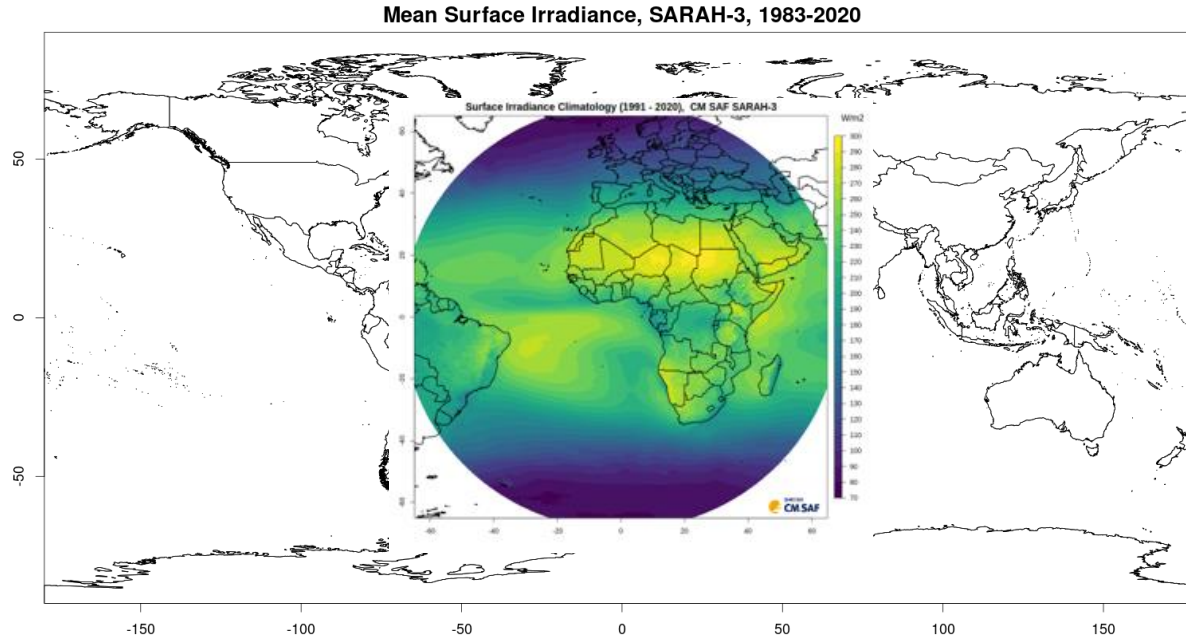


Analyzing climate variability of surface solar radiation parameters from the CM SAF SARA3 climate data record

Uwe Pfeifroth, Jörg Trentmann and the CM SAF Team



Satellite Application Facility on Climate Monitoring



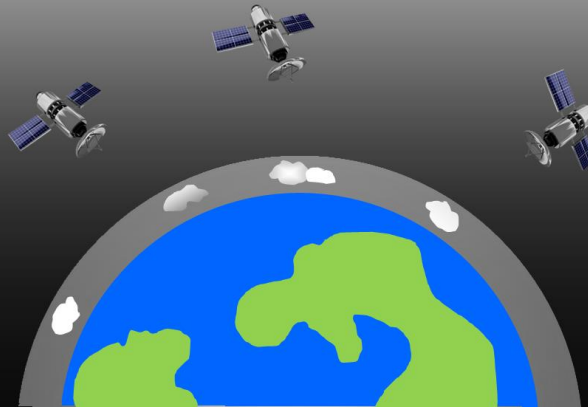
-> www.cmsaf.eu

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

Image source: Fotostudio.com



CM SAF SARA3

Surface Solar Radiation Dataset – Heliosat

→ Variables

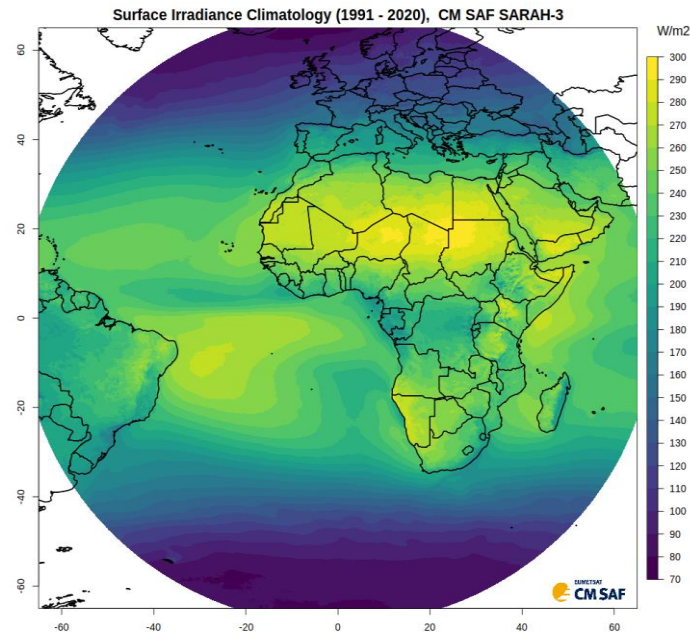
- Surface Solar Irradiance (SIS)
- Surface Direct Irradiance (SID, DNI)
- Sunshine Duration (SDU)
- Photosynthetic Active Radiation (PAR)
- Daylight (DAL)
- Effective Cloud Albedo (CAL)

→ Resolution

- Spatial: $0.05^\circ \times 0.05^\circ$
- Temporal: 30-min, daily-, monthly mean

→ Coverage

- Spatial: regional ($\pm 65^\circ$)
- Temporal: 1983 to 2020 (CDR)
2021 to date (ICDR)
- Available at www.cmsaf.eu

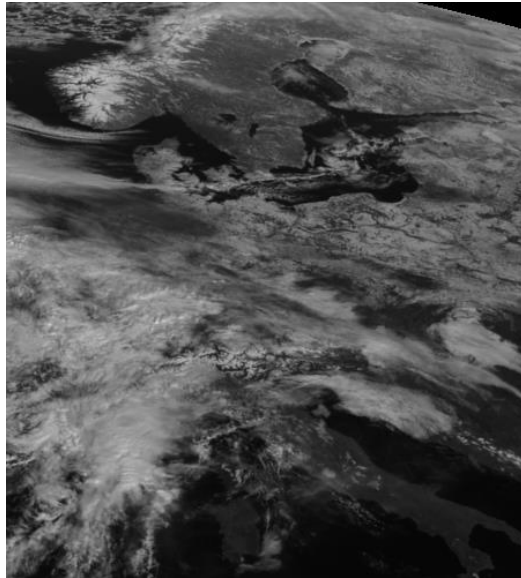


Pfeifroth, Uwe; Kothe, Steffen; Drücke, Jaqueline; Trentmann, Jörg; Schröder, Marc; Selbach, Nathalie; Hollmann, Rainer (2023): Surface Radiation Data Set - Heliosat (SARA3) - Edition 3, Satellite Application Facility on Climate Monitoring, DOI:10.5676/EUM_SAF_CM/SARA3/V003.



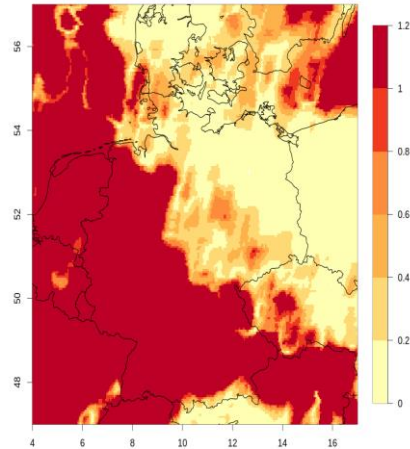
SARAH-3 -> Improved surface irradiance over snow

- internal daily snow information (HELSSNOW-Algorithm)



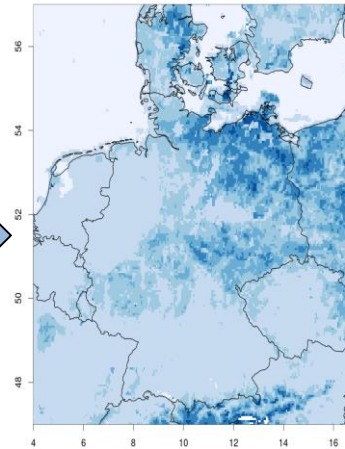
Calculation of „speed“
with optical flow

Optical Flow Speed (Farnebaeck), 2013-03-23, 13 UTC



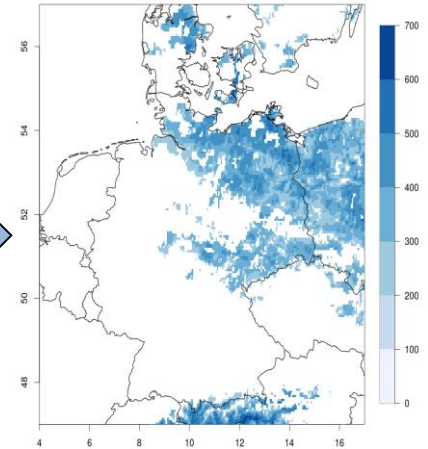
Instantaneous
(potential) snow mask

Potential Snow Reflectivity, 2013-03-23, 13 UTC



Daily snow mask
and reflectivity

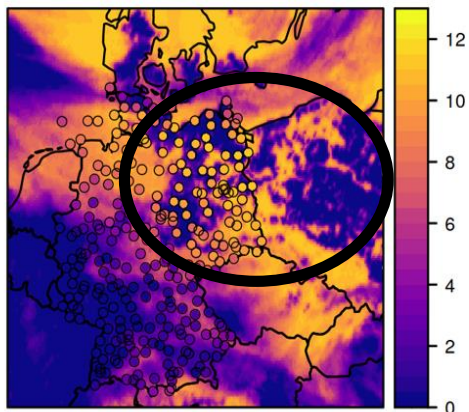
Snow mask/reflectivity (counts), 2013-03-23



SARAH-3 -> Improved surface irradiance over snow

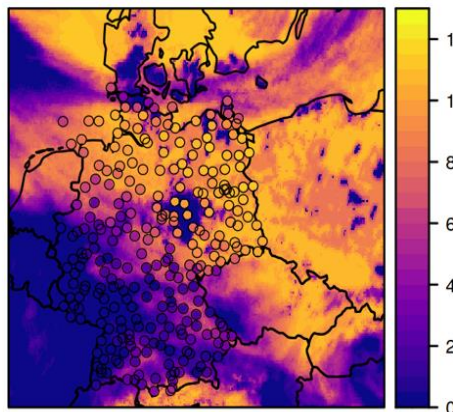
- internal daily snow information (HELSSNOW-Algorithm)

SDU (h) SARAH2 and CDC



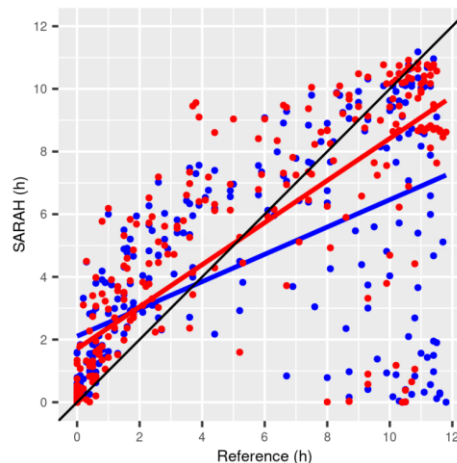
old

SDU (h) SARAH3 and CDC

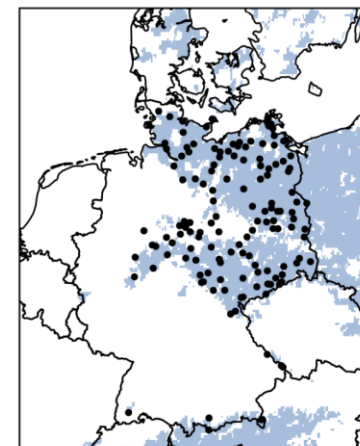


new

Linear Regression



Snowmask SARAH-3

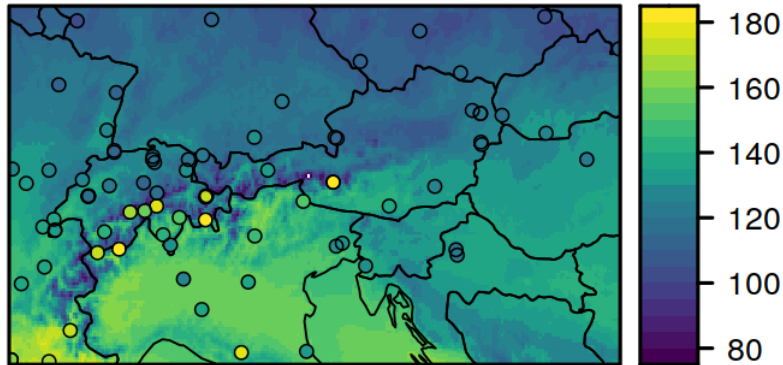


SARAH-3 -> Improved surface irradiance over snow

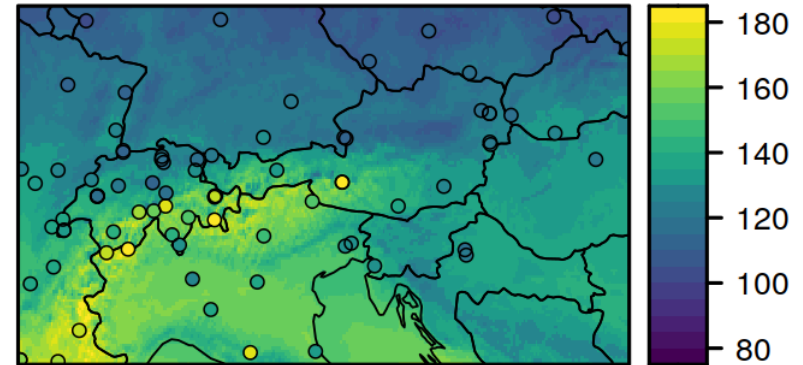
- SARAH-3 shows higher surface irradiance in **alpine** regions

March Climatologies

SIS (W/m²), SARAH2 and GEBA



SIS (W/m²), SARAH3 and GEBA

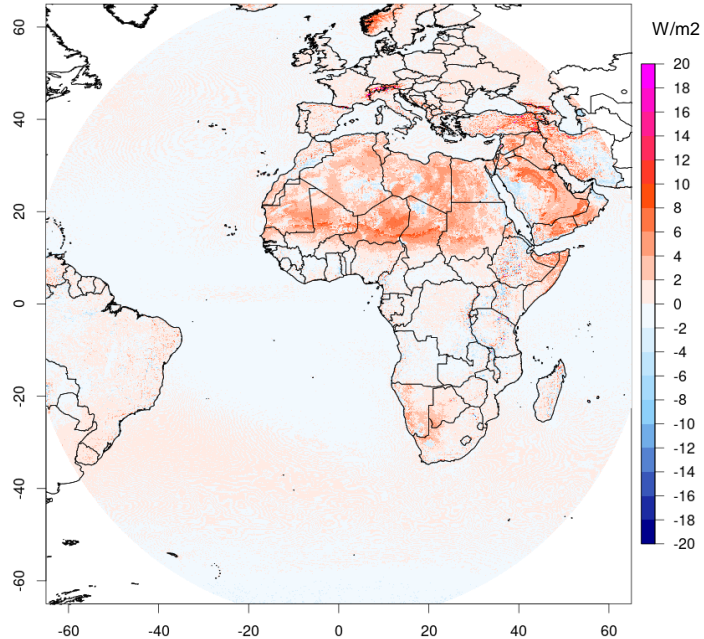


Stations: GEBA - Global Energy Budget Archive



SARAH-3 -> Comparison to SARAH-2.1

Difference in Climatologies SARAH-3 minus SARAH-2.1



- Changes in alpine regions due to **improved treatment of snow**
- Changes in subtropics due to **new surface albedo** auxiliary data
- **Daily ERA-5** auxiliary data (water vapor and ozone)
- **Aerosol climatology**, as in SARAH-2.1



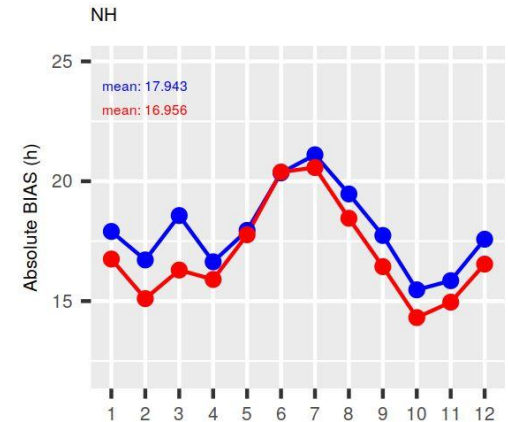
SARAH-3 – Validation

➤ daily surface irradiance vs. BSRN stations

data	Ndays	Bias [W/m2]	MAD [W/m2]	AnomCor
SARAH-3	84.789	2.18	10.9	0.96
SARAH-2.1 + ICDR	84.815	1.52	11.5	0.95
SARAH-2.1	72.087	1.51	11.7	0.95
SARAH-2	57.128	1.74	11.8	0.95
SARAH	48.605	1.12	12.1	0.95
MVIRI	29.790	4.41	15.1	0.92

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

➤ monthly sunshine duration vs CLIMAT stations



BSRN:
CLIMAT:

Baseline Surface Radiation Network
Collection of monthly meteorological
data from stations



SARAH-3 – Validation ➤ daily SSR, comparison to other data records

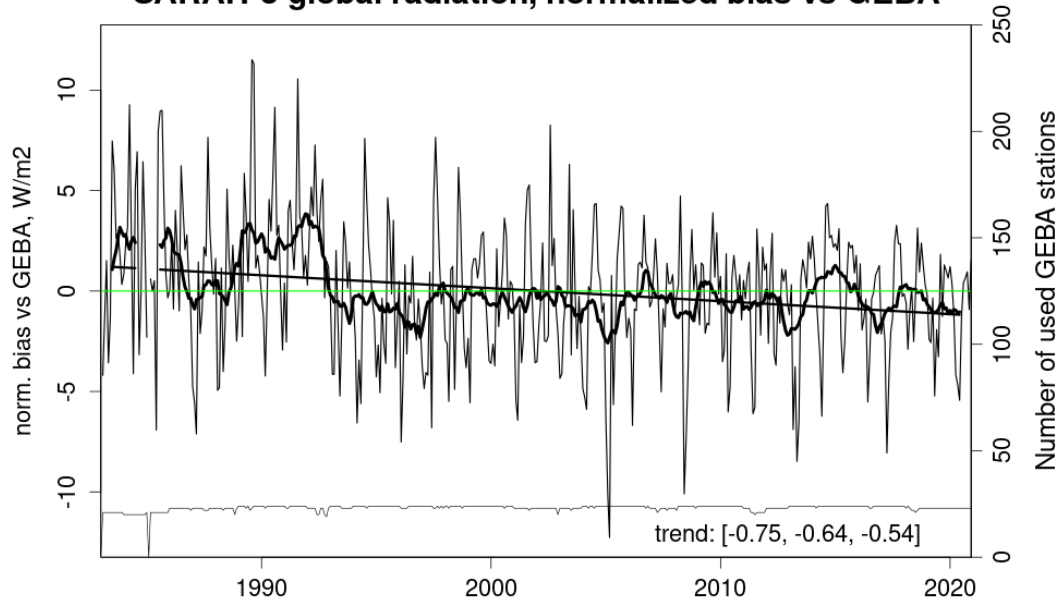
data	Mean SSR [W/m ²]	Bias [W/m ²]	MAD [W/m ²]	RMSE [W/m ²]	MAD [W/m ²]	RMSE [W/m ²]
ERA-5	134.4	2.7	19.3	27.8	7.1	9.2
CAMS-RAD 4.6	134.3	2.3	10.5	14.5	5.9	7.3
SARAH-3	134.4	2.7	10.9	15.2	5.9	7.2
CLARA-A3	133.3	1.0	11.8	16.6	5.0	6.4
SARAH-2.1	133.8	2.1	11.3	15.6	5.9	7.3
CLARA-A2.1	133.0	-2.5	12.9	18.1	5.8	7.6

Courtesy: Ruben Urraca; numbers taken from Urraca et al., 2024, under review



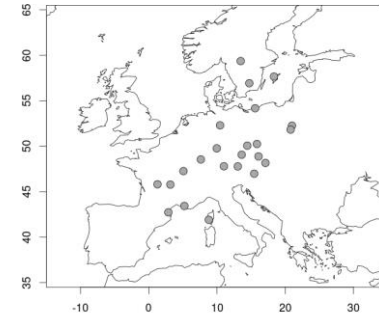
Trends and variability of global radiation in Europe: Comparison with GEBA*

SARAH-3 global radiation, normalized bias vs GEBA



- Reasonable agreement
- Small negative trend in the bias (-0.64 W/m²/decade)
- Higher deviations in early years

GEBA-stations used for Trendraster-Plots



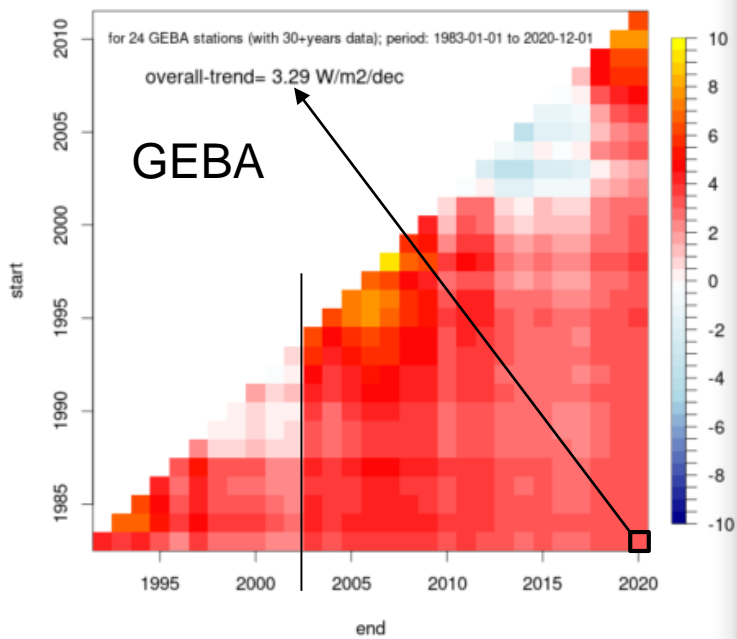
Selection of GEBA-stations in cooperation with R. Urraca

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

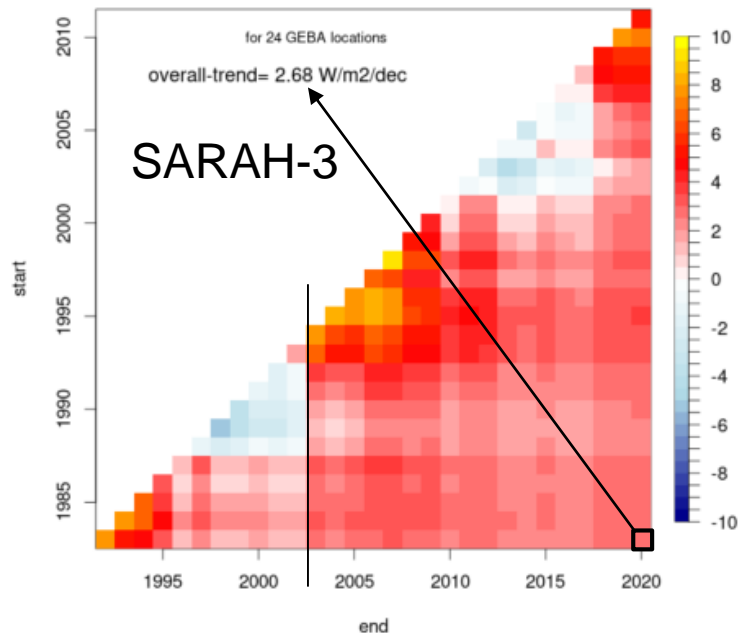


Trends and variability of global radiation in Europe: Comparison with GEBA*

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

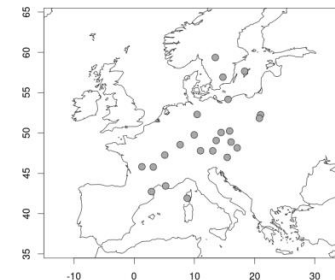


SARAH-3 SIS Trendraster-Plot [W/m²/decade], Europe, 1983-2020



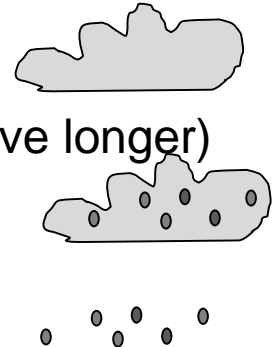
➤ **Good agreement !**

GEBA-stations used for Trendraster-Plots



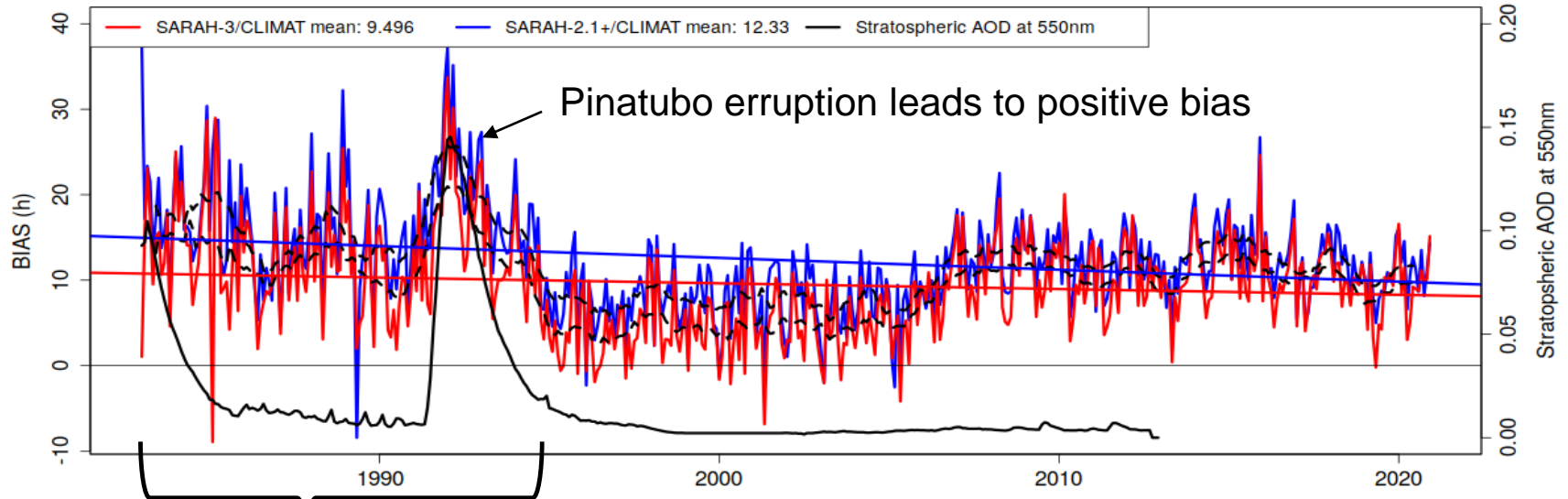
Discussion on causes for positive trend in surface radiation in last 3 to 4 decades (given the SARAH-3 data record and algorithm):

- **Clouds** mostly determined variability and trend
- **Aerosol indirect effects** observed through clouds (brighter and live longer)
- **Aerosol direct effect** not accounted for in SARAH data record
 - Underestimation of trend (~20 %)
- **Challenges**
 - Aerosol data quality and availability for the full satellite-era
 - Stability of satellite data records
 - Reference data quality and availability



Effect of aerosol on bias in SARAH-3 Sunshine Duration

BIAS, SDU (1983-2020)

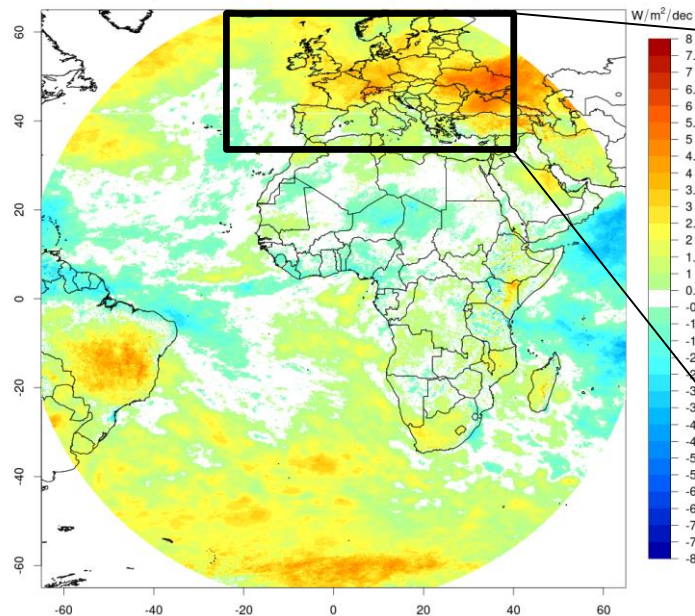


More deviations in early years of data record



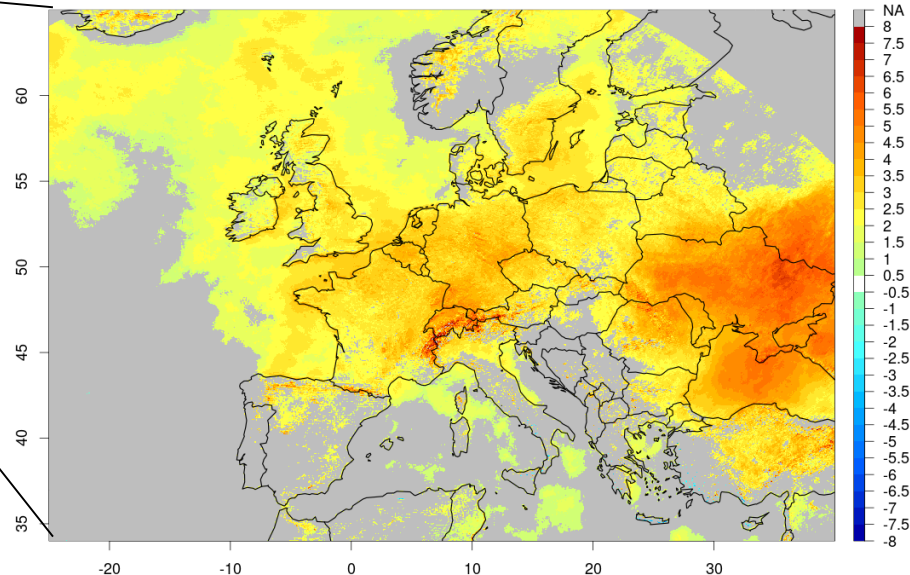
Trend (1991-2020) in global irradiance from SARA-3

Trend [W/m²/dec] in Global Radiation, SARA-3, 1991-2020



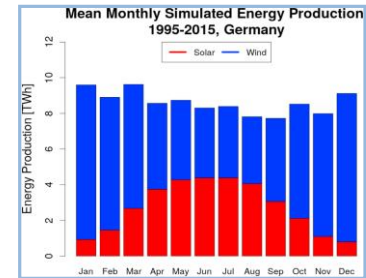
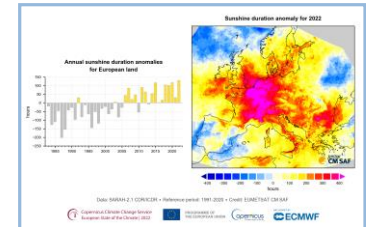
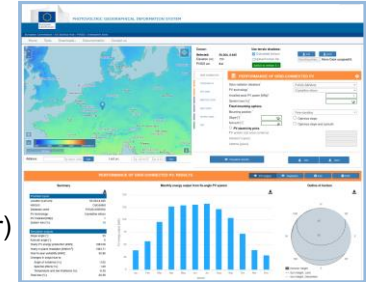
Trend of the global radiation, 1991-2020

Data source: EUMETSAT CM SAF SARA-3 || Unit: W/m²/decade || Colored: Significant trends



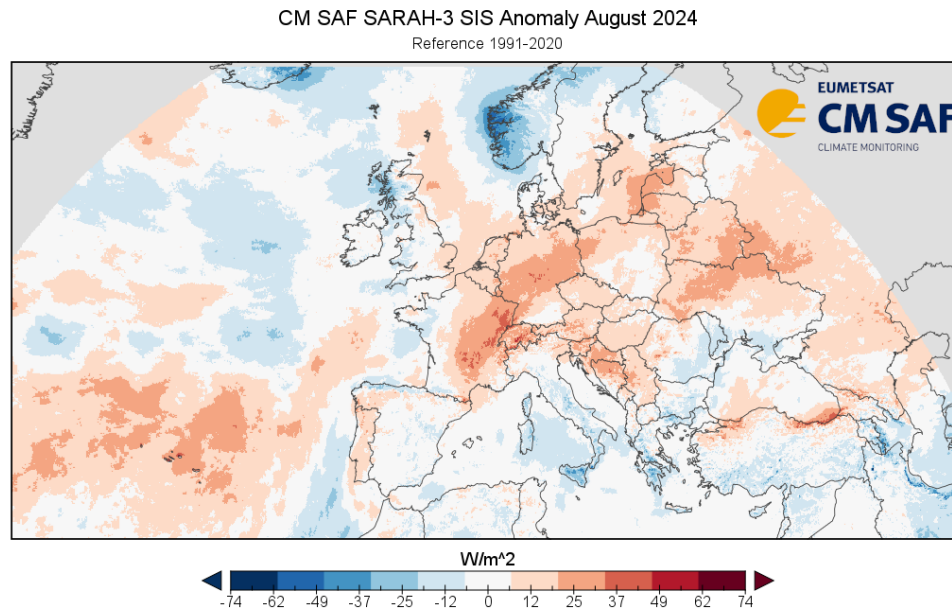
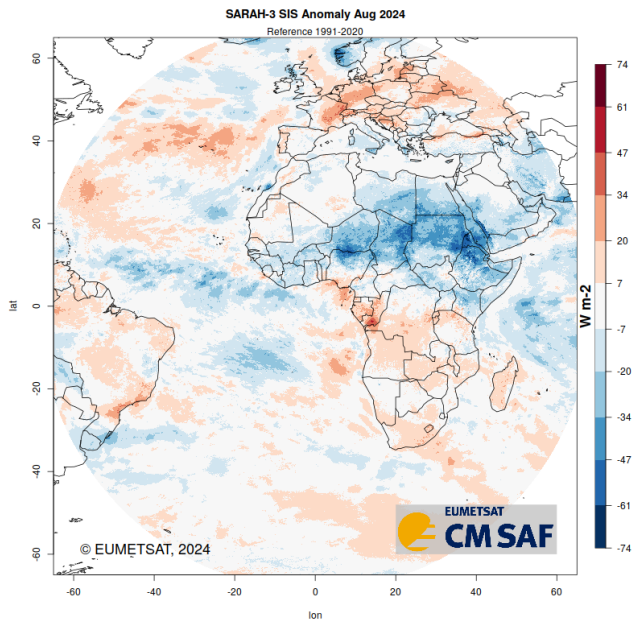
Application of the CM SAF radiation data records

- 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 reports, WMO Regional Climate Center)
- 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](#)
- Many peer-reviewed publications

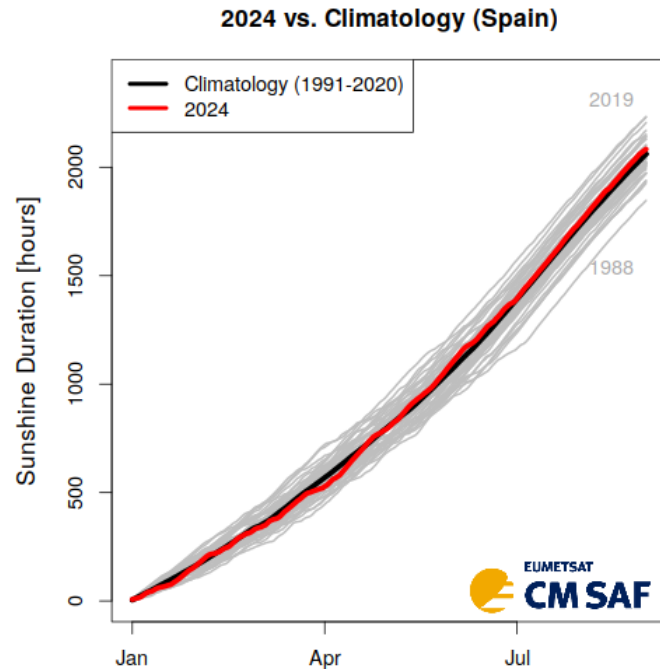
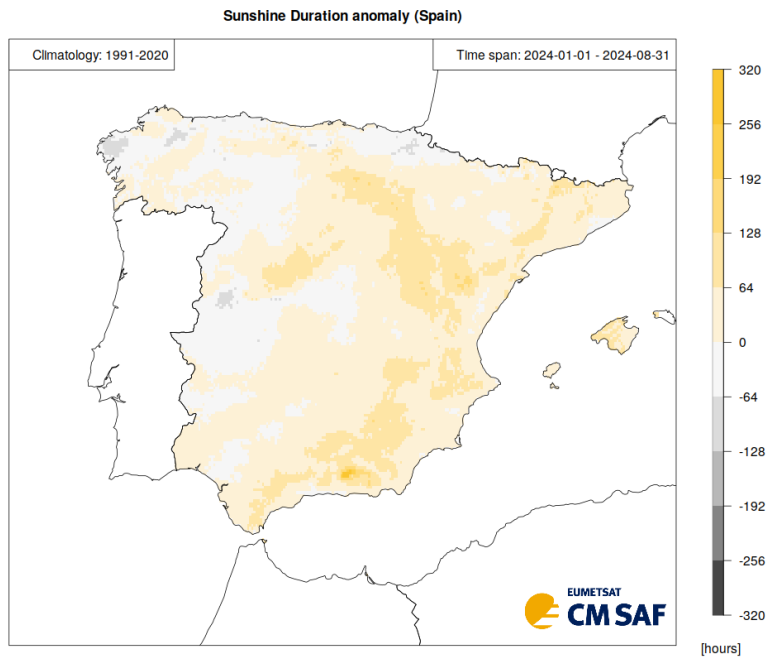


Anomaly Service ...currently set up in close cooperation with EUMETSAT

Surface solar radiation anomaly **August 2024** (Reference period:1991-2020)

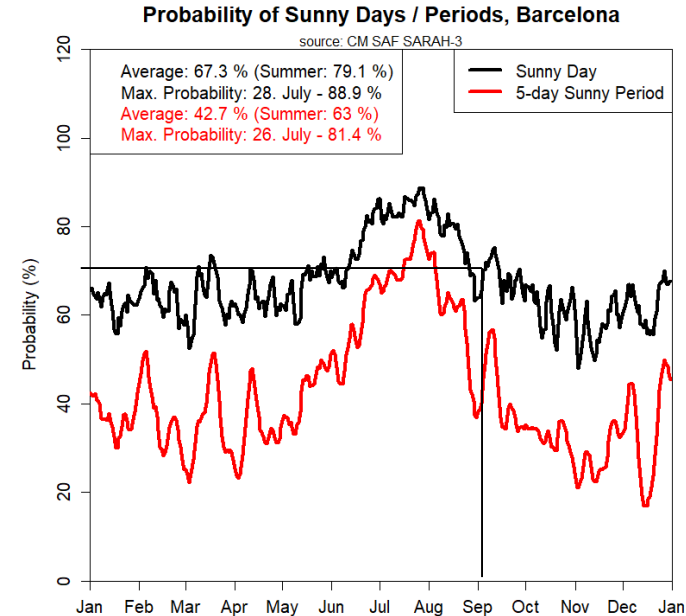


Sunshine duration for Spain for 2024



Summary

- ➔ **SARAH-3** provides various surface radiation parameters for a wide range of applications
- ➔ offers **high quality** and covers more than 40 years
- ➔ covers the current **climate normal period**
- ➔ provides **consistent near-realtime** processing of all parameters (ICDR)
- ➔ data **freely available** via <https://wui.cmsaf.eu>
- ➔ **DOI:** 10.5676/EUM_SAF_CM/SARAH/V003
- ➔ **ESSD paper:** Pfeifroth et al. 2024 [preprint], <https://doi.org/10.5194/essd-2024-91>



CM SAF 1-day Workshop on 24th October 2024



**Workshop on latest developments on
satellite climate data supporting climate
services and NMHSs**

Date: 24 October 2024

Location: Deutscher Wetterdienst, Offenbach, Germany & Online

