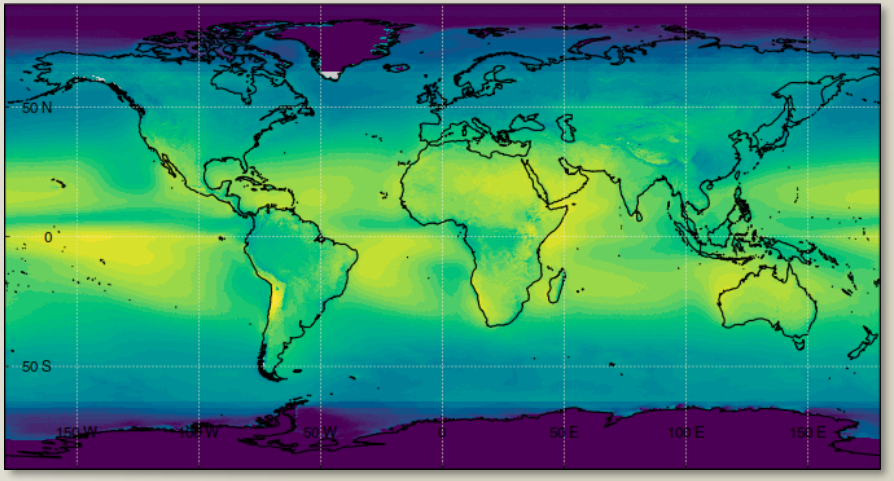
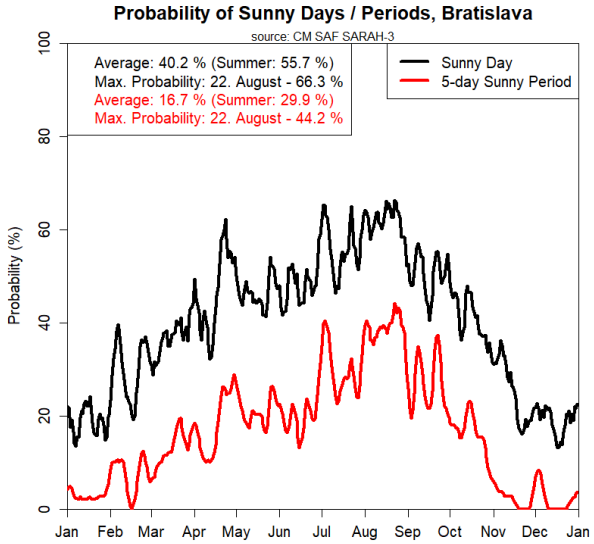


# Summary

- **SARAH-3** provides various surface radiation parameters and enables a wide range of applications
- SARAH-3 offers **high quality** data
- 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 https://wui.cmsaf.eu
- **DOI**: 10.5676/EUM_SAF_CM/SARAH/V003