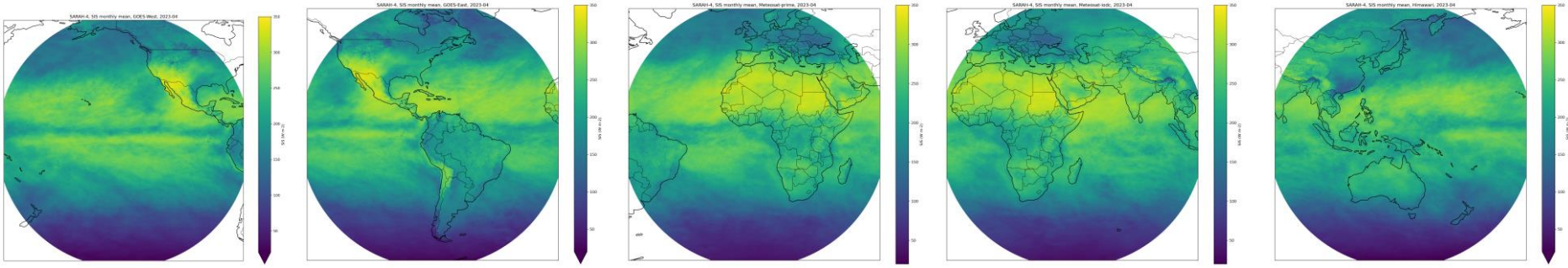
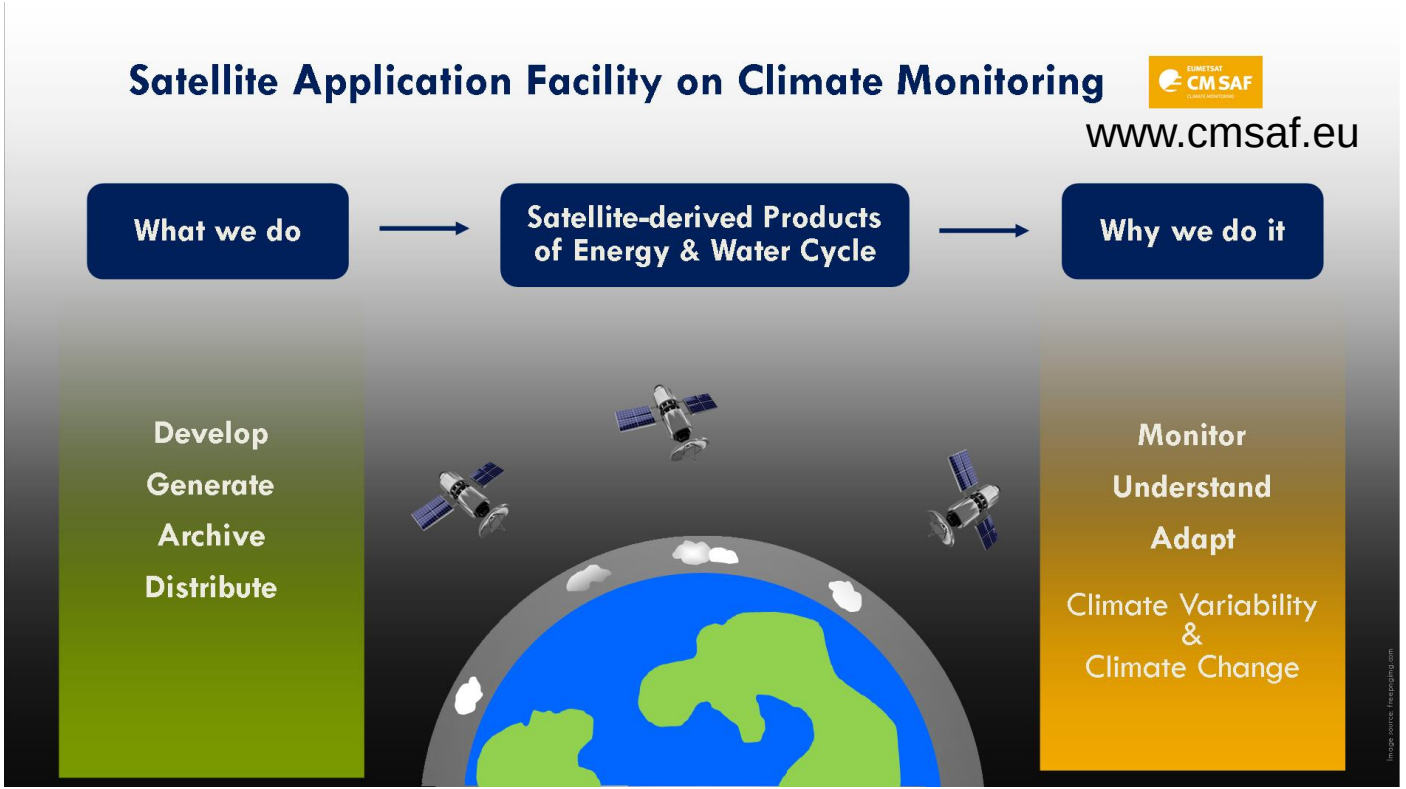
Satellite-based surface solar radiation data records from the CM SAF – developing towards the new SARAH-4 climate data record

Uwe Pfeifroth, Jens Eller, Beke Kremmling and Jörg Trentmann

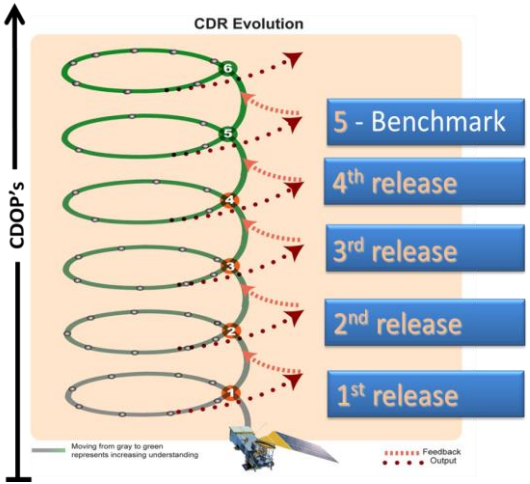
Deutscher Wetterdienst, Climate and Environment, Offenbach, Germany




Satellite Application Facility on Climate Monitoring
EUMETSAT CM SAF
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

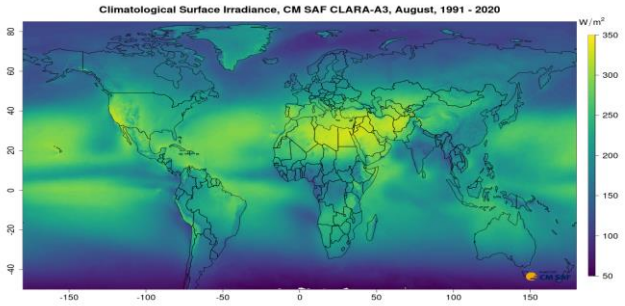
CM SAF data records of surface solar radiation

- **CLARA**-A3: CM SAF cLoud, Albedo and surface RAdiation dataset from AVHRR data – Edition 3
- **SARAH**-3: Surface Radiation Data Set - Heliosat - Edition 3
- **HANNA**: High-Resolution European Surface Radiation Data Record



CM SAF Data Records including Surface Solar Radiation

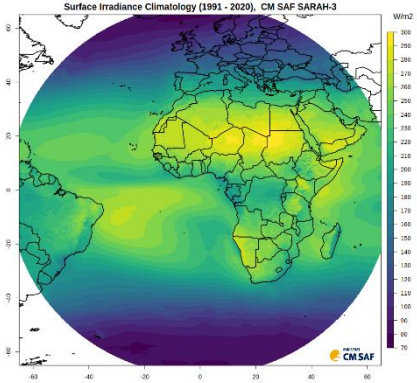
CLARA-A3



- 1979 to date
- 0.25°
- daily, monthly
- Radiation (ToA, Surface), Albedo, Clouds

DOI:10.5676/EUM_SAF_CM/CLARA_AVHRR/V003

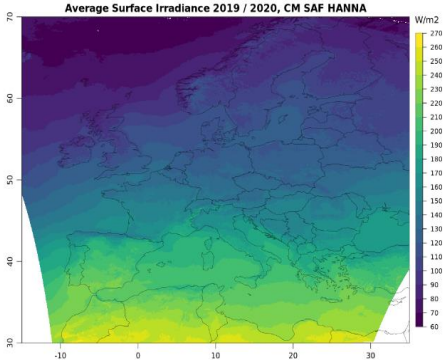
SARAH-3



- 1983 to date
- 0.05°
- 30 min, daily, monthly
- Surface Solar Radiation

DOI:10.5676/EUM_SAF_CM/SARAH/V003

HANNA

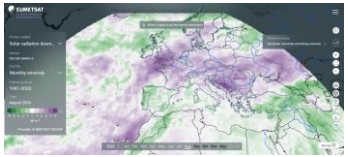


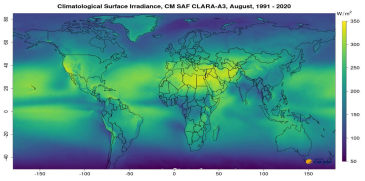
- 2019 + 2020
- 0.01°
- 15 min, daily, monthly
- Surface Solar Radiation

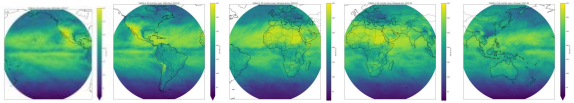
https://www.cmsaf.eu/demo_hanna

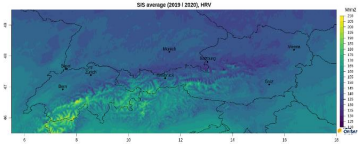
Developments

- **CM SAF / EUMETSAT Climate Anomaly Service** (can.eumetsat.int)
- **CLARA-A3.5** updated data record will include „**VIIRS instruments**“ + ICDR (planned release 2027)
- **SARAH-4** will be provided for five geostationary orbits (**geo-ring**) + Meteosat ICDR (planned release 2027)
- Extend **HANNA** to become a full **climate data record** + ICDR (tbd, release 2029+)

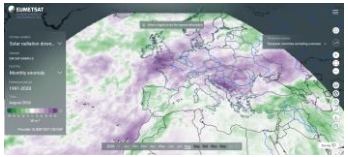








Developments



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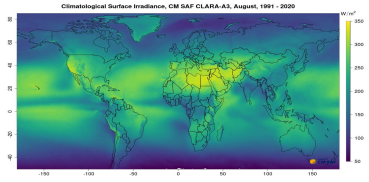

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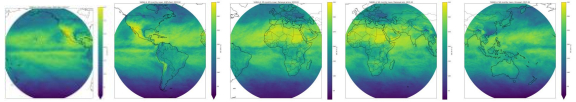

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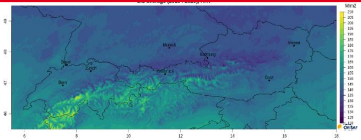

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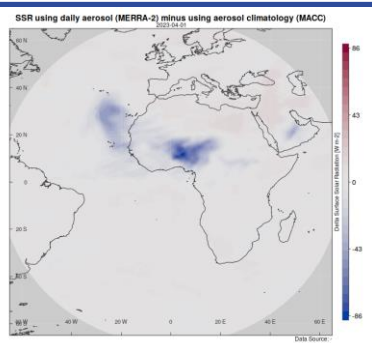
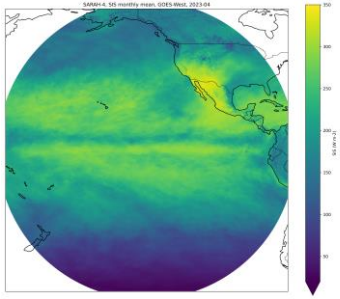
SARAH-4 main developments

- Further improvements in case of snow
- Daily varying aerosol input
- 5 geostationary orbits
- Correction at higher viewing angles and low sun elevation



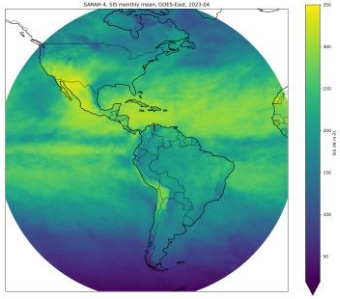
Aerosol impact on surface radiation: climatology vs. daily mean

Western Pacific



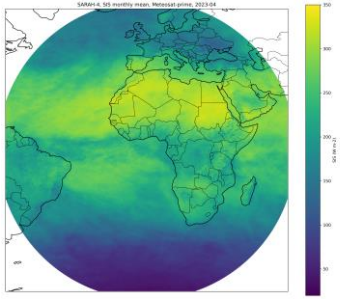
GOES-West

Americas



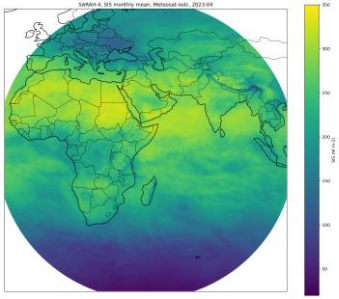
GOES-East

Europe, Africa



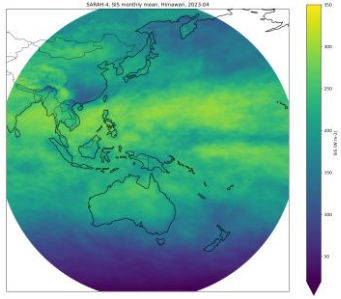
METEOSAT

Africa, Indian Ocean



METEOSAT-IODC

Eastern Pacific



HIMAWARI

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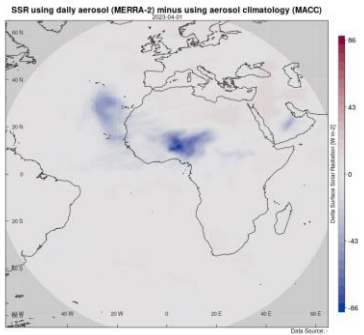
- 5 geostationary orbits
- Correction at higher viewing angles and low sun elevation



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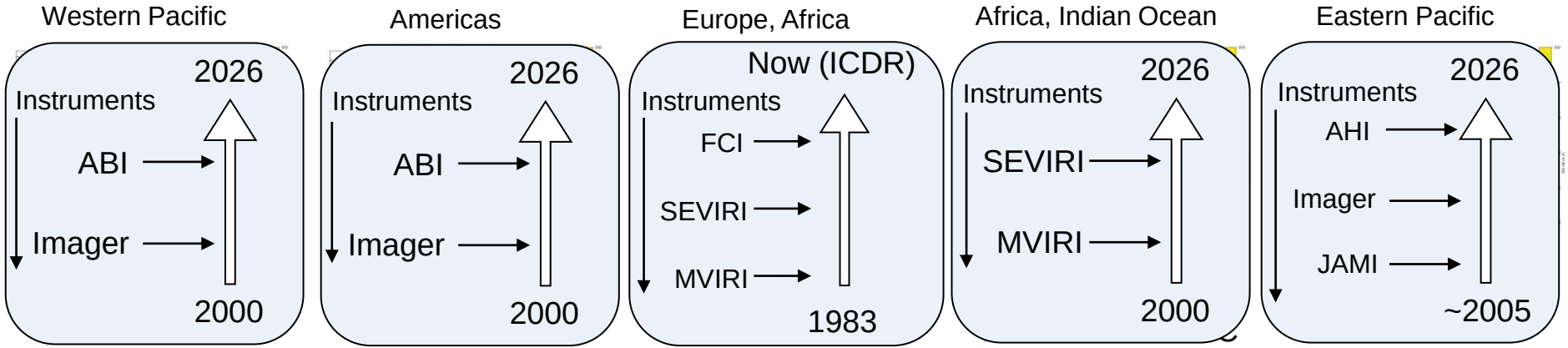
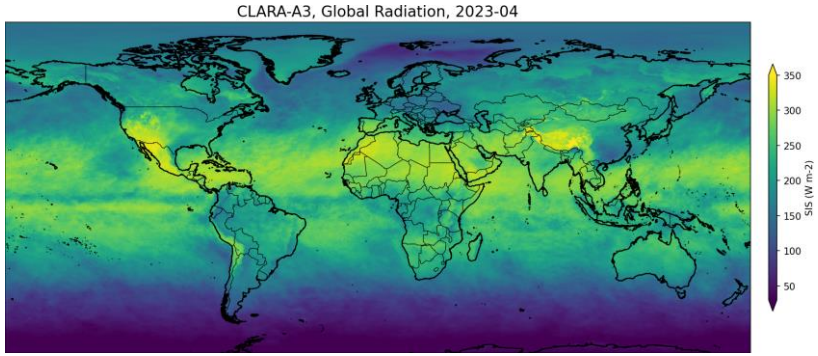
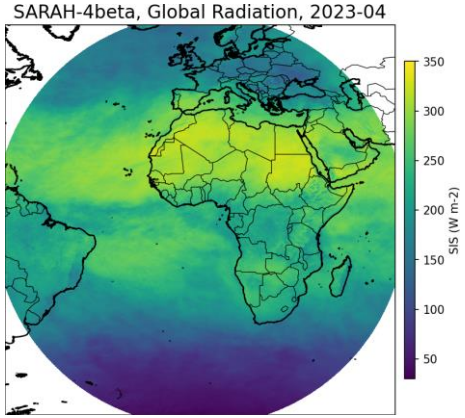


Comparisons for 2023-04

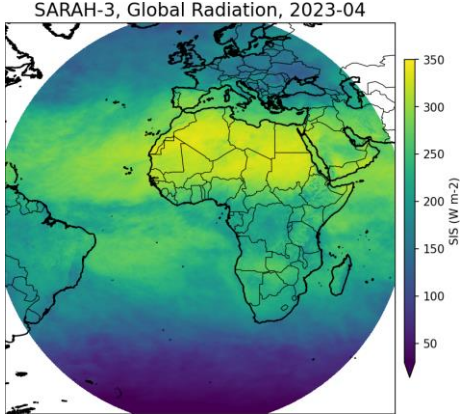
CLARA-A3



SARAH-4beta

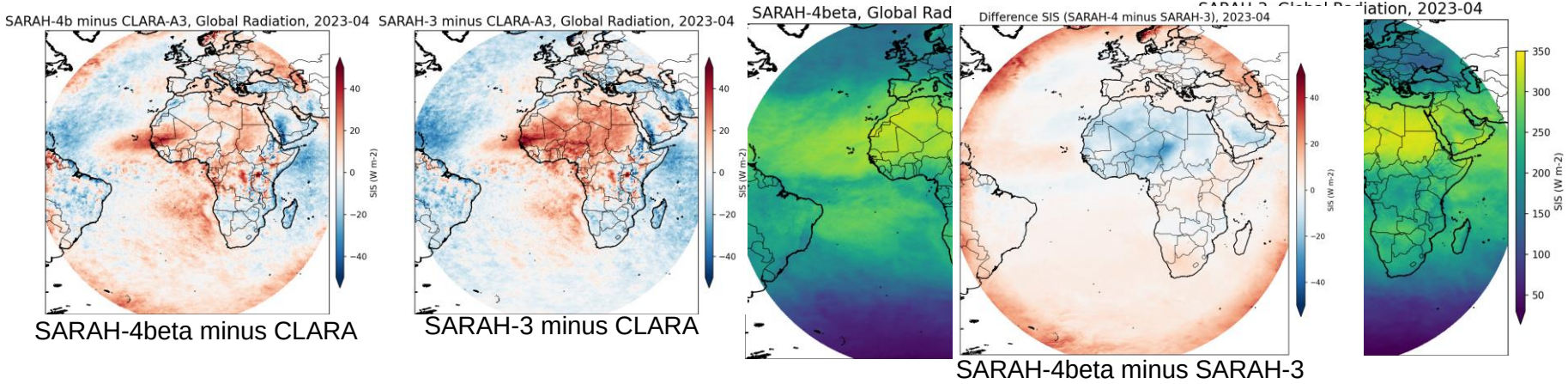


SARAH-3



Comparisons for 2023-04

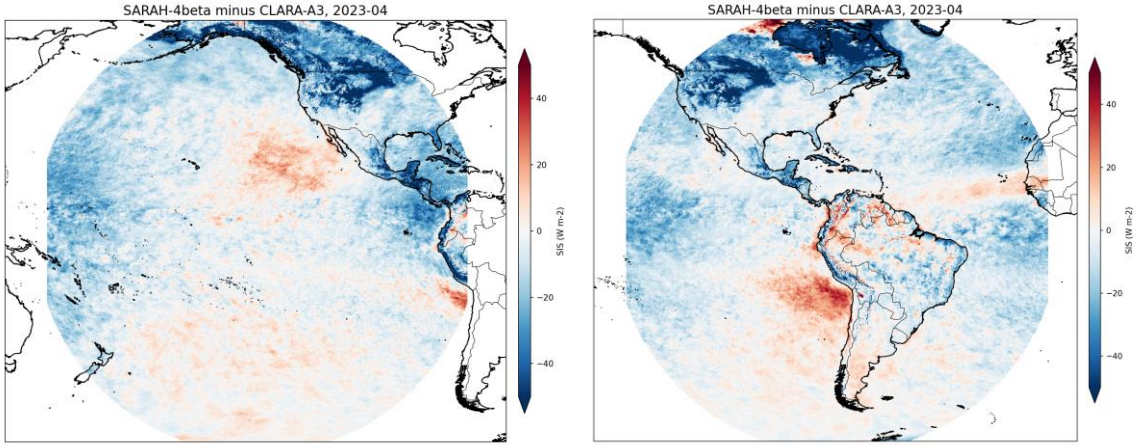
CLARA-A3 | **SARAH-4beta** | **SARAH-3**



SARAH-4beta minus CLARA | SARAH-3 minus CLARA | SARAH-4beta minus SARAH-3

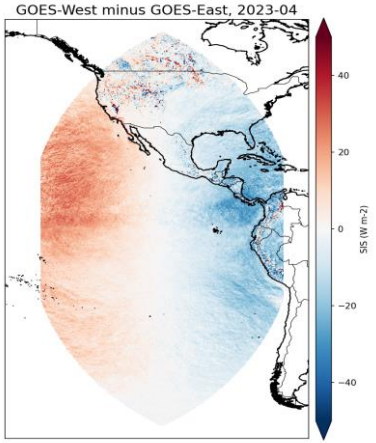
- Better agreement in North Africa between SARAH-4beta and CLARA-A3 (new aerosols)
- Higher values in stratocumulus regions off western coasts of Africa (better sampling in SARAH compared to CLARA)
- SARAH-4beta has higher values at borders of METEOSAT field-of-view (overcorrection –> in developement)

GOES-Comparison: SARAH-4beta vs CLARA-A3



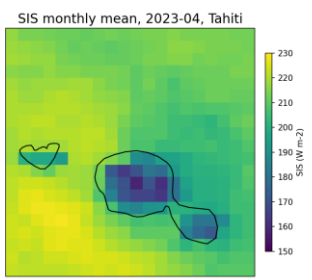
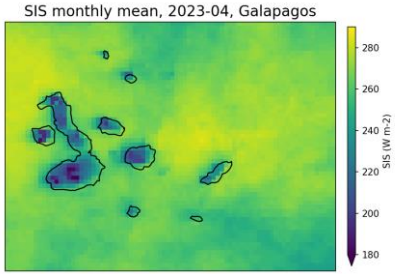
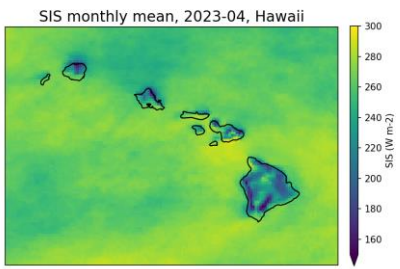
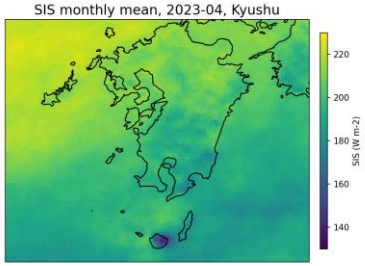
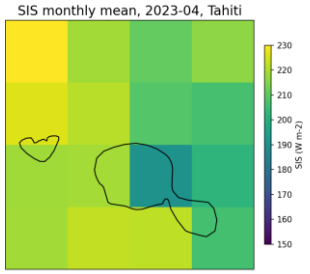
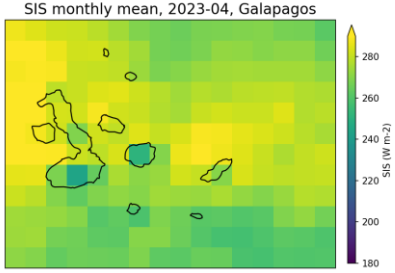
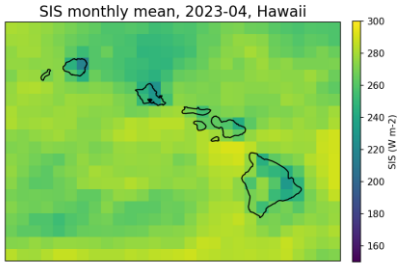
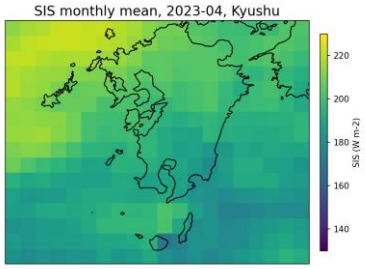
- Snow detection not yet activated
- Higher values in stratocumuls regions in SARAH-4beta

SARAH-4beta overlapping areas



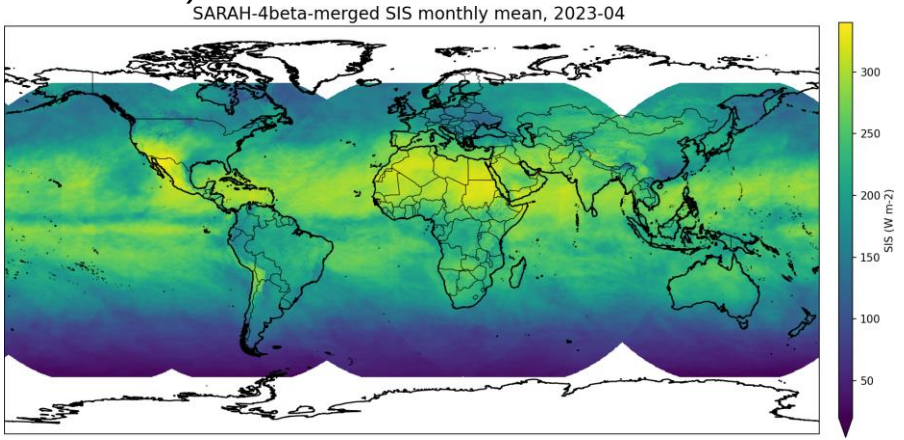
- Lower surface radiation values at lower viewing angles (Similar viewing angles -> Similar values)

SARAH-4 - high spatial resolution, globally

	Tahiti	Galapagos	Hawaii	Kyūshū
SARAH 0.05°x 0.05°				
CLARA 0.25°x 0.25°				

Summary

- **CM SAF** data records provide surface radiation parameters for a **wide range of applications**
- Data have **high quality** and cover more than **4 decades,** regularly **extended**
- **Anomaly Service**
- **SARAH-4 Developements ongoing (**planned release 2027)
- Data **freely available** via https://wui.cmsaf.eu



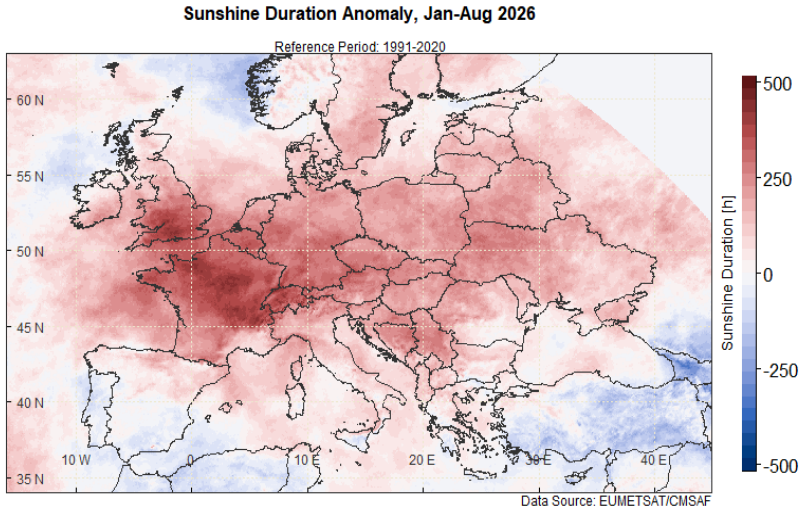
Outlook

- **Update of CLARA** to Version 3.5
- **SARAH-4** for the **Geo-ring**
- **HANNA** to provide **0.01°** resolution for Europe

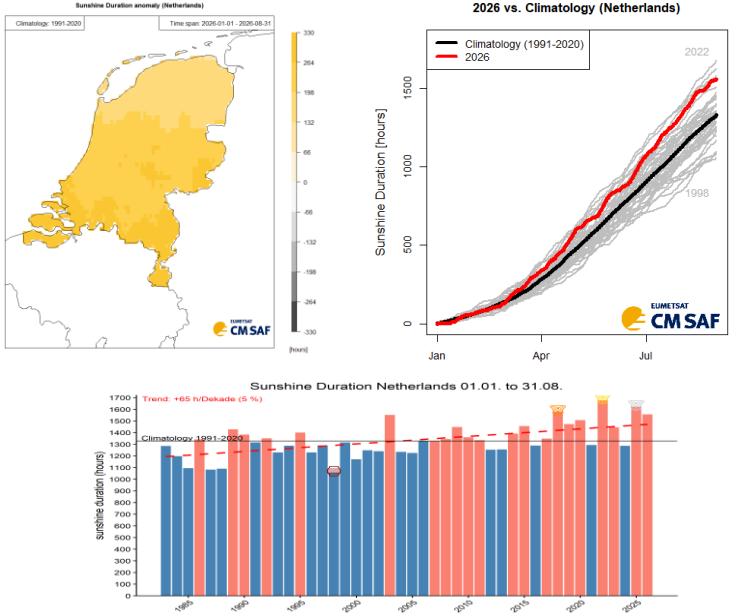
Insight into recent data (CDR + ICDR)

2026 Jan to Aug – Sunshine Duration Anomalies *based on SARAH-3 CDR+ICDR*

Europe



Netherlands



Thank You!

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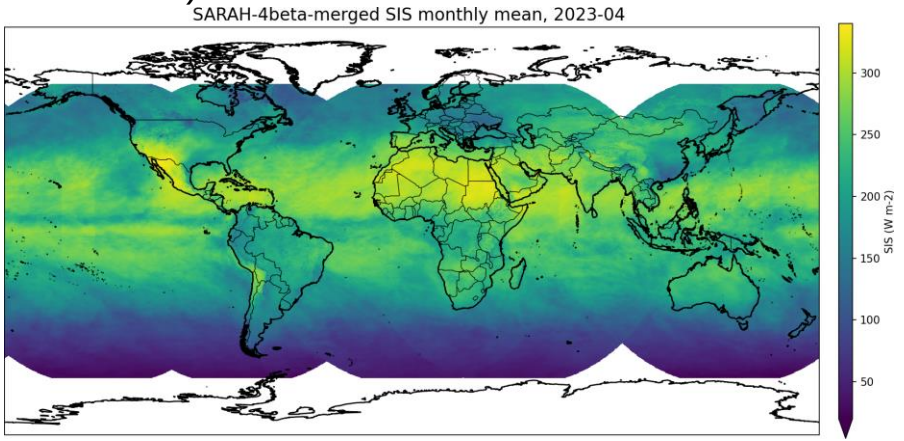
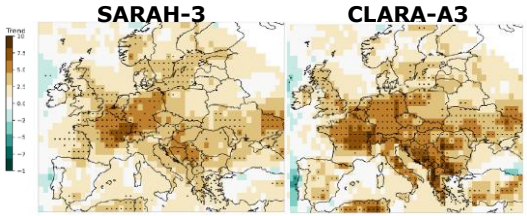


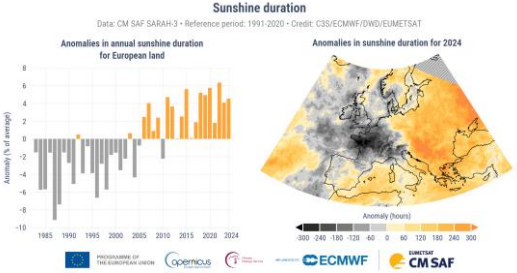
Selected Application of Surface Radiation Data

Climate analysis



Urraca et al., 2023

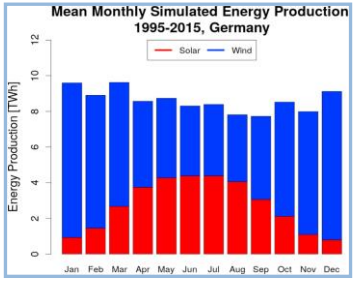
Climate monitoring



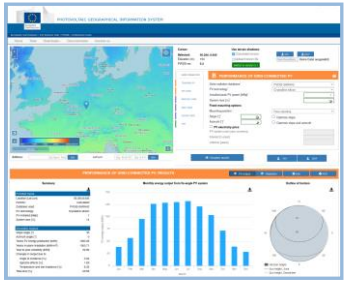
Copernicus European State of the Climate 2024

+300 scientific articles

Solar energy

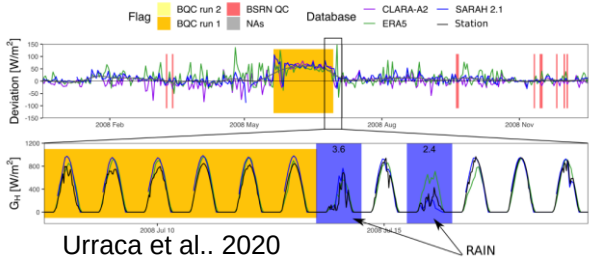


Drücke et al., 2021



PV-GIS

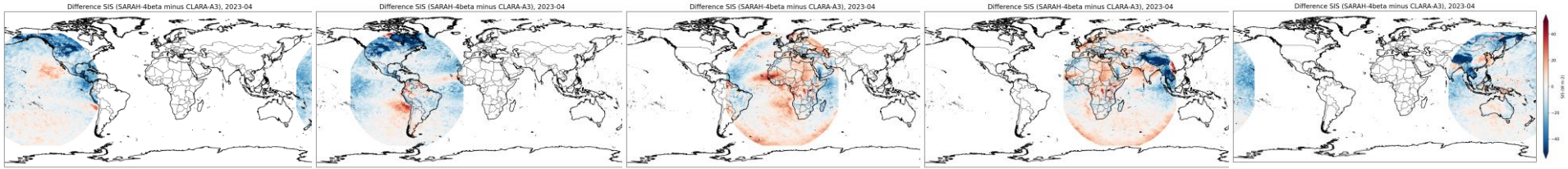
QC of station data



Urraca et al.. 2020

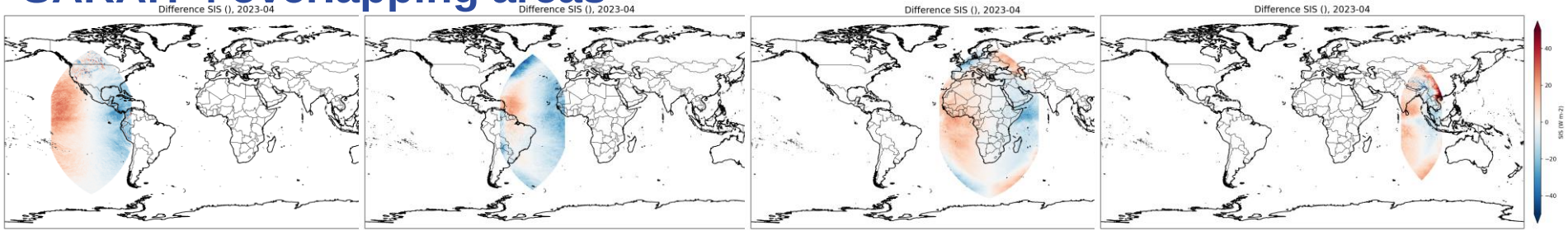
SARAH-4 vs CLARA-A3

GOES-West | GOES-East | METEOSAT | METEOSAT-IODC | HIMAWARI



- Higher values in stratocumuls regions
- Snow detection not yet activated (beside METEOSAT)

SARAH-4 overlapping areas



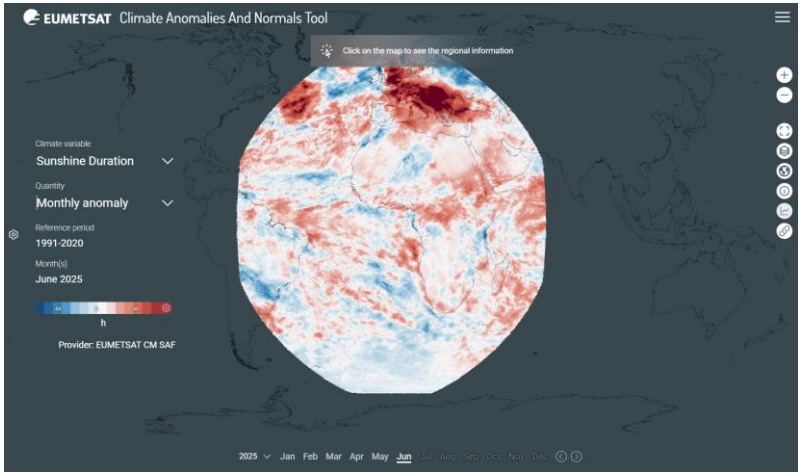
- Lower surface radiation values at lower viewing angles (Similar viewing angles -> Similar values)

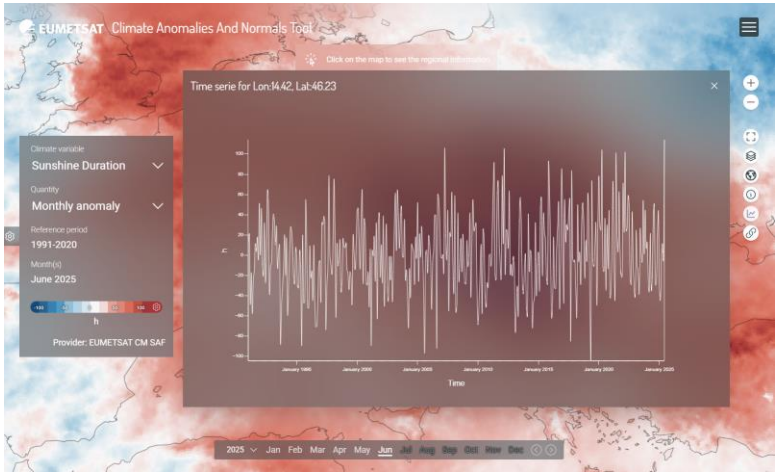
Which data to use for what ?

- **CLARA** -- for studies needing **global data and longest possible time series** (46+ years) + regular extentions (timeliness ~ 7 days), while a moderate resolution is sufficient; Data access: https://doi.org/10.5676/EUM_SAF_CM/CLARA_AVHRR/V003
- **SARAH** -- **for higher spatial and temporal resolution and additional surface radiation parameters** (e.g. direct radiation, sunshine duration) + regular extentions (timeliness ~ 2 days); Data access: https://doi.org/10.5676/EUM_SAF_CM/SARAH/V003
- **HANNA** -- currently a demo data set with **very high spatio-temporal (0.01°x0.01°, 15 min) resolution** (major benefits in rough terrain/topography);
  Data access: follow instructions on https://www.cmsaf.eu/demo_hanna

Anomaly Service

EUMETSAT will provide visualizer and underlying data from CM SAF and other SAFs





CLARA-A3

Variables

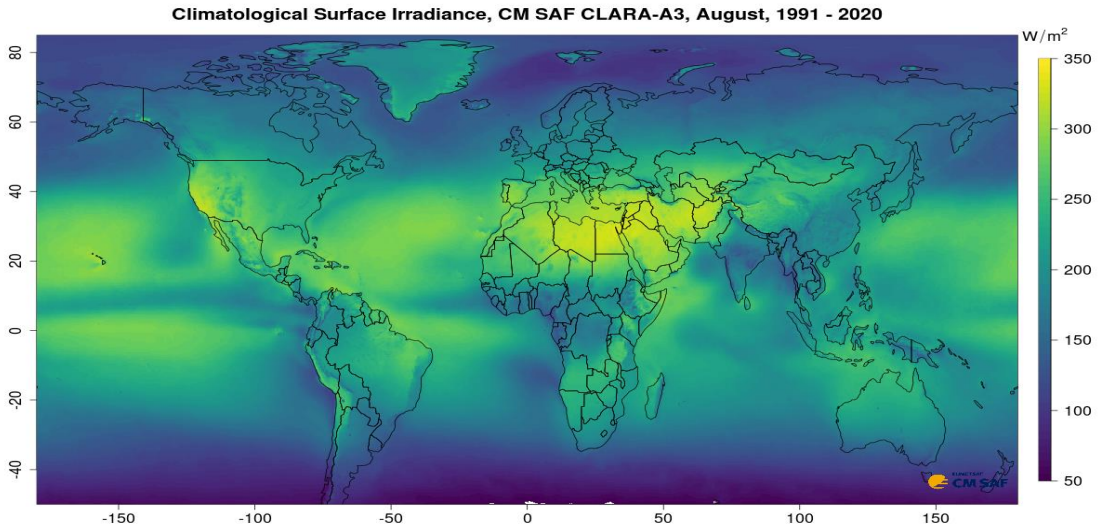
- Cloud properties (fraction, height, microphysical properties)
- Surface albedo
- Surface radiation
- TOA Radiation

Resolution

- Spatial: 0.25°×0.25° (+ polar projections 25 x 25 km)
- Temporal: daily, pentad, monthly

Coverage

- Spatial: global
- Temporal: 1979 to date



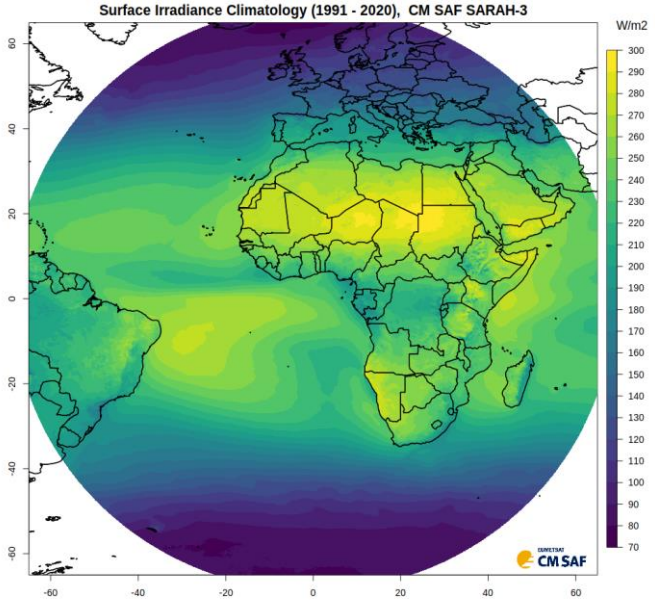
Karlsson et al. (2023): CLARA-A3: CM SAF cLoud, Albedo and surface RAdiation dataset from AVHRR data - Edition 3, Satellite Application Facility on Climate Monitoring, **DOI:10.5676/EUM_SAF_CM/CLARA_AVHRR/V003**

Karlsson, K.-G. et al., 2023: Earth Syst. Sci. Data, 15, 4901–4926, doi: 10.5194/essd-15-4901-2023

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)



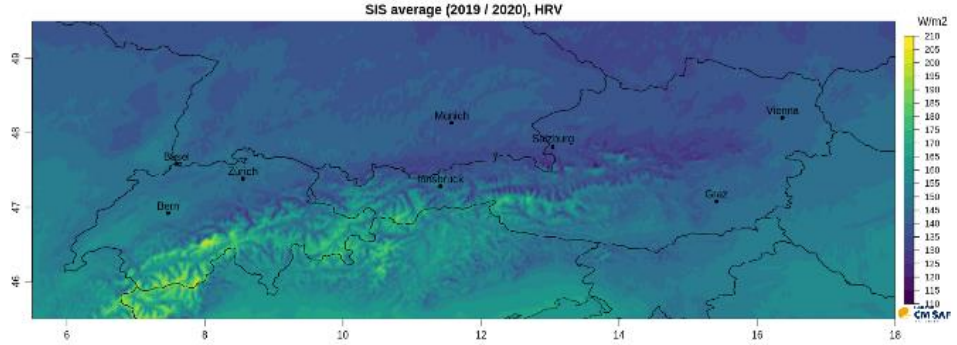
Pfeifroth, Uwe; Kothe, Steffen; Drücke, Jaqueline; Trentmann, Jörg; Schröder, Marc; Selbach, Nathalie; Hollmann, Rainer (2023): Surface Radiation Data Set - Heliosat (SARAH) - Edition 3, Satellite Application Facility on Climate Monitoring, **DOI:10.5676/EUM_SAF_CM/SARAH/V003**.

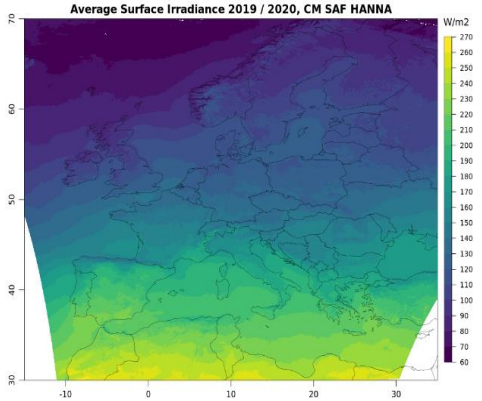
Pfeifroth et al., 2024, Earth Syst. Sci. Data, https://doi.org/10.5194/essd-16-5243-2024.

HANNA

Demonstrational data set

- **Variables**
  - Surface Solar Irradiance (SIS)
- **Resolution**
  - Spatial: 0.01° × 0.01°
  - Temporal: 15-min, daily-, monthly mean
- **Coverage**
  - Spatial: Europe
  - Temporal: 2019 + 2020

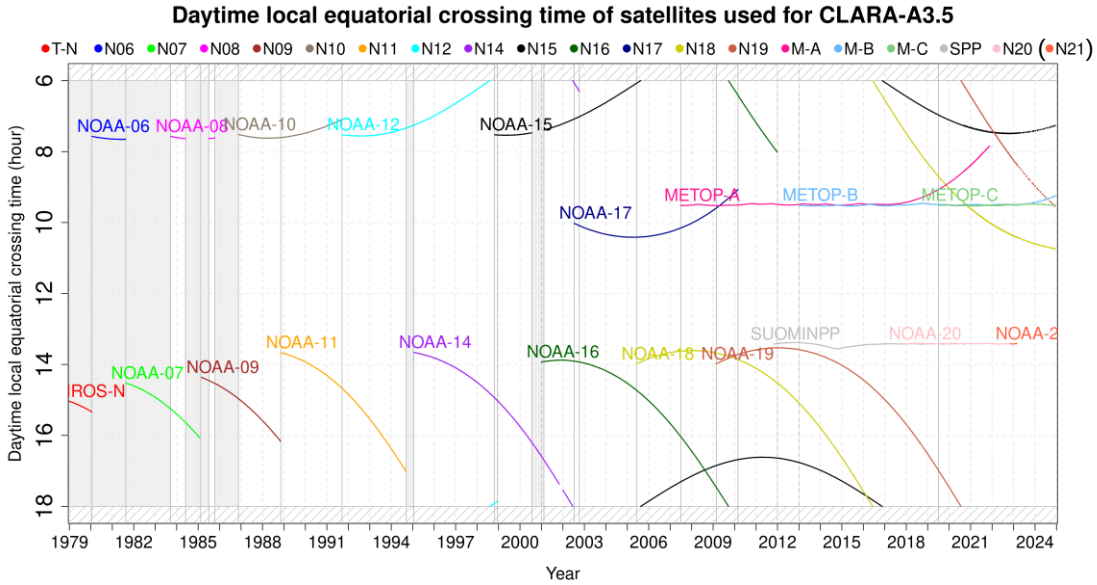




https://www.cmsaf.eu/demo_hanna

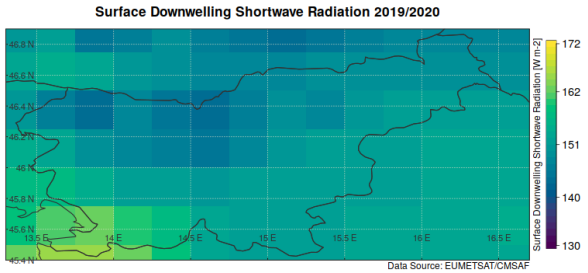
CLARA-A3.5 developements

➔ Consistently extended data record by using the VIIRS instruments (mapped on to AVHRR-channels), to regain afternoon coverage

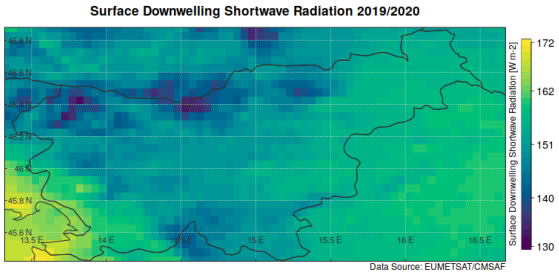


HANNA developements

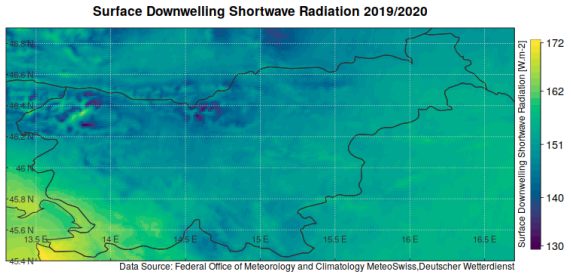
- Based on the feedback of the HANNA demonstrator data, a full climate data record (2005 onwards) including an ICDR is envisaged
- Climate data record to be based on MSG SEVIRI HRV and MTG FCI instruments on a 0.01°x0.01° grid, with a 15 min temporal resolution



CLARA (0.25°x0.25°)



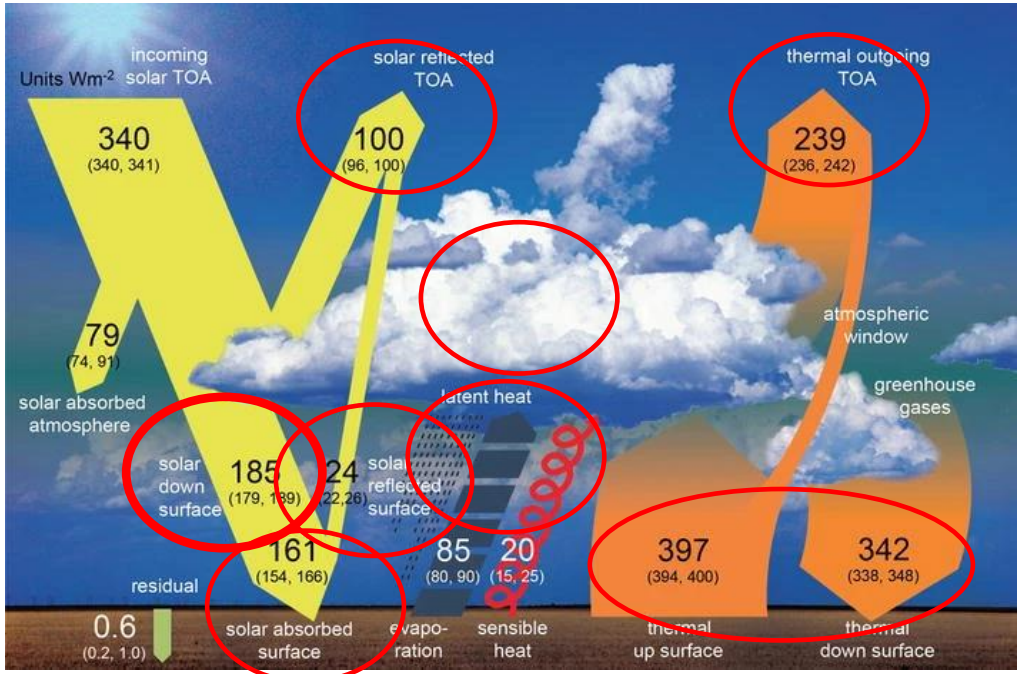
SARAH (0.05°x0.05°)



HANNA (0.01°x0.01°)

Energy Balance of the Earth-Atmosphere System

CM SAF provides data on many relevant parameters !



Source: Wild et al., 2013