EUMETSAT CM SAF
CLIMATE MONITORING

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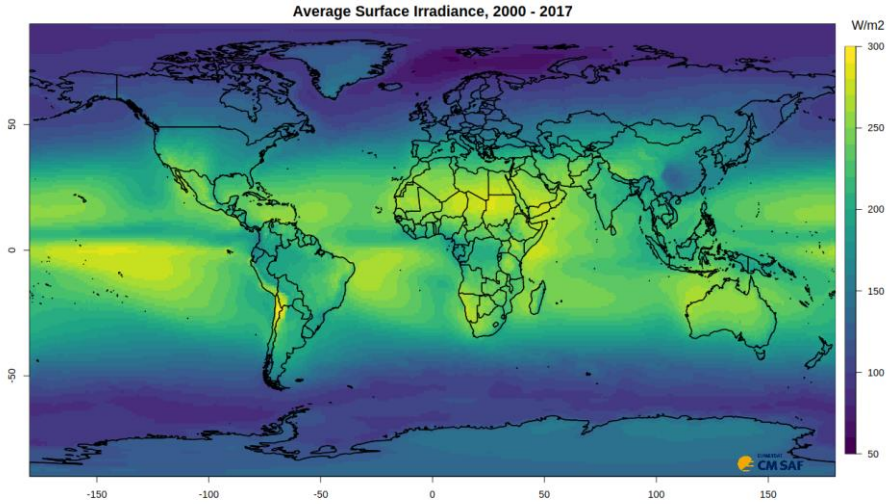
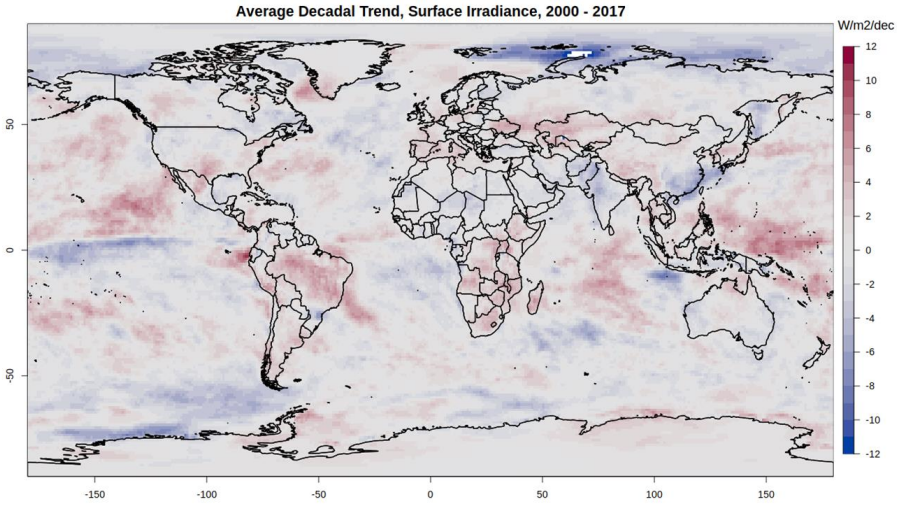
DWD

Assessing the quality of gridded Climate Data Records of Surface Irradiance using global Reference Data Sets

Jörg Trentmann, Uwe Pfeifroth





Introduction

Gridded climate data records of surface irradiance (either based on satellite measurements or derived from reanalysis) are available for the analysis of climate variability and climate trends. A thoroughful anaylsis of the quality of these data records is mandatory for the proper selection of data records and the interpretation of the results. Here, we assess the quality of six gridded data records by comparing them to surface radiation measurements from the GEBA archive.

Gridded Climate Data Records

Data Set	Coverage	Resolution
CM SAF CLARA-A3	1979 – ongoing	0.25 deg
CERES-EBAF, Edition 4.2	2000 – 2022	1 deg
GEWEX-SRB, Rel4-IP	1982 – 2017	1 deg
ESA Clouds CCI, V3	1982 – 2020	0.5 deg
ERA-5 Reanalysis	1959 – ongoing	0.25 deg
MERRA-2 Reanalysis	1990 - ongoing	0.625 / 0.5 deg

Reference Data

- Global Energy Balance Archive (GEBA, https://geba.ethz.ch/)*
- Data available since about 1950s
- Monthly surface irradiance data from > 1000 stations
- ‚Poor-mans' quality check applied

*We thank all contributors for collecting and providing surface radiation data! GEBA is co-funded by the Federal Office of Meteorology and Climatology MeteoSwiss within the framework of GCOS Switzerland.

Methodology

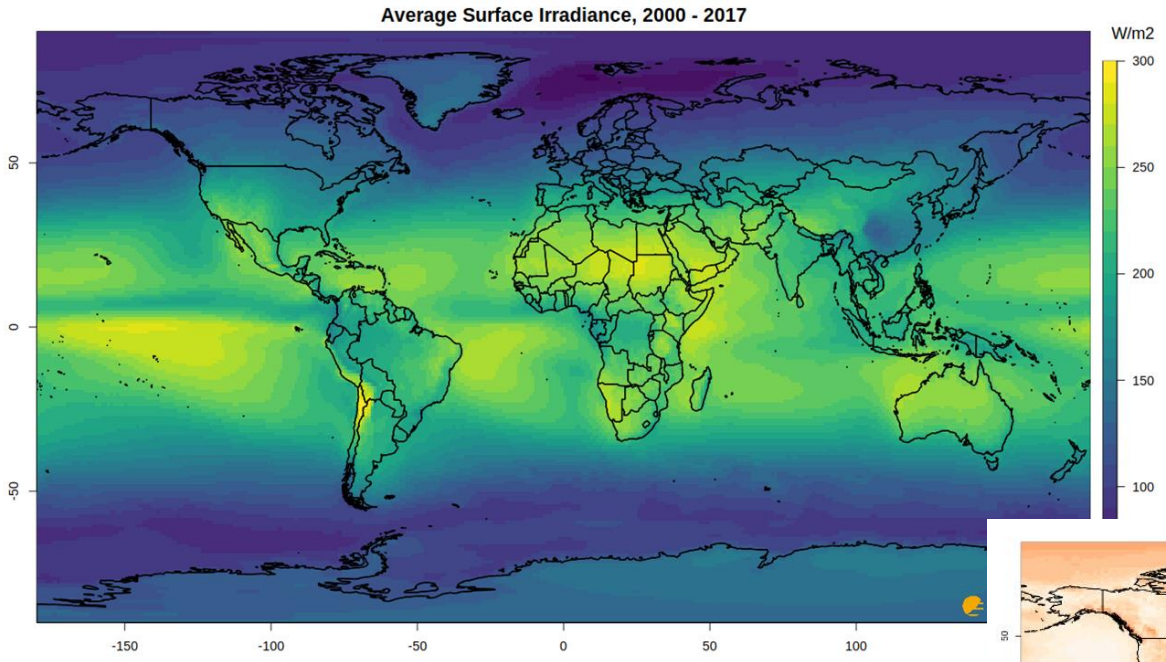
- Comparison with GEBA data for 2000 - 2017 and full period.
- Focus on accuracy, trend / stability
- Average irradiance derived w/o MERRA-2; average trend derived w/o MERRA-2 and GEWEX-SRB

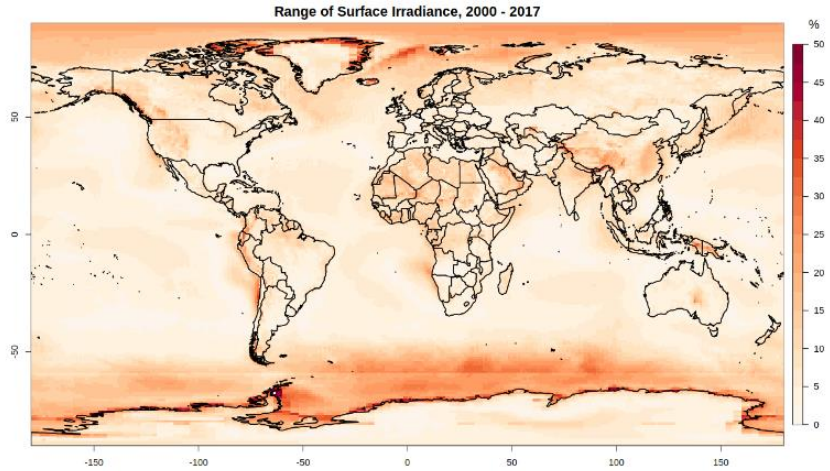
Validation Results, Surface Irradiance

	Full Time Period				2000 – 2017			
Data Set	#	bias [W/m²]	MAD [W/m²]	Stab. [W/m²/dec]	#	bias [W/m²]	MAD [W/m²]	Stab. [W/m²/dec]
CLARA-A3	226,872	5.2	11.6	[-0.3, -0.1, 0]	78,929	3.7	9.2	[-0.8,-0.3,0.1]
CERES	94,741	1.7	9.5	[-0.6, -0.3, 0]	79,644	1.8	9.7	[-0.5,-0.1,0.2]
GEWEX	190,727	6.3	14.1	[-0.5, -0.2, 0.2]	79,644	4.5	12.2	[-0.5, 0.3, 1.2]
ESA CCI	211,317	6.7	13.7	[-0.4, 0, 0.2]	79,644	4.5	11.3	[-1.8, -1.0, -0.2]
ERA-5	259,762	8.0	13.7	[-0.3, -0.1, 0.2]	79,644	7.2	11.9	[-2.1, -1.2, -0.3]
MERRA-2	228,844	22.4	25.7	[-1.4, -0.9, -0.3]	79,644	19.4	22.4	[-3.5, -1.6, 0.3]

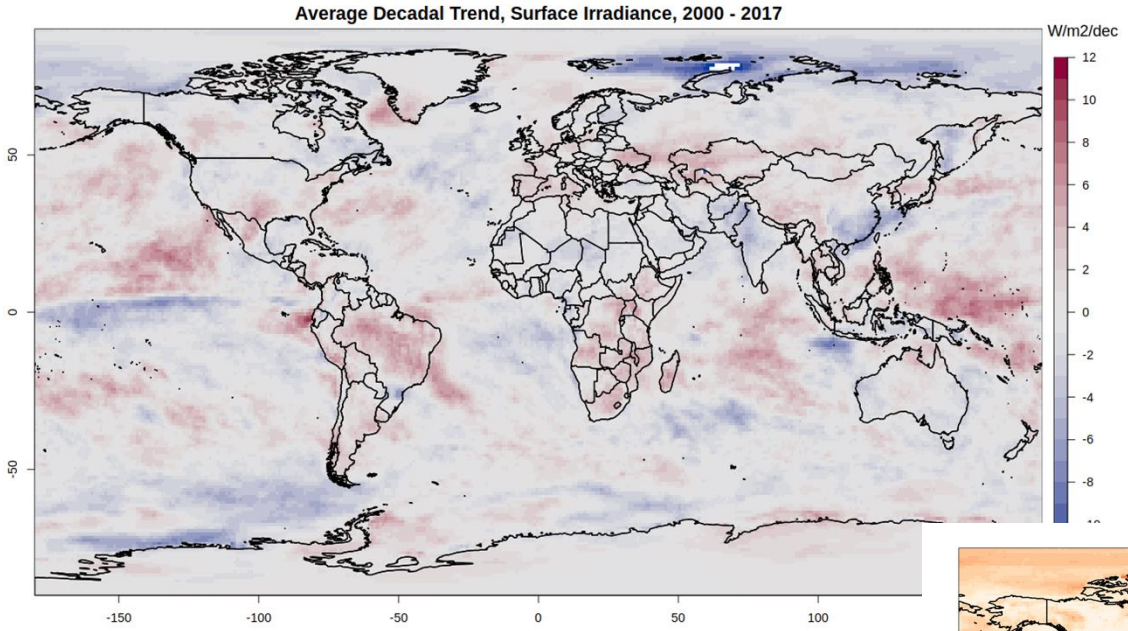
#: number of monthly data used for the evaluation, bias: mean difference; MAD: mean absolute difference; Stab: stability, derived from the linear trend of the bias (incl confidence interval)

Surface Irradiance, 2000 - 2017

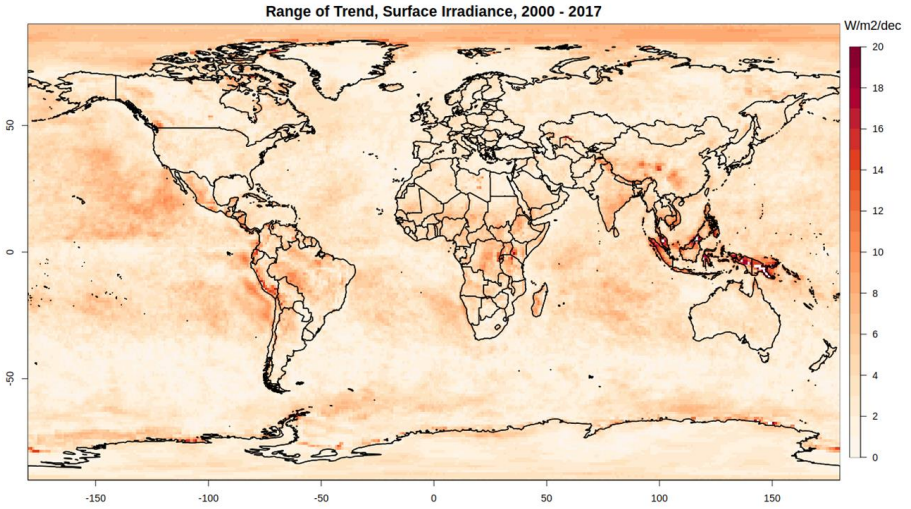




- Global average surface irradiance: 187.4 W/m^2
- Largest differences between gridded data over desert regions, East Asia, Sea Ice areas, West Coast of South America

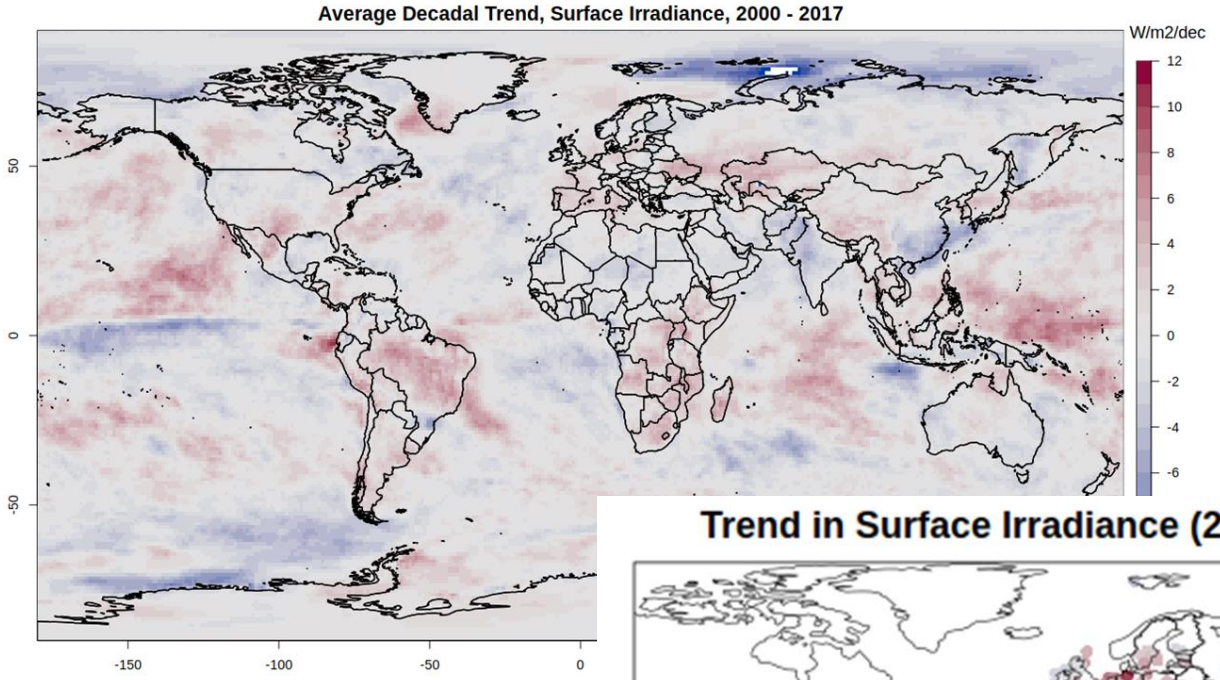


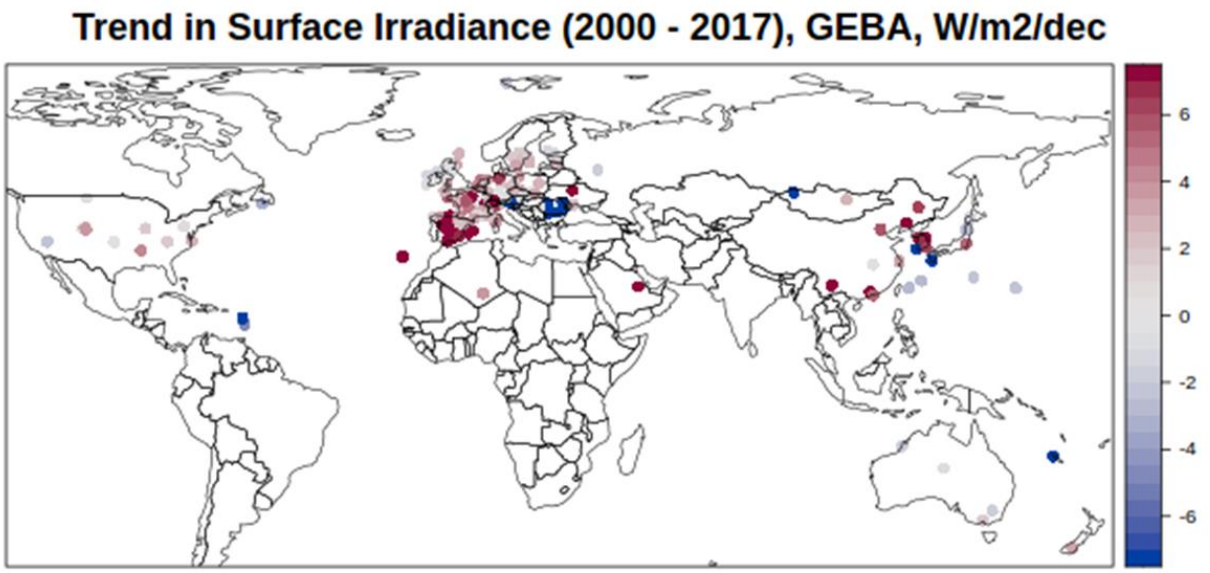
Average Trend, Surface Irradiance, 2000 - 2017



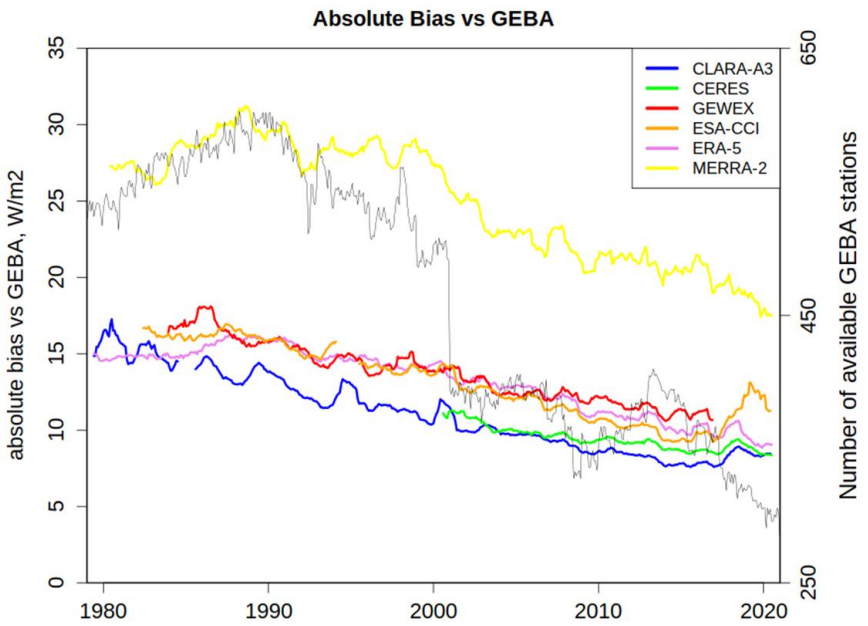
- Decadal trends spatially highly variable
- Large differences: Pacific, Indonesia, South America, Central Africa.

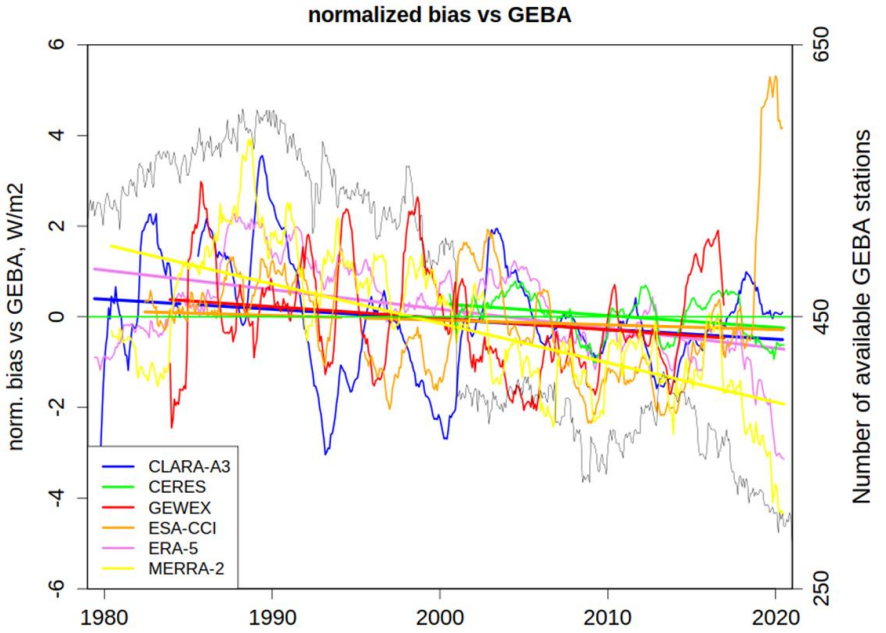
Average Trend, Surface Irradiance, 2000 - 2017





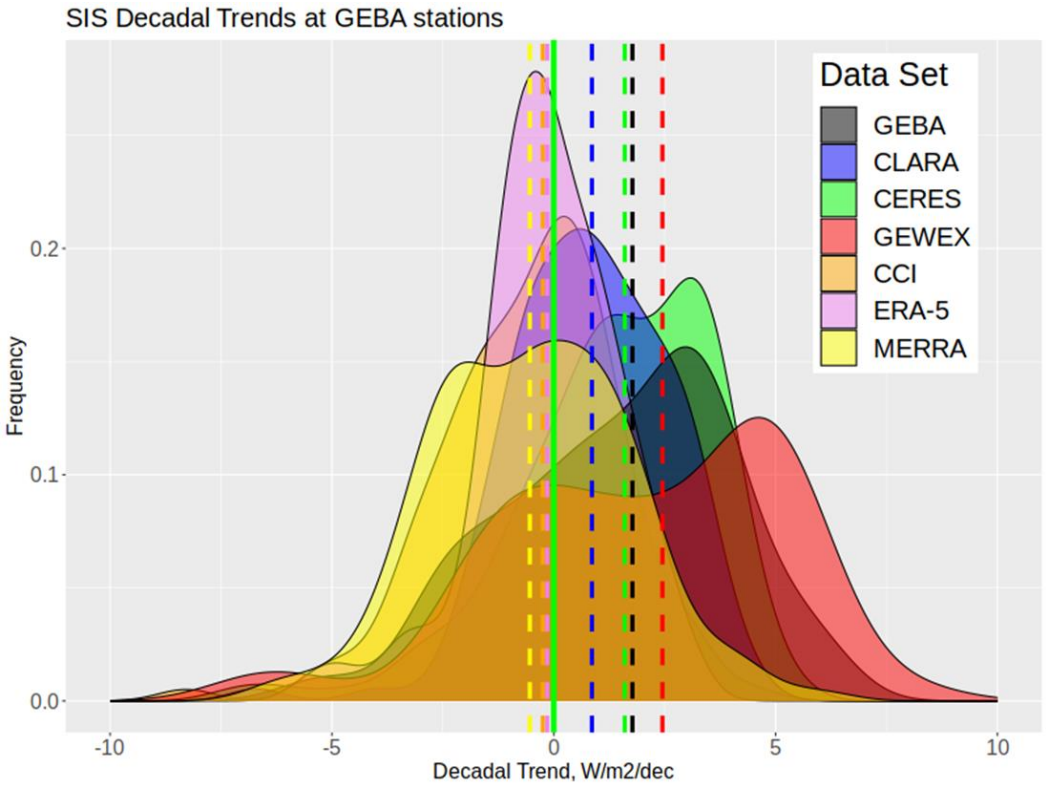
Temporal evolution of absolute bias, normalized bias





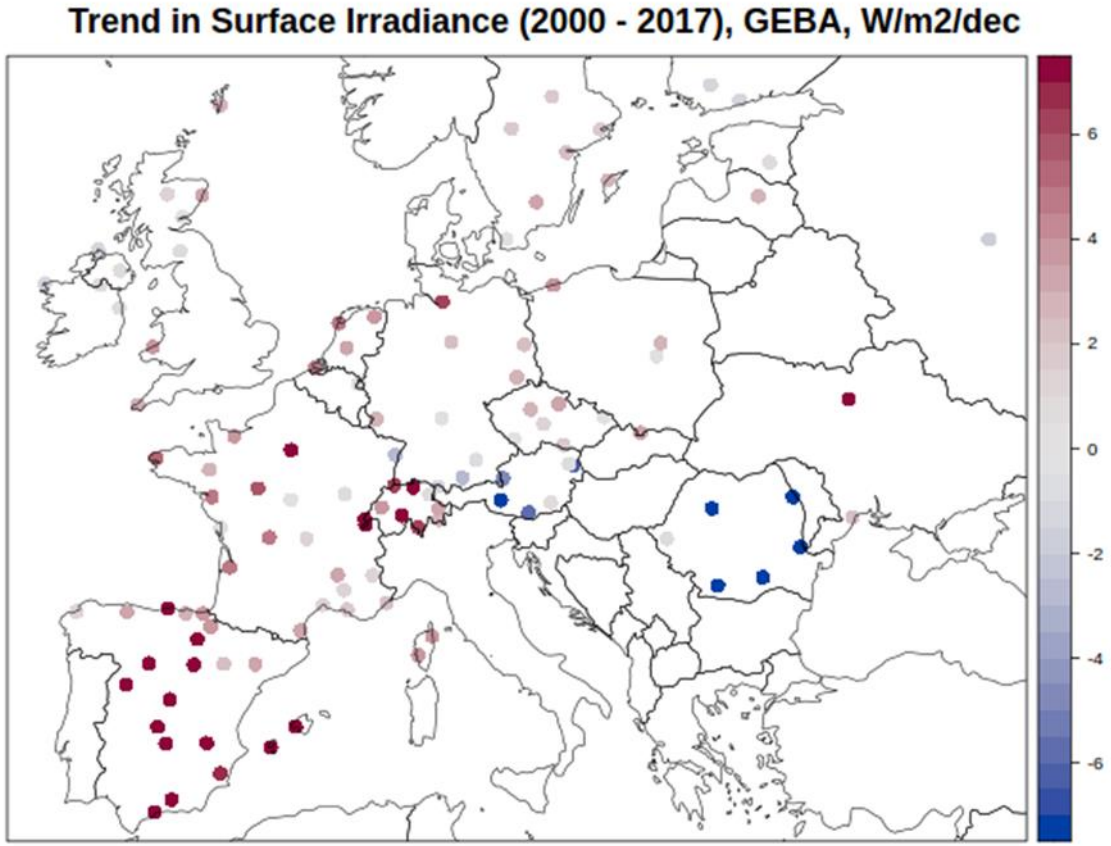
- Number of available stations in GEBA drops sharply in 2000.
- Comparison to GEBA data improves with time for all data sets; accuracy of MERRA-2 substantially reduced compared to other data sets
- Higher temporal stability for satellite-derived than for reanalysis data sets.

Decadal Trends, 2000 – 2017



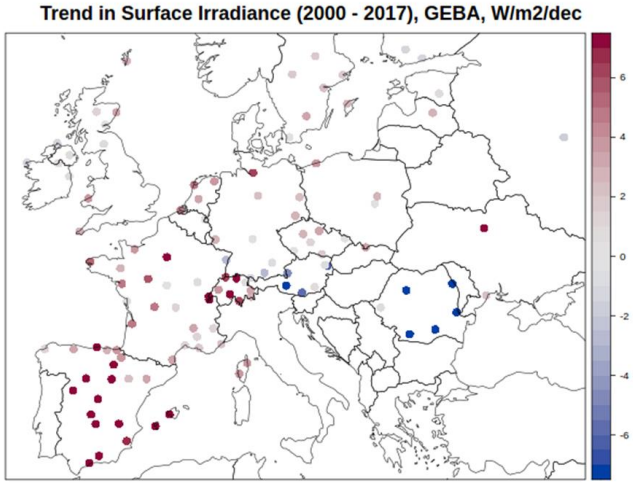
- The majority of GEBA stations indicate a positive trend in surface irradiance (2000 – 2017).
- Most satellite-derived data sets correspond better to the trends derived from GEBA.

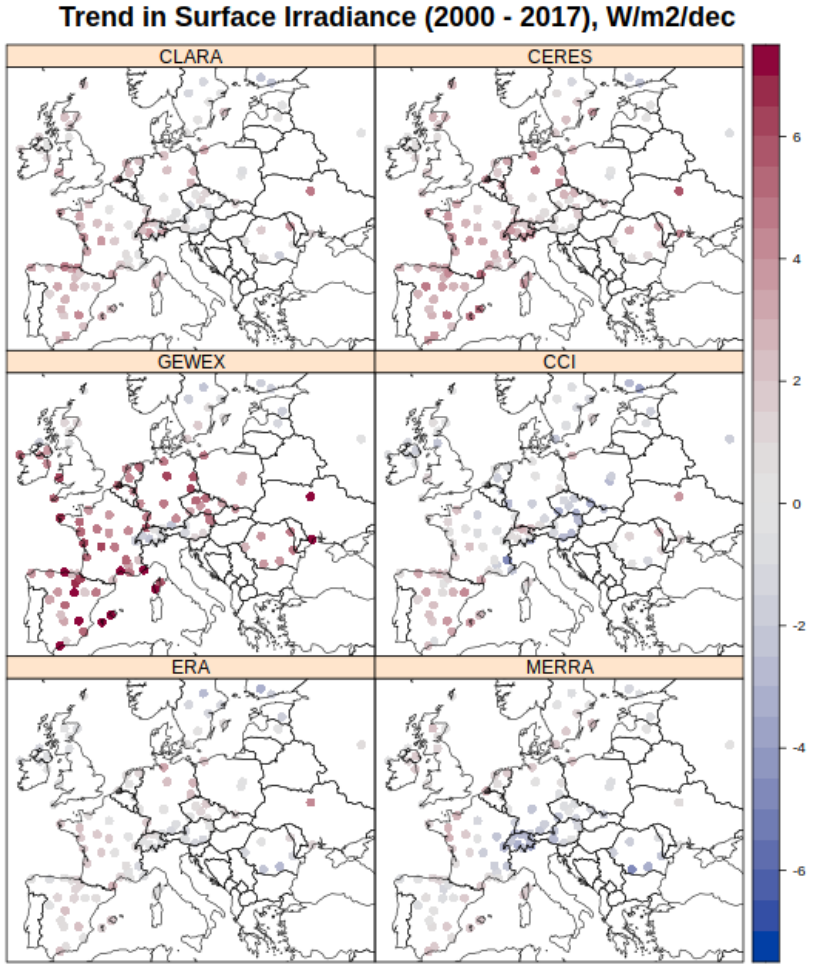
Europe, Trends in Surface Irradiance, 2000 - 2017



- Increase in surface irradiance in Europe
- Largest increase in Spain / Switzerland; decrease in Romania

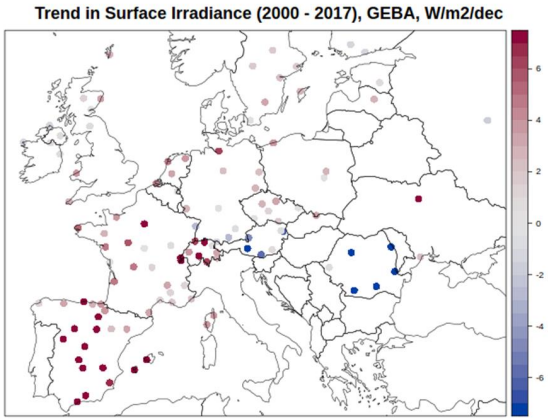
Europe, Trends in Surface Irradiance, 2000 - 2017

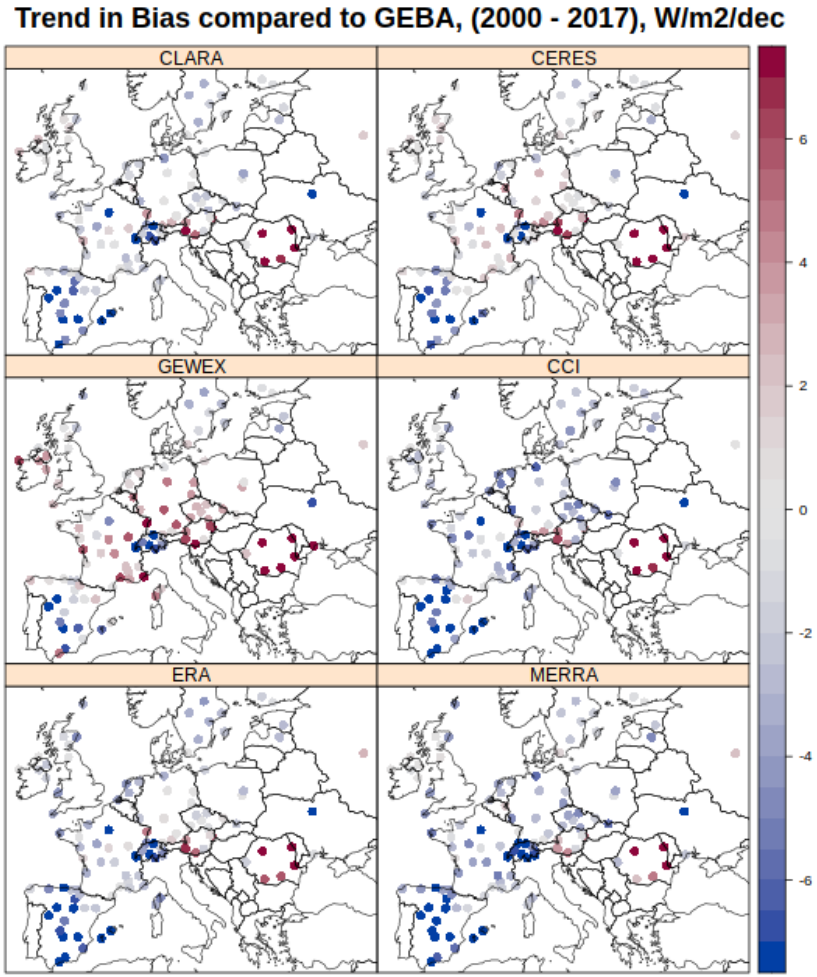




- Comparable trends for all gridded data sets

Europe, Trends in Surface Irradiance, 2000 - 2017





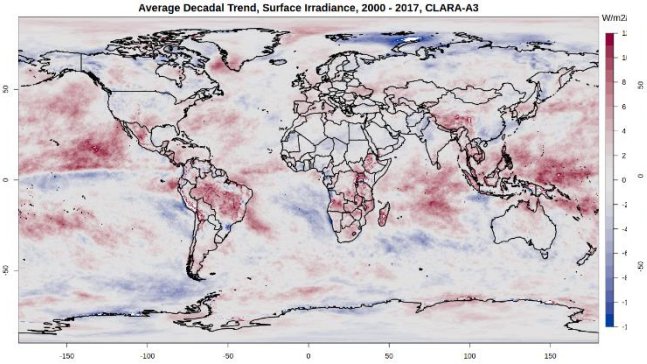
- Largest deviations with GEBA in Spain, Switzerland and Romania
- Consistent deviations of gridded data sets indicate problems in reference data

Summary and Conclusions

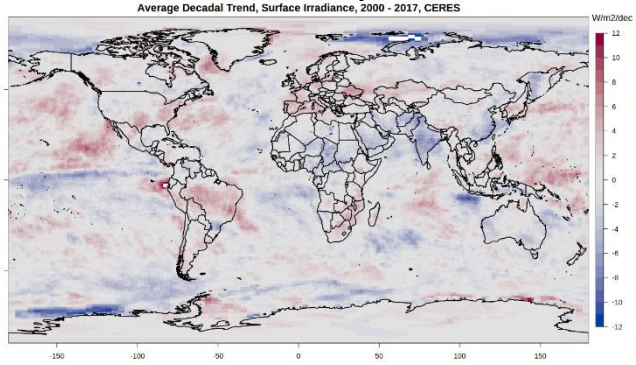
- Six global gridded climate data records of surface irradiance have been compared to surface reference measurements from GEBA
- Accuracy: Most data records perform comparable (MAD between 9 and 12 W/m^2), exception MERRA-2.
- Stability: Satellite data (exception ESA CCI) tend to be more stable than reanalysis; depending on considered time period.
- Global surface irradiance (2000 to 2017): 187 W/m^2; trend: spatially very heterogeneous.
- Regions with largest differences between the gridded data records have been identified.
- Most GEBA stations experience a positive trend.
- Systematic differences, e.g., in Spain, Romania, indicate problems in GEBA reference data.

Decadal Trends of Gridded Datasets (2000 – 2017)

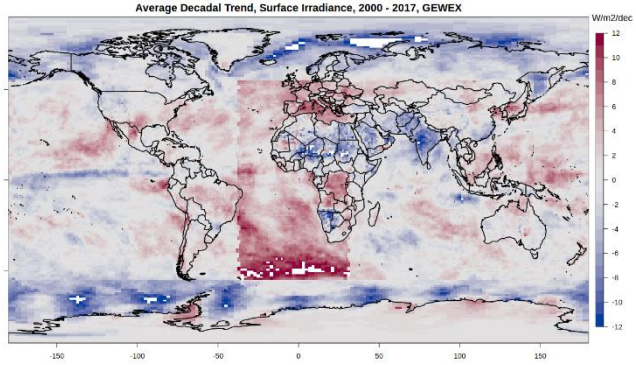
CLARA-A3



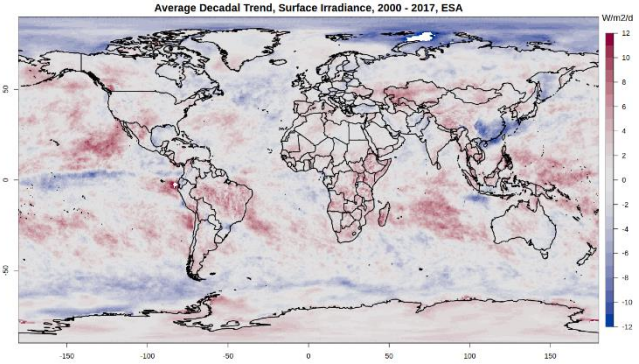
CERES-EBAF, Ed.4.2



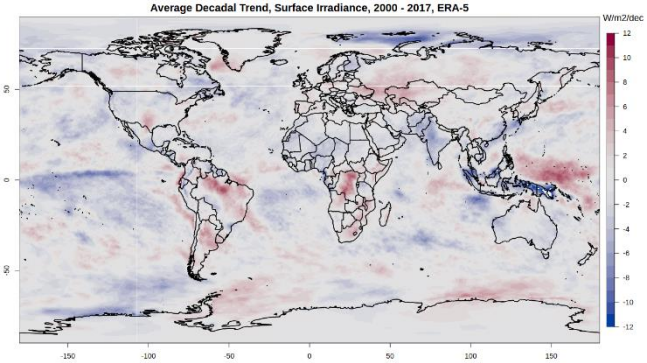
GEWEX-SRB



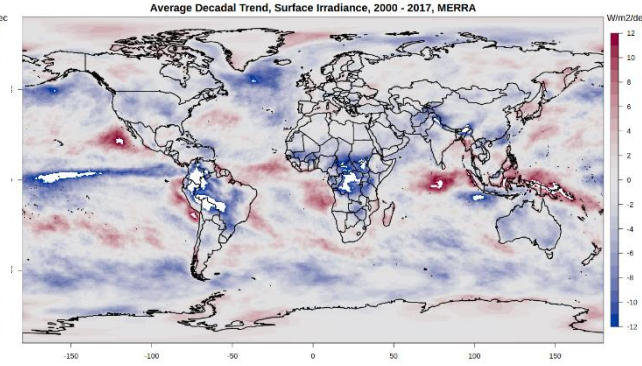
ESA-CCI



ERA-5

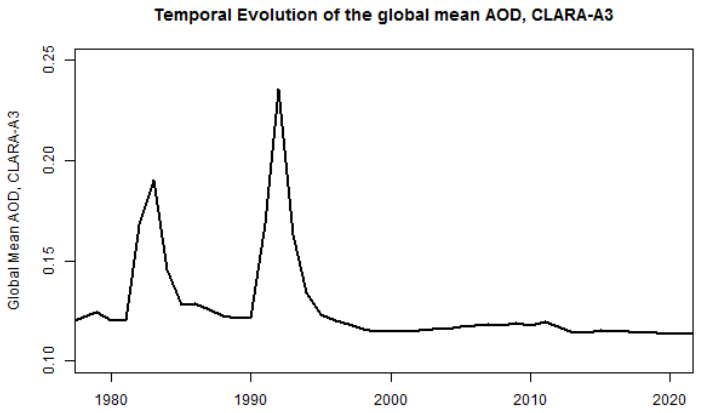


MERRA-2



Assessing the impact of aerosol variability on CLARA-A3 retrieval and derived trends

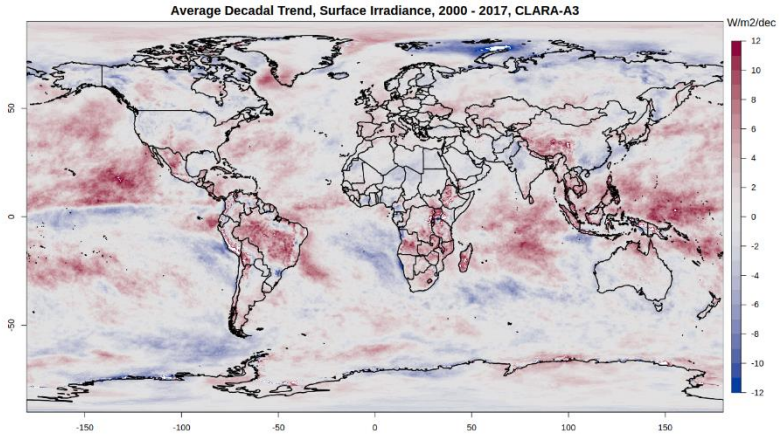
- CLARA-A3 uses monthly climatological aerosol information to derive daily mean clear-sky surface irradiance (used to estimate daily all-sky radiation)
- Dynamic Aerosol (Fielder et al., 2019 a,b):
  - MACv2 natural aerosol
  - Anthropogenic aerosol:
    MACv2-SP (1979 – 2014) +
    SSP2-45 scenario (2015 -2020)
  - Stratospheric Aerosol: GISS



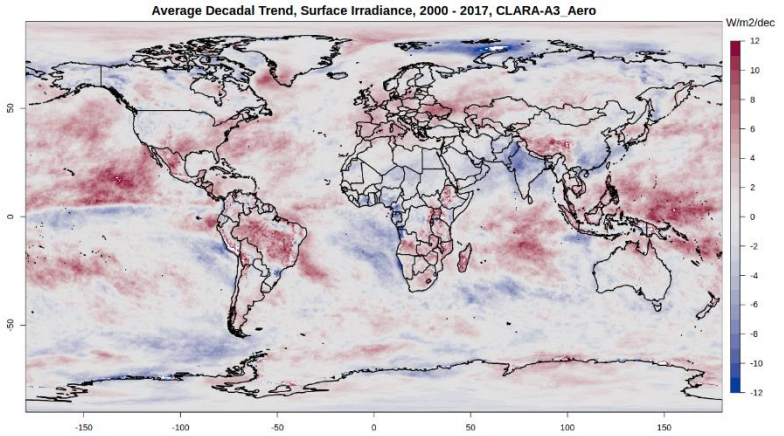
- Monthly aerosol information used to derived daily clear-sky surface radiation.
- Comparison of surface irradiance from CLARA-A3_Aero to CLARA-A3

Impact of CMIP6 aerosol variability on CLARA-A3 retrieval

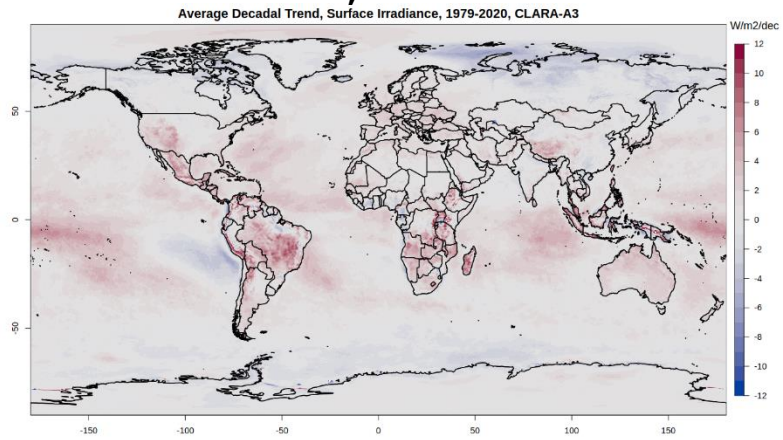
CLARA-A3, 2000 - 2017



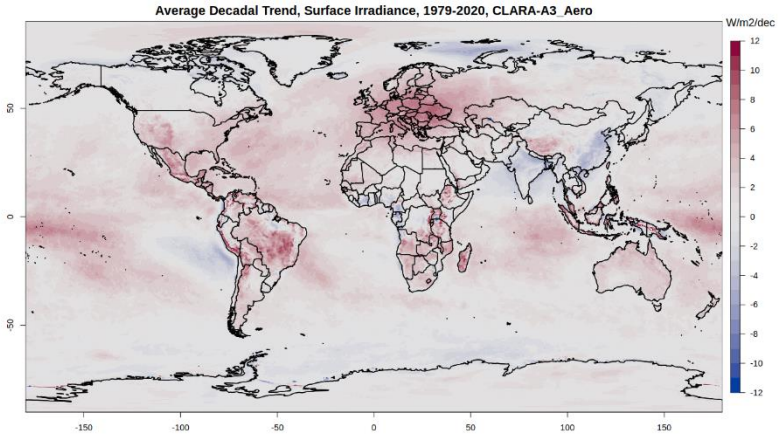
CLARA-A3_Aero, 2000 - 2017



CLARA-A3, 1979 - 2020

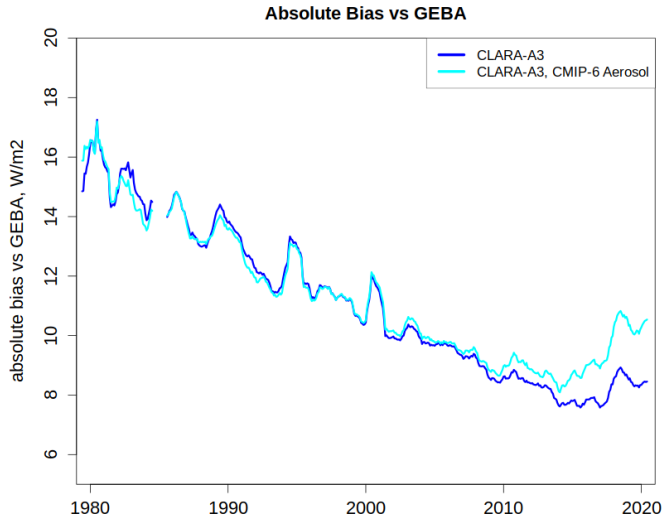


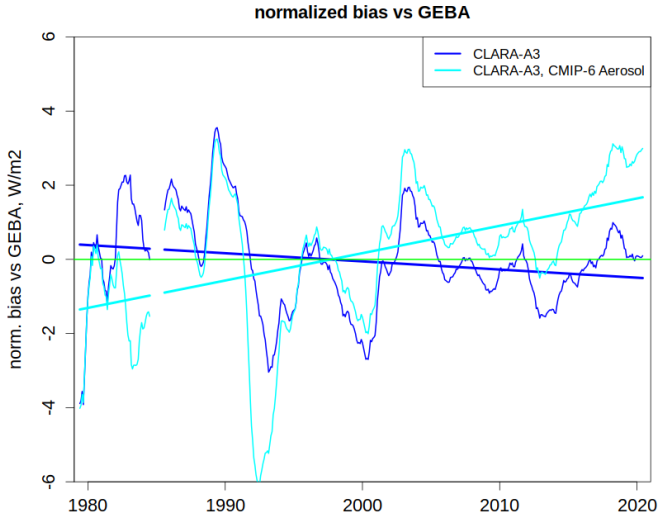
CLARA-A3_Aero, 1979 - 2020



Comparison with GEBA

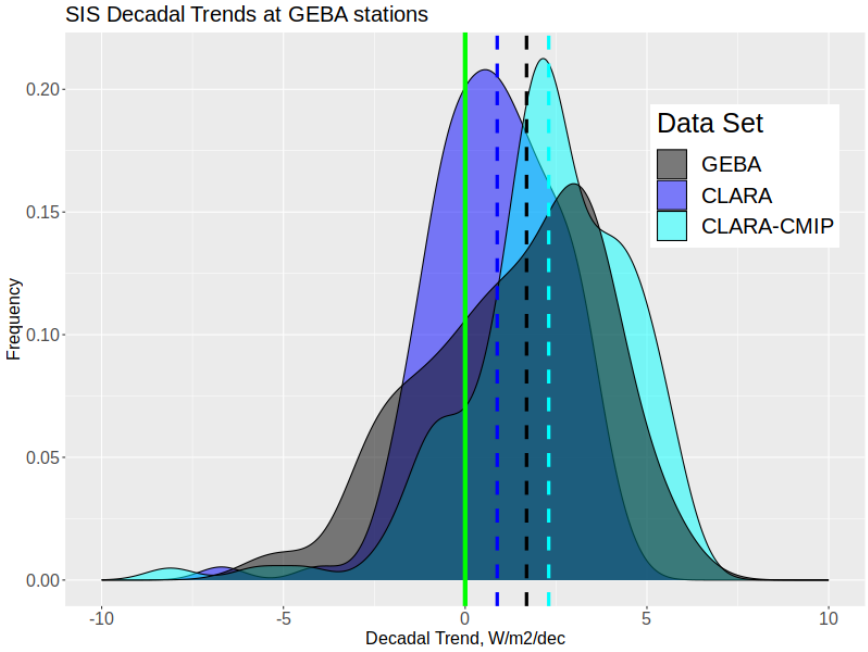
	Full Time Period				2000 – 2017			
Data Set	#	bias [W/m²]	MAD [W/m²]	Stab. [W/m²/dec]	#	bias [W/m²]	MAD [W/m²]	Stab. [W/m²/dec]
CLARA-A3	226,872	5.2	11.6	[-0.3, -0.1, 0]	78,929	3.7	9.2	[-0.8,-0.3,0.1]
CLARA-A3 Aero	226,872	4.8	11.8	[0.5, 0.8, 1.0]	78,929	5.1	9.6	[-0.2,0.4,1.0]



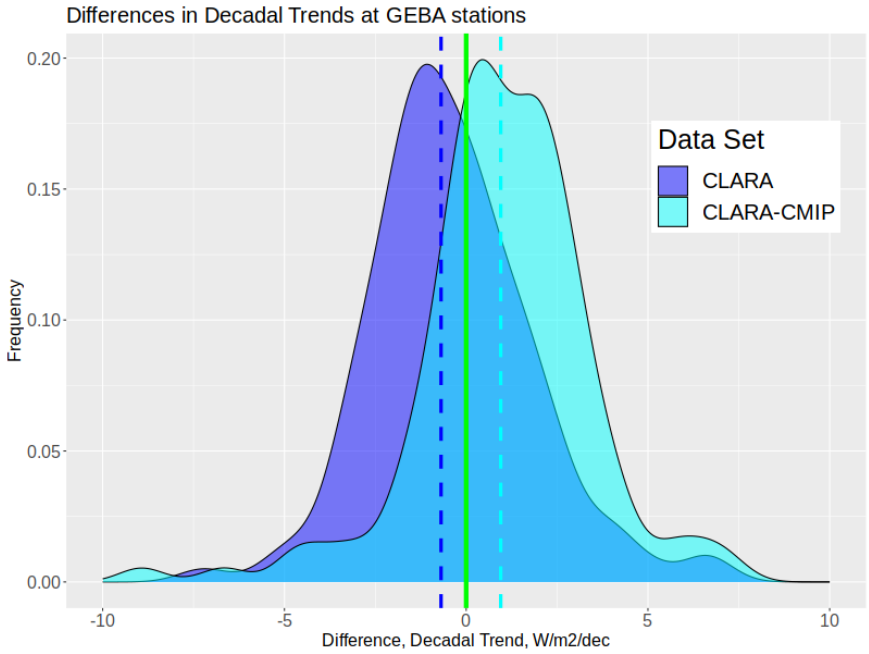


Comparison with GEBA; Trends w and w/o aerosol variability

Decadal Trends, 2000 - 2017

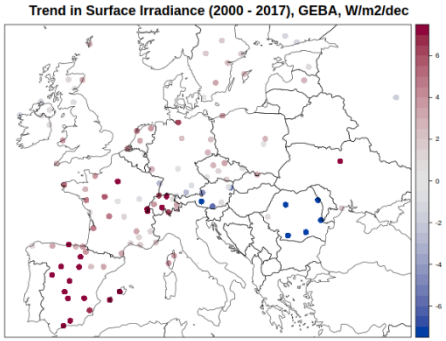


Differences in Decadal Trends, 2000 - 2017

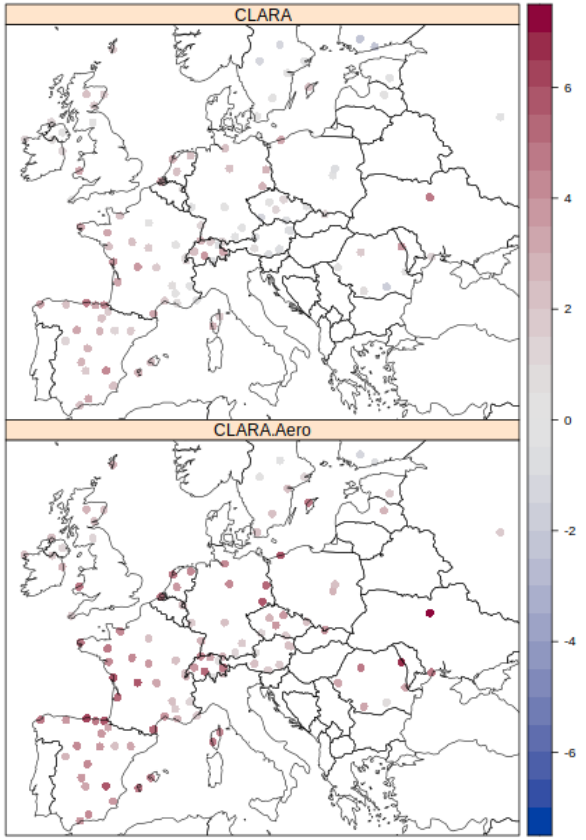


Comparison with GEBA; Europe

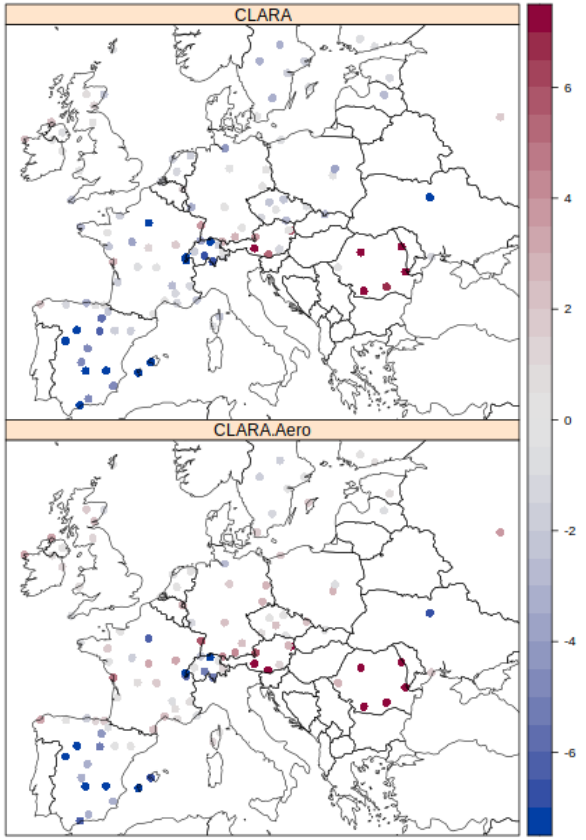
GEBA, 2000 - 2017



Trend in Surface Irradiance (2000 - 2017), W/m2/dec



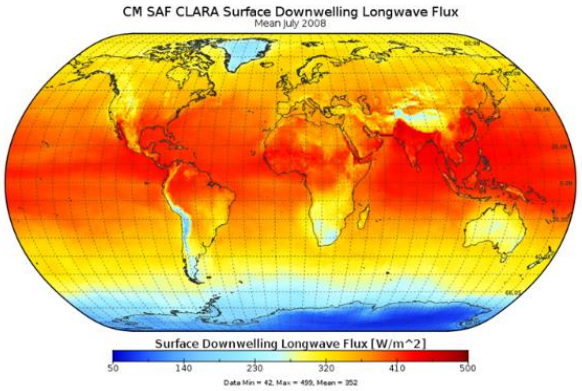
Trend in Bias compared to GEBA, (2000 - 2017), W/m2/dec



CM SAF Climate Data Records

- CM SAF provides a variety of global and regional climate data records on clouds, radiation, surface parameters (e.g., LST), precipitation (ocean only)
- Availability: 1979 to the day before yesterday
- Resolution: Daily, monthly / 0.05°, 0.25°, 1°
- All data are freely available at www.cmsaf.eu

CLARA-A3 / ICDR



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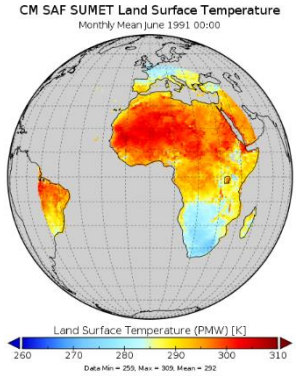
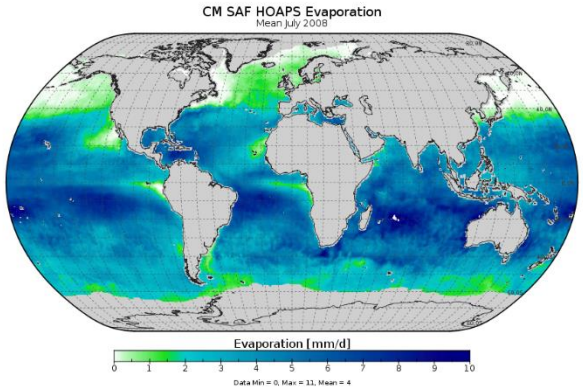
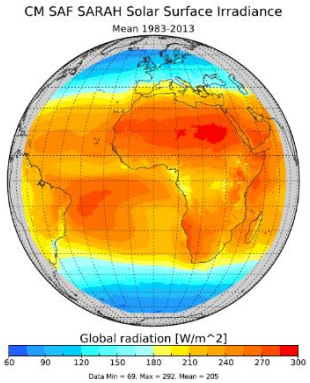


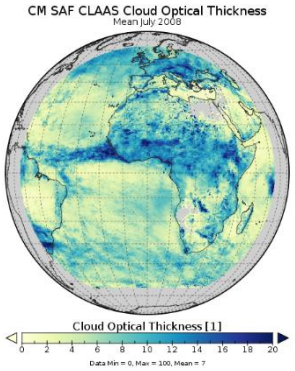
HOAPS 4.0



SARAH-3 / ICDR



CLAAS-3 / ICDR



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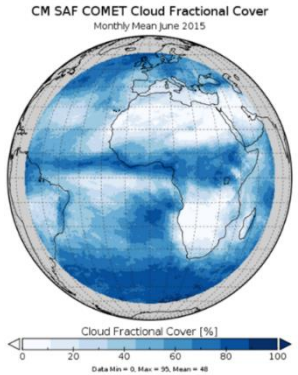
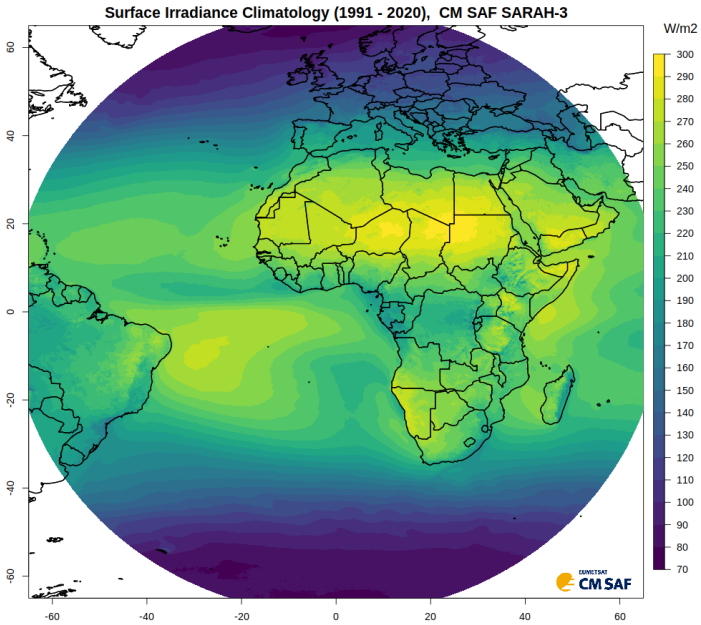


CM SAF SARAH-3

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*
- Available in May 2023 at www.cmsaf.eu
  currently available via: contact.cmsaf@dwd.de



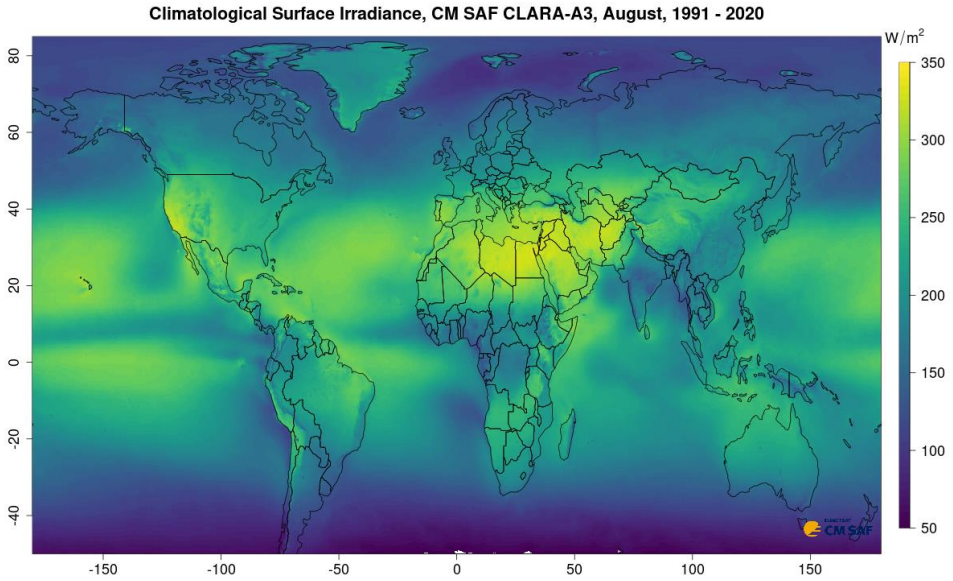
Müller, R. et al. (2015) *Remote Sens., 7*, 8067-8101, doi:10.3390/rs70608067
Pfeifroth, U. et al.. (2018) *J. Geophys, Res., 123,* 1735-1754, doi:10.1002/2017JD027418.

DOI:10.5676/EUM_SAF_CM/SARAH/V003

CM SAF CLARA-A3

CM SAF Clouds, Albedo and Radiation dataset from AVHRR

- **Variables**
  - Cloud properties
  - Surface albedo
  - Surface Radiation
  - *ToA Radiation*
- **Resolution**
  - Spatial: 0.25° × 0.25°
  - Temporal: daily-, pentad-, monthly mean
- **Coverage**
  - Spatial: global
  - Temporal: *1979 to 2020*
- Available in May 2023 at www.cmsaf.eu
  currently available: CLARA-A2.1



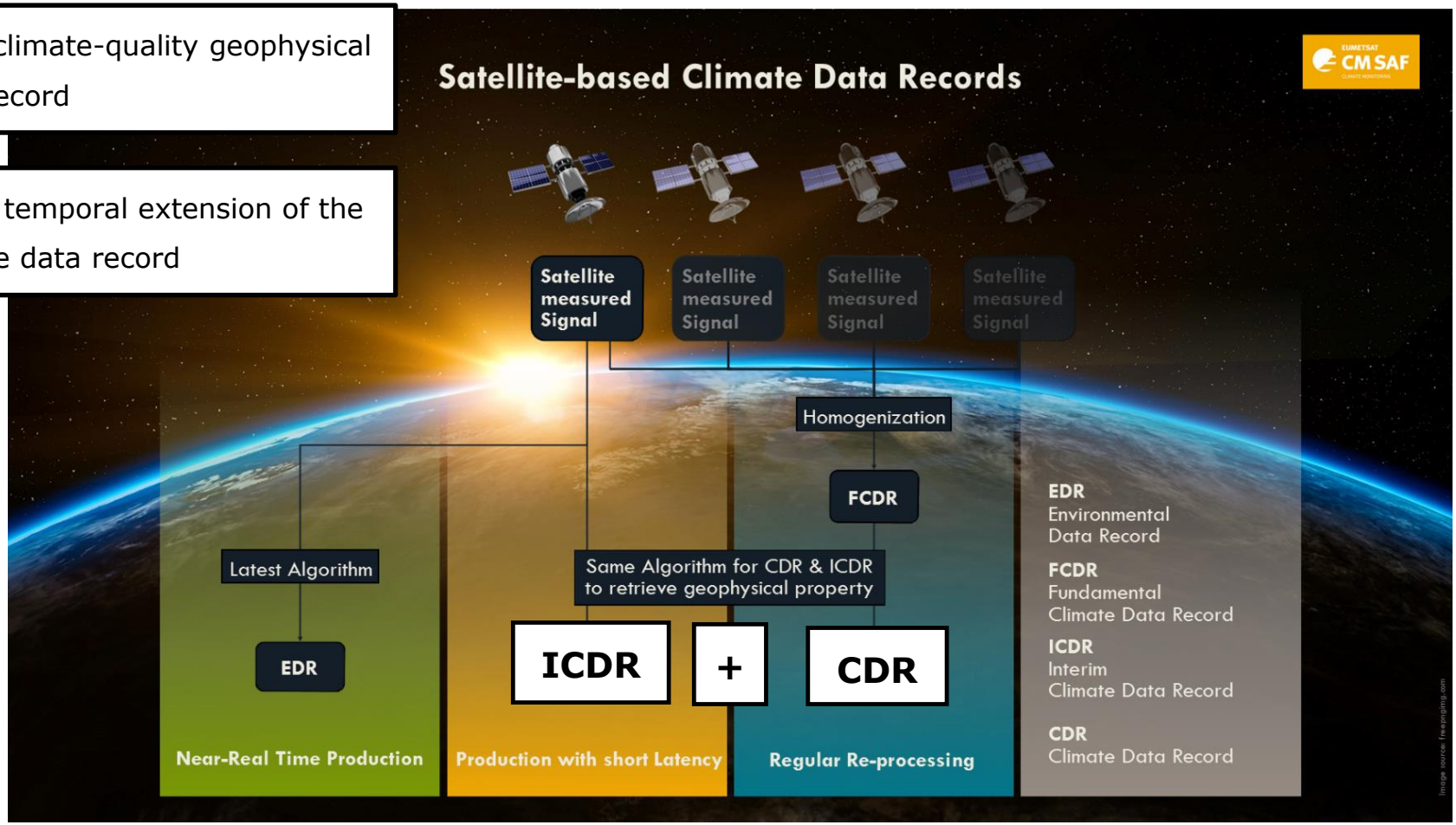
Karlsson, K.-G. et al., (2017), *Atmos. Chem. Phys., 17*, 5809-5828, doi:10.5194/acp-17-5809-2017

DOI:10.5676/EUM_SAF_CM/CLARA_AVHRR/V003

Climate Data Record + Interim Climate Data Record

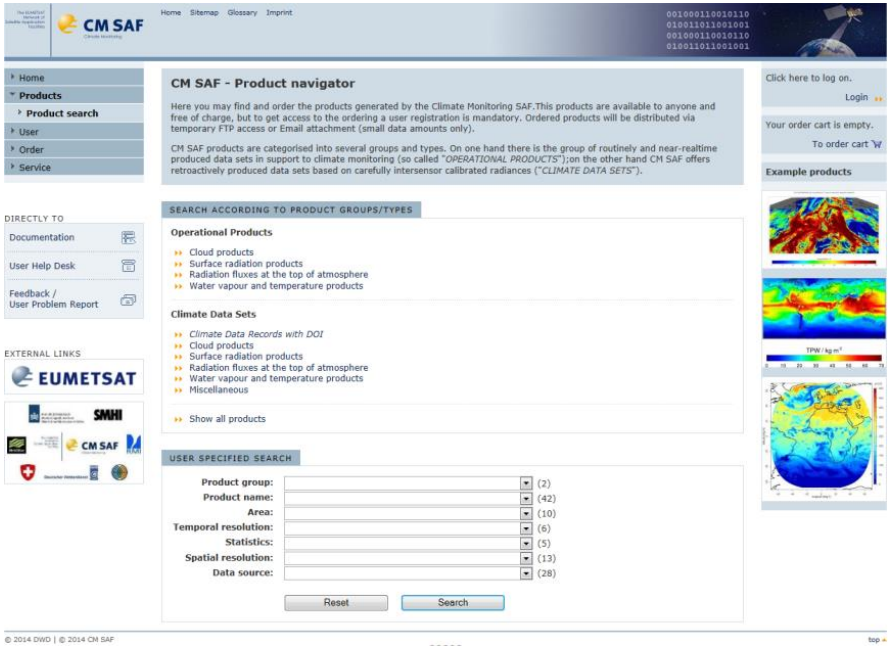
CDR: climate-quality geophysical data record

ICDR: temporal extension of the climate data record



Data Access

- **Web User Interface**
  - Easy selection and online ordering
  - Possibility of regular data delivery
  - Postprocessing
    - Spatial, temporal selection
  - Data format (NetCDF)
  - Download via https or sftp
  - All data free of charge
- **EUMETCast**
- **User Help Desk**



https://wui.cmsaf.eu

CM SAF R Toolbox

www.cmsaf.eu/R_toolbox

- CM SAF provides the CM SAF R Toolbox (based on the open source software R)
- Designed to access, analyse, and visualize CM SAF (and other SAF) data
- No programming skills required
- Can be used within scripts or as a stand-alone GUI
- (Video-)Tutorials available