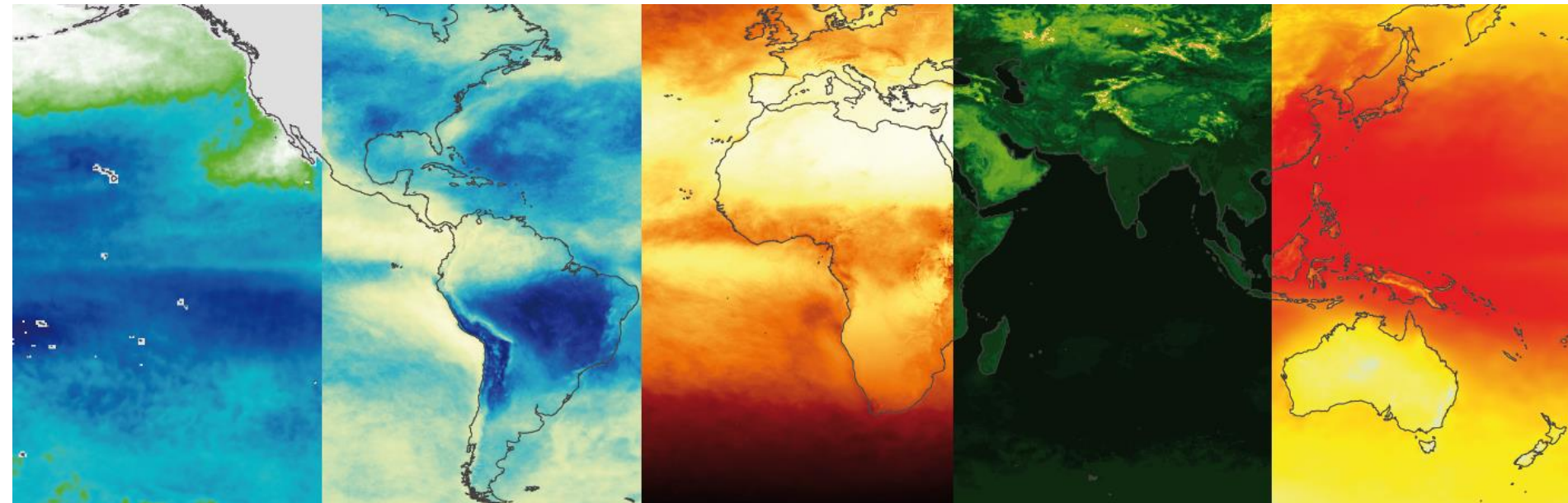


Die CM SAF R Toolbox

Ein Werkzeug zur einfachen Analyse und Visualisierung von Klimadaten im NetCDF-Format

Steffen Kothe, Uwe Pfeifroth, Rainer Hollmann
Deutscher Wetterdienst



The EUMETSAT SAF Network



1 EUM/SCIR/VWG/18/992176, v2D, 13 April 2021

 EUMETSAT



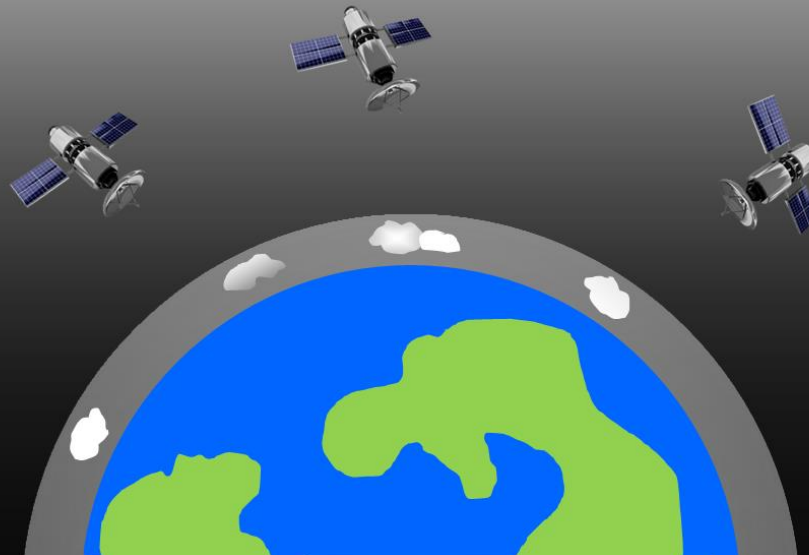
Satellite Application Facility on Climate Monitoring

What we do

Satellite-derived Products
of Energy & Water Cycle

Why we do it

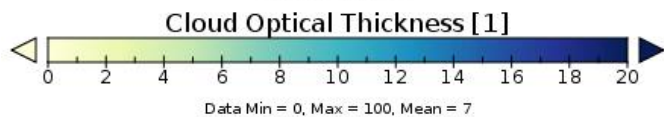
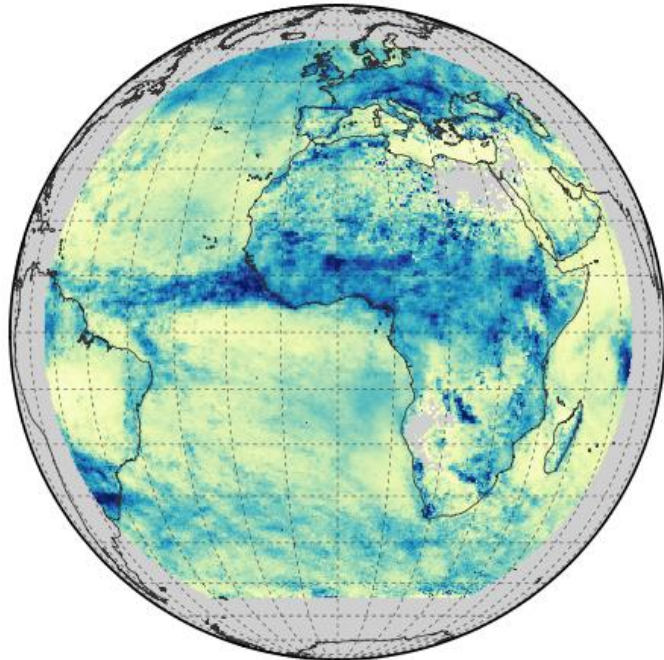
Develop
Generate
Archive
Distribute



Monitor
Understand
Adapt
Climate Variability
&
Climate Change

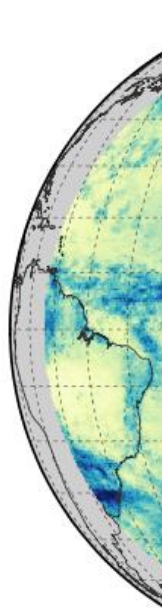
CM SAF Data Records

CM SAF CLAAS Cloud Optical Thickness
Mean July 2008

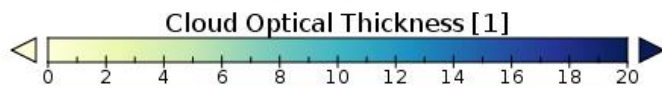
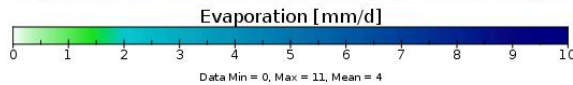
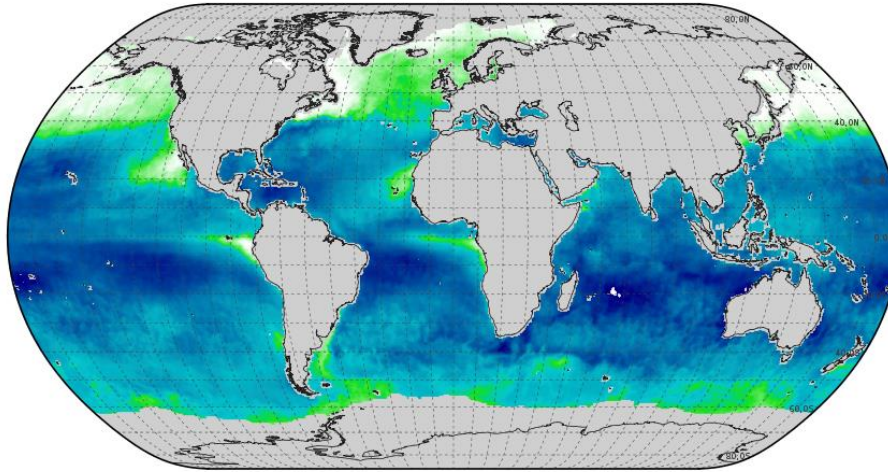


CM SAF Data Records

CM SAF CLAAS Cloud Optical Thickness
Mean July 2008



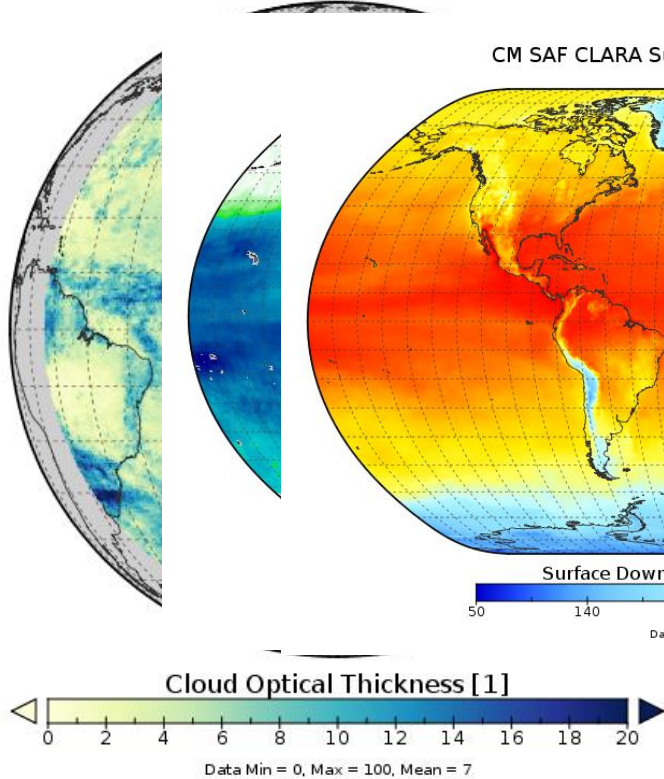
CM SAF HOAPS Evaporation
Mean July 2008



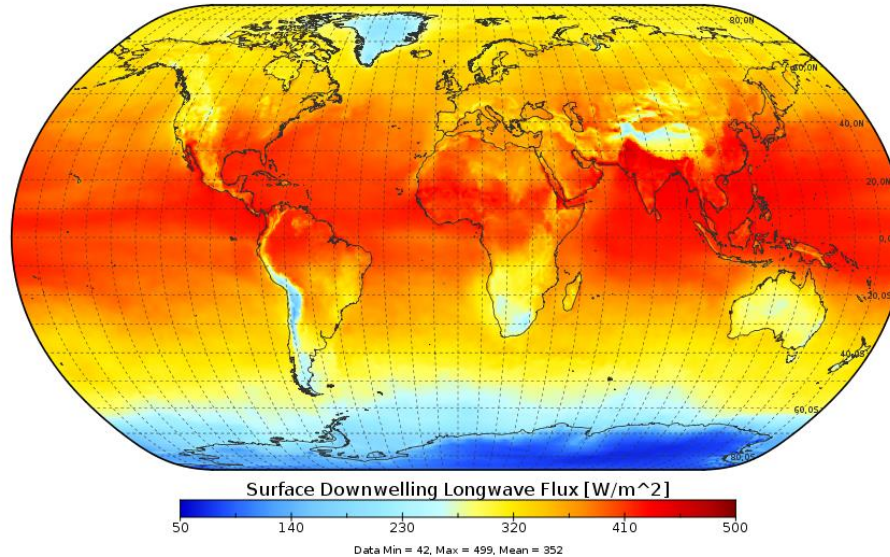
Data Min = 0, Max = 100, Mean = 7

CM SAF Data Records

CM SAF CLAAS Cloud Optical Thickness
Mean July 2008

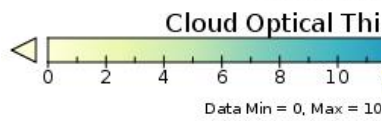
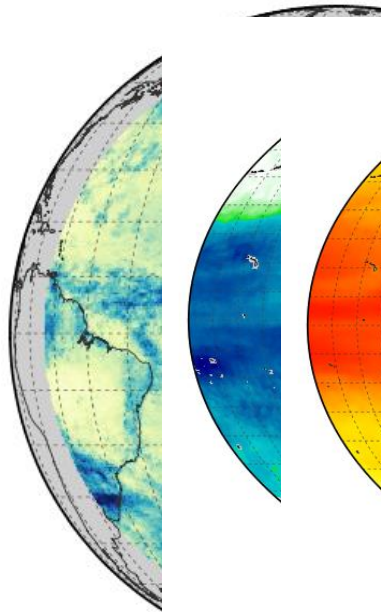


CM SAF CLARA Surface Downwelling Longwave Flux
Mean July 2008

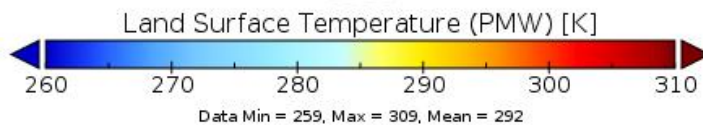
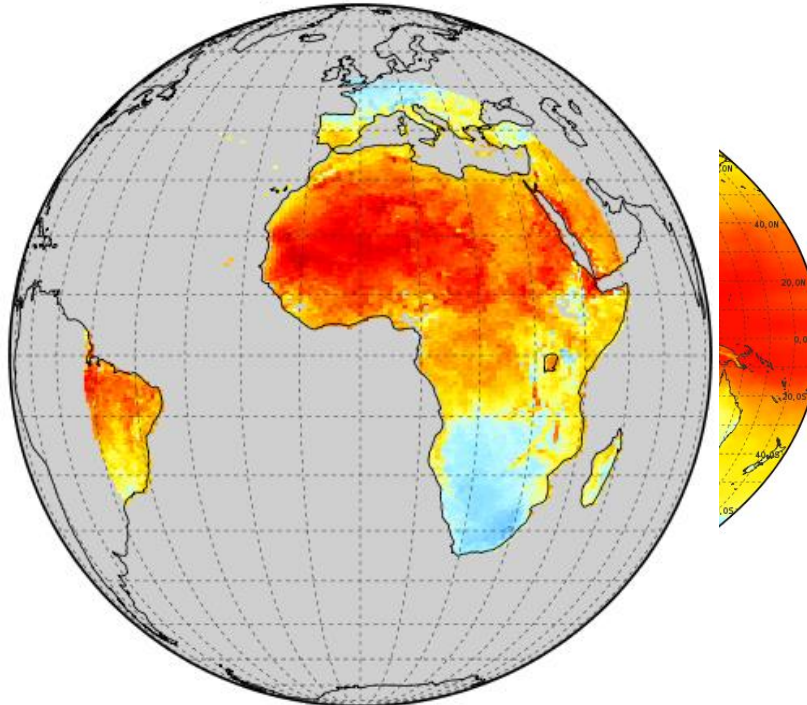


CM SAF Data Records

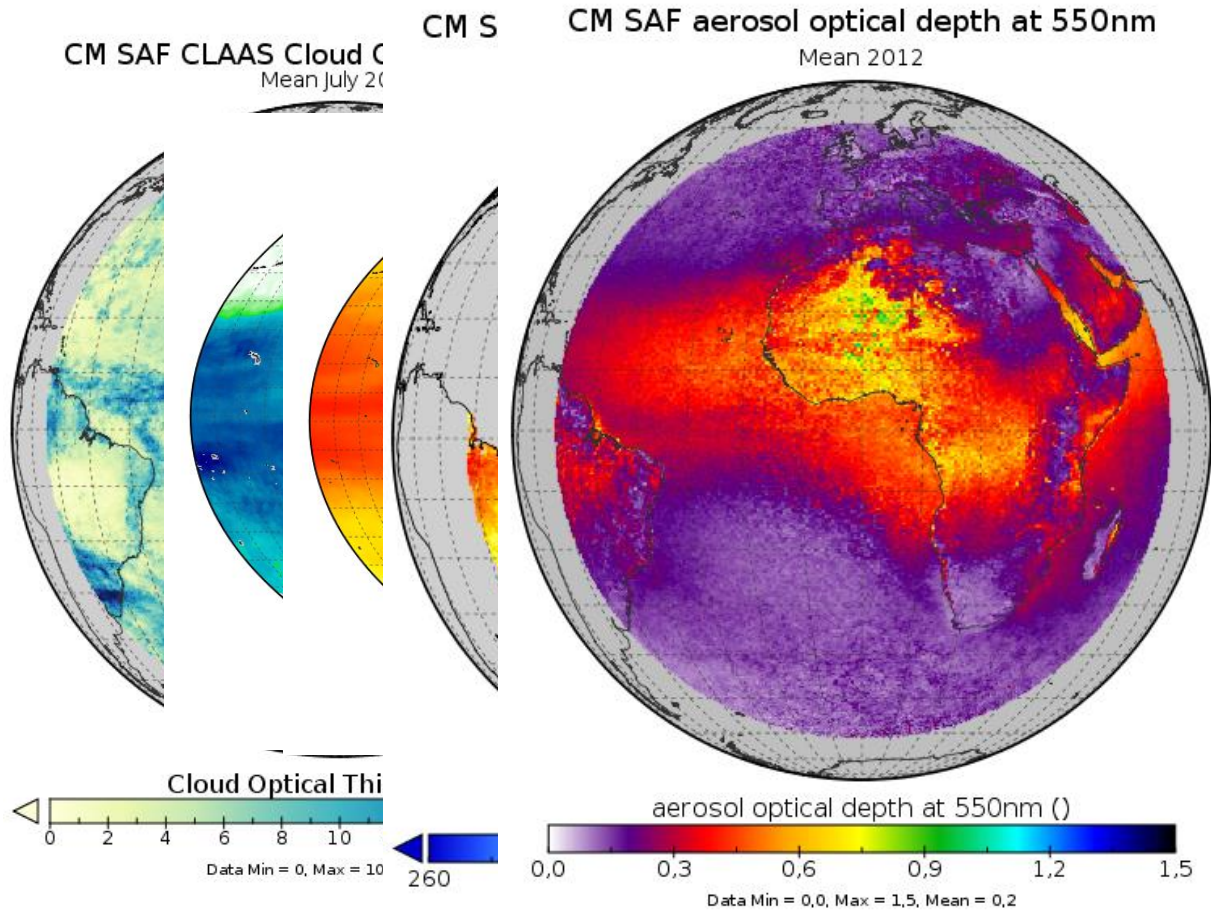
CM SAF CLAAS Cloud C
Mean July 20



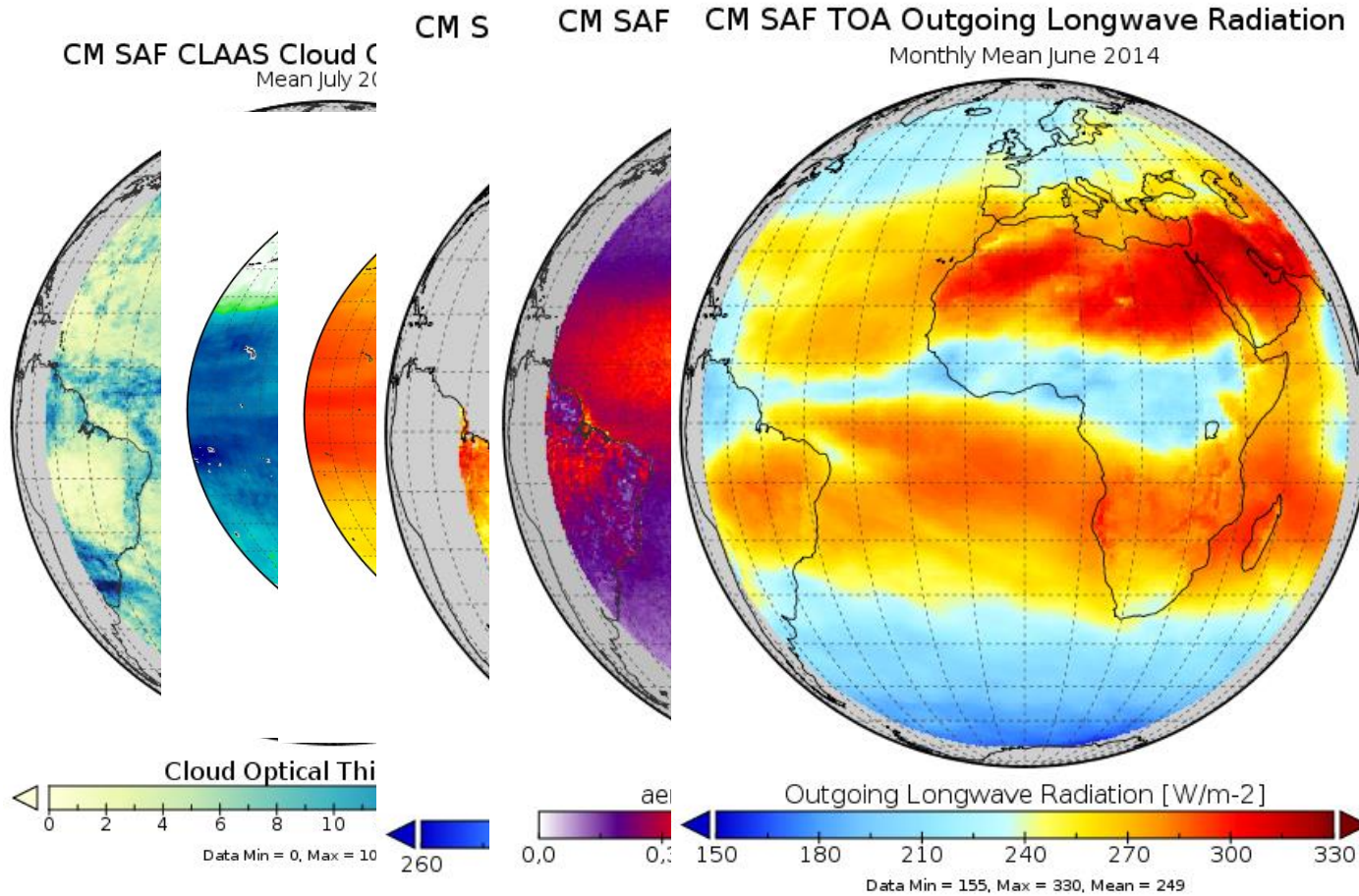
CM SAF SUMET Land Surface Temperature
Monthly Mean June 1991 00:00



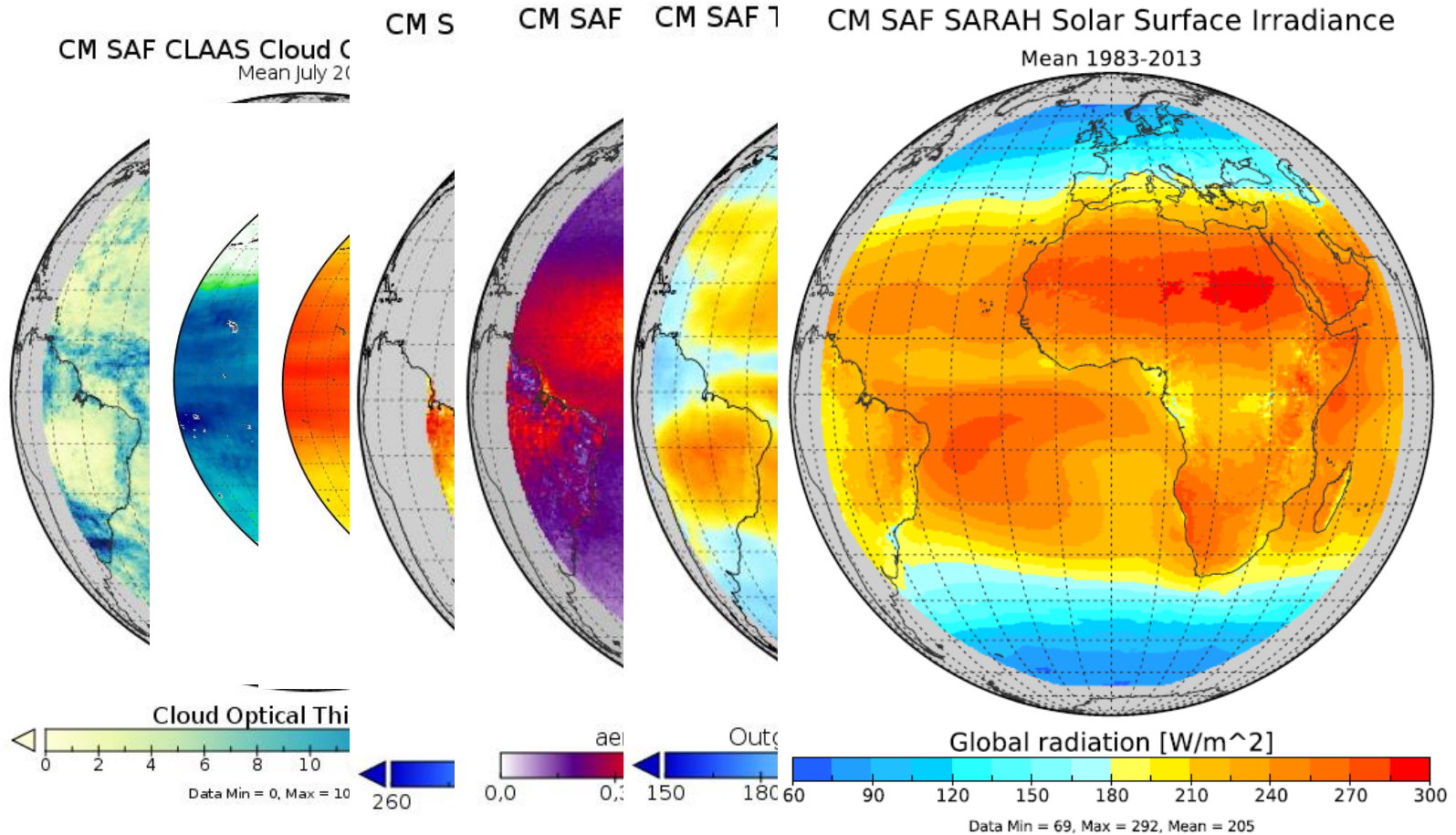
CM SAF Data Records



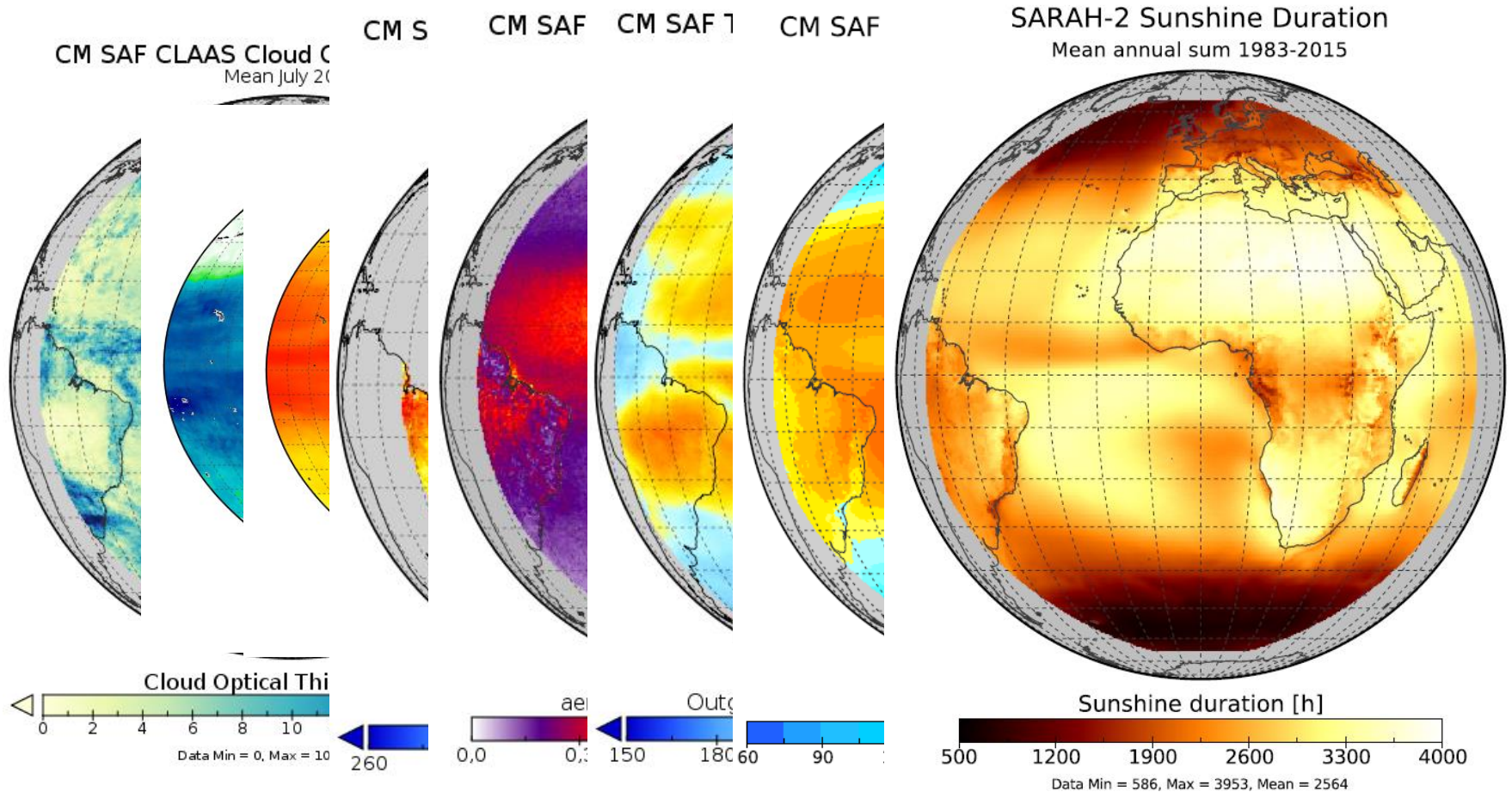
CM SAF Data Records



CM SAF Data Records



CM SAF Data Records



???



What is the CM SAF R Toolbox?



What is the CM SAF R Toolbox?

R-based

cmsafops – Analysis

cmsafvis – Visualization

cmsaf – GUI & Preparation



What is the CM SAF R Toolbox?

R-based

cmsafops – Analysis

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cmsaf – GUI & Preparation

GUI or Command Line

Apply via graphical user
interface or directly via
command line



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Freely available

All R-packages freely available via CRAN (<https://cran.r-project.org/>)

What is the CM SAF R Toolbox?

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CRAN (<https://cran.r-project.org/>)

Prepare

Ready-to-use NetCDF files



What is the CM SAF R Toolbox?

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Prepare

Ready-to-use NetCDF files

Analyze

Data analysis and manipulation

Freely available

All R-packages freely available via
CRAN (<https://cran.r-project.org/>)

What is the CM SAF R Toolbox?

R-based

cmsafops – Analysis
cmsafvis – Visualization
cmsaf – GUI & Preparation

GUI or Command Line

Apply via graphical user interface or directly via command line



Prepare

Ready-to-use NetCDF files

Analyze

Data analysis and manipulation

Visualize

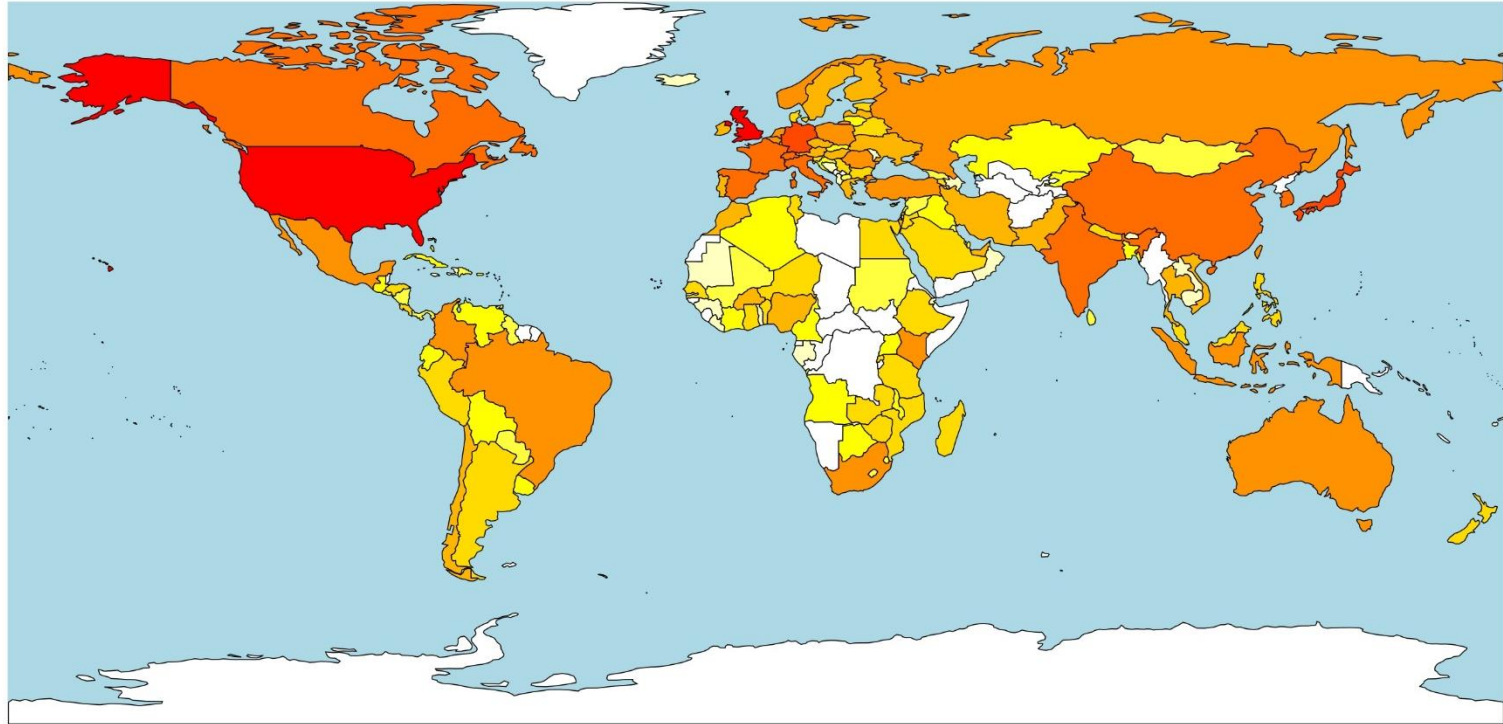
Data visualization and info

Freely available

All R-packages freely available via CRAN (<https://cran.r-project.org/>)

'cmsaf' R-package downloads since 26-06-2015

Total downloads: 53.949 (12 February 2022)





Prepare

Analyze

Visualize

EXIT

View or edit the user directory.

The CM SAF R TOOLBOX 3.4.1 -- 'Just Read the Instructions'

The intention of the CM SAF R Toolbox is to help you using
CM SAF NetCDF formatted climate data

This includes:

1. Preparation of data files.
2. Analysis and manipulation of prepared data.
3. Visualization of the results.

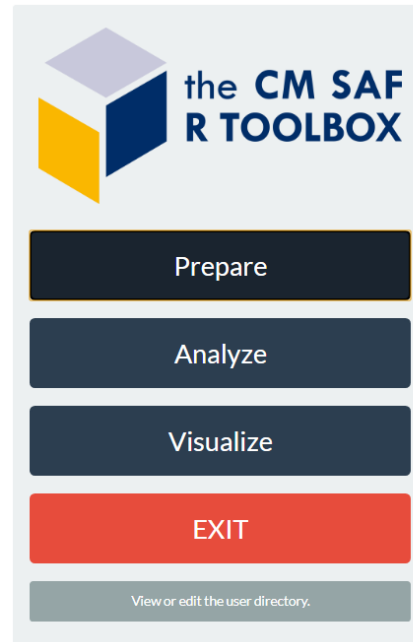
To begin, choose a .tar file or a .nc file in the prepare section or jump
right in and analyze or visualize a .nc file.

Suggestions for improvements and praise for the developers
can be sent to contact.cmsaf@dwd.de.

- Steffen Kothe - 2022-02-15 -

Prepare

- Extract
- Choose time & region
- Merge files



Prepare

Please select a TAR file (.tar), a NetCDF file (.nc) or a NetCDF URL to start the preparation of your data. This is the first step after you downloaded your ordered tar-file(s) or NetCDF files or obtained a direct URL. For NetCDF files, you only need to select the first file and the others are selected automatically.

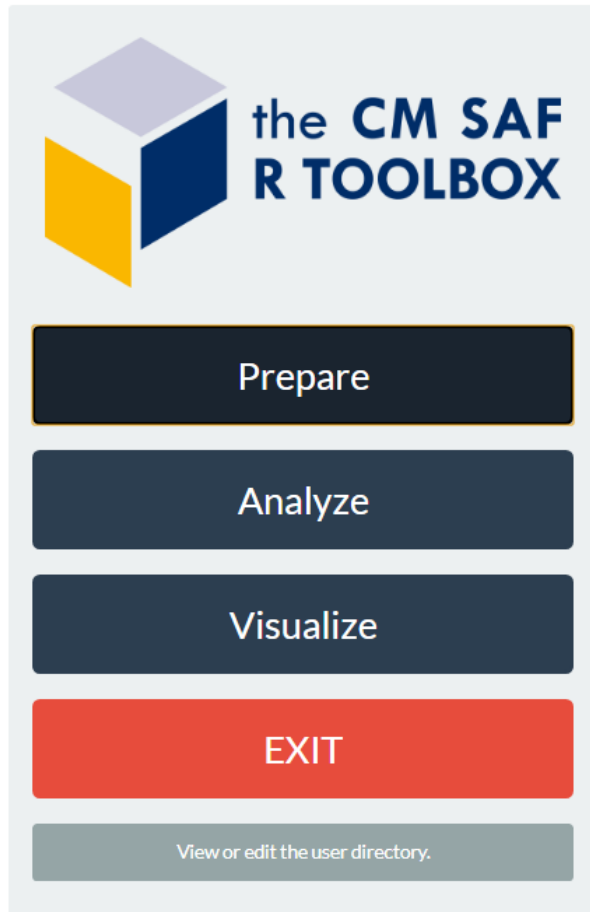
This application will help you to extract, unzip and merge the data. In addition, you can select a time range and region from your data.

Finally, a NetCDF file will be created for you. You can find it in the output directory located at C:/Users/stkothe/Documents/CMSAF-Toolbox

The app guides through all steps.

or or

Prepare



Prepare

Please select a TAR file (.tar), a NetCDF file (.nc) or a NetCDF URL to start the preparation of your data. This is the first step after you downloaded your ordered tar-file(s) or NetCDF files or obtained a direct URL. For NetCDF files, you only need to select the first file and the others are selected automatically.

This application will help you to extract, unzip and merge the data. In addition, you can select a time range and region from your data.

Finally, a NetCDF file will be created for you. You can find it in the output directory located at `C:/Users/stkothe/Documents/CMSAF-Toolbox`

The app guides through all steps.

Choose a .tar-file...

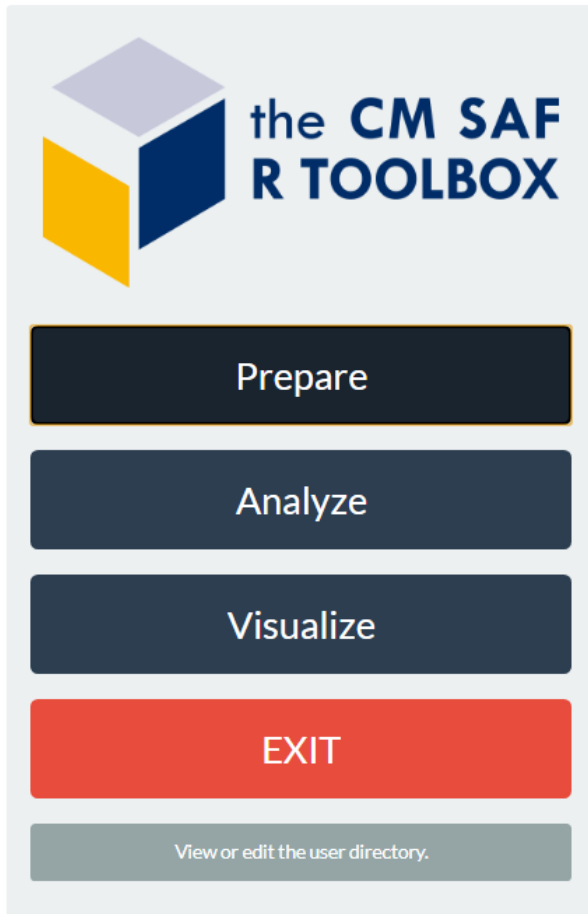
or

Choose .nc-files...

or

Enter .nc file URL...

Prepare



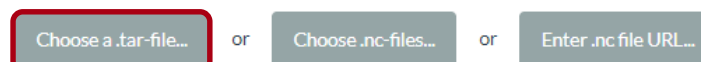
Prepare

Please select a TAR file (.tar), a NetCDF file (.nc) or a NetCDF URL to start the preparation of your data. This is the first step after you downloaded your ordered tar-file(s) or NetCDF files or obtained a direct URL. For NetCDF files, you only need to select the first file and the others are selected automatically.

This application will help you to extract, unzip and merge the data. In addition, you can select a time range and region from your data.

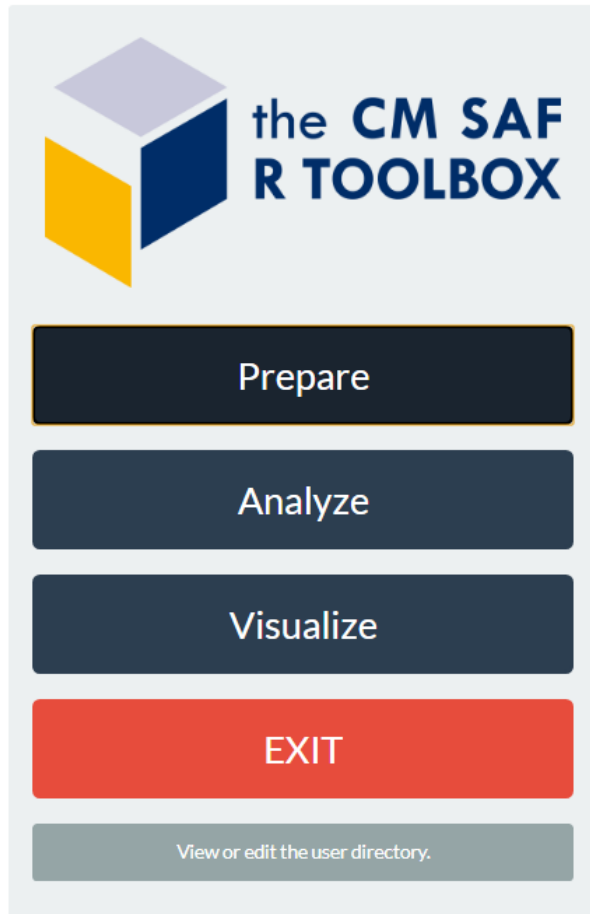
Finally, a NetCDF file will be created for you. You can find it in the output directory located at `C:/Users/stkothe/Documents/CMSAF-Toolbox`

The app guides through all steps.



Prepare ordered tar-files

Prepare



Prepare

Please select a TAR file (.tar), a NetCDF file (.nc) or a NetCDF URL to start the preparation of your data. This is the first step after you downloaded your ordered tar-file(s) or NetCDF files or obtained a direct URL. For NetCDF files, you only need to select the first file and the others are selected automatically.

This application will help you to extract, unzip and merge the data. In addition, you can select a time range and region from your data.

Finally, a NetCDF file will be created for you. You can find it in the output directory located at `C:/Users/stkothe/Documents/CMSAF-Toolbox`

The app guides through all steps.

Choose a .tar-file...

or

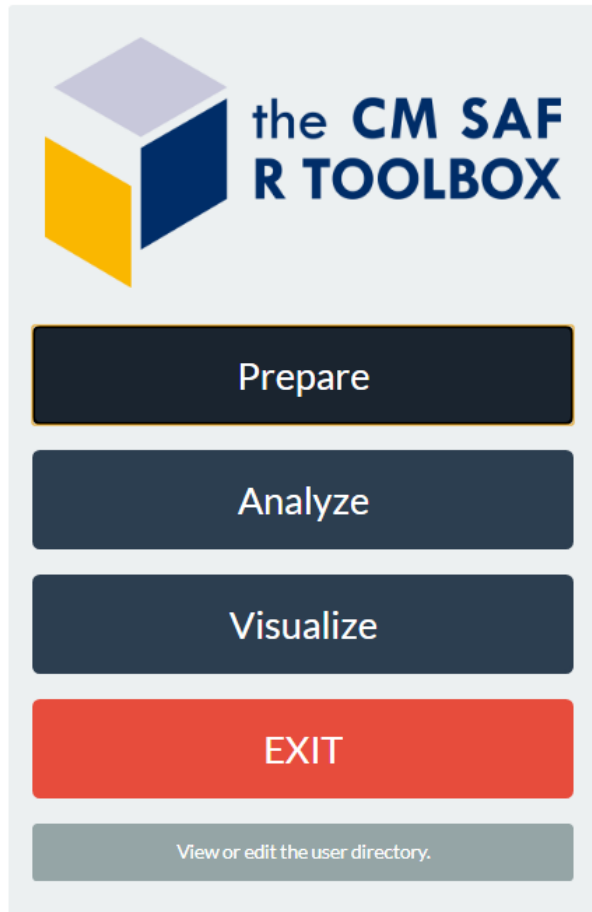
Choose .nc-files...

or

Enter .nc file URL...

Prepare NetCDF files

Prepare



Prepare

Please select a TAR file (.tar), a NetCDF file (.nc) or a NetCDF URL to start the preparation of your data. This is the first step after you downloaded your ordered tar-file(s) or NetCDF files or obtained a direct URL. For NetCDF files, you only need to select the first file and the others are selected automatically.

This application will help you to extract, unzip and merge the data.
In addition, you can select a time range and region from your data.

Finally, a NetCDF file will be created for you. You can find it in the output directory located at `C:/Users/stkothe/Documents/CMSAF-Toolbox`

The app guides through all steps.

Choose a .tar-file...

or

Choose .nc-files...

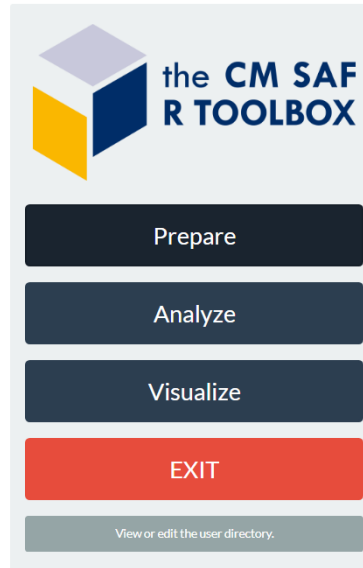
or

Enter .nc file URL...

Open files via URL

Analyze

- ➔ Analysis & manipulation of NetCDF data
- ➔ More than 100 operators
- ➔ Wide range from basic statistics to complex operations



the CM SAF
R TOOLBOX

Prepare

Analyze

Visualize

EXIT

View or edit the user directory.

Please choose a variable

SDU

Select a group of operators

Monthly statistics

Select an operator.

Monthly anomalies

Select output format

NetCDF4

Do you want to apply another operator afterwards?

Do you want to visualize the results right away?

Hint: You can start with a new input file by clicking on 'Analyze'.

Apply operator

If you would like to have more functions included contact: training.cmsaf@dwd.de

Short File Information

The file: C:\Users\stkothe\Documents\CHSAF-Toolbox\output\SDU_1983-01-1


Variable:
SDU

With following dimensions:
lon with length 401 (range -15 to 5)
lat with length 401 (range 45 to 65)
time with length 468 (range 1983-01-01 to 2021-12-01)

Operator Group Info

Monthly statistics
Calculate monthly statistics from all timesteps of the same month. Multi-year operators will give you values for each month of the year. The date information in the output file is the date of the first contributing input field.

Analyze



the CM SAF
R TOOLBOX

Prepare

Analyze

Visualize

EXIT

View or edit the user directory.

Please choose a variable

SDU

Select a group of operators

Monthly statistics

Select an operator.

Monthly anomalies

Select output format

NetCDF4

- Do you want to apply another operator afterwards?
- Do you want to visualize the results right away?

Hint: You can start with a new input file by clicking on 'Analyze'.

Apply operator

If you would like to have more functions included contact:
training.cmsaf@dwd.de

Short File Information

The file: C:\Users\stkothe\Documents\CMSAF-Toolbox\output\SDU_1983-01-01-

Variable:
SDU

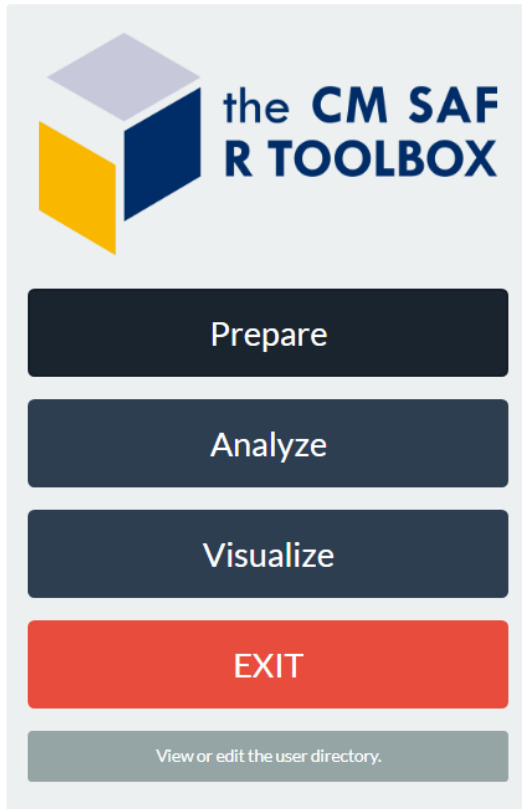
With following dimensions:
lon with length 401 (range -15 to 5)
lat with length 401 (range 45 to 65)
time with length 468 (range 1983-01-01 to 2021-12-01)



Operator Group Info

Monthly statistics
Calculate monthly statistics from all timesteps of the same month. Multi-year operators will give you values for each month of the year. The date information in the output file is the date of the first contributing input field.

Analyze



the CM SAF
R TOOLBOX

Prepare

Analyze

Visualize

EXIT

View or edit the user directory.

Please choose a variable

SDU

Select a group of operators

Monthly statistics

Select an operator.

Monthly anomalies

Select output format

NetCDF4

Do you want to apply another operator afterwards?

Do you want to visualize the results right away?

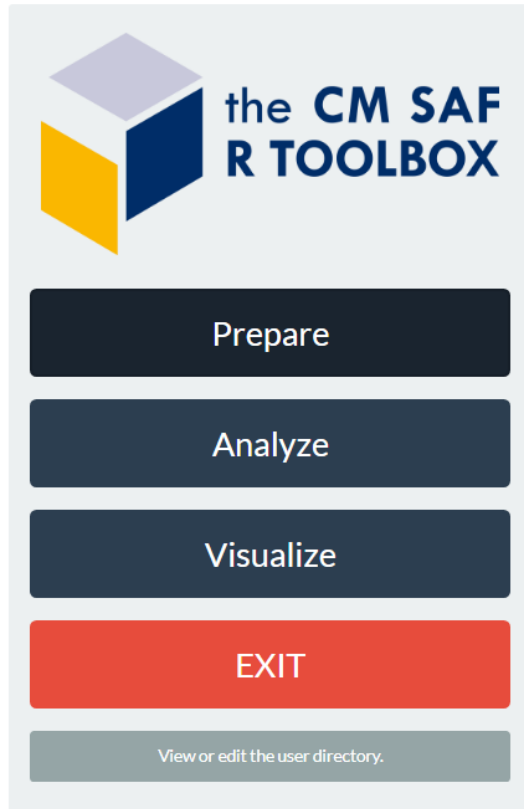
Hint: You can start with a new input file by clicking on 'Analyze'.

Apply operator

If you would like to have more functions included contact: training.cmsaf@dwd.de

- Hourly statistics
- Daily statistics
- Monthly statistics
- Seasonal statistics
- Annual statistics
- Temporal operators
- Time range statistics
- Running statistics
- Zonal statistics
- Meridional statistics
- Grid boxes statistics
- Spatial operators
- Correlation and covariance
- Mathematical operators
- Selection
- Data manipulation
- Climate Analysis
- Compare Data

Analyze



the CM SAF
R TOOLBOX

Prepare

Analyze

Visualize

EXIT

View or edit the user directory.

Please choose a variable

SDU

Select a group of operators

Monthly statistics

Select an operator.

Monthly anomalies

Select output format

NetCDF4

Do you want to apply another operator afterwards?

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Apply operator

If you would like to have more functions included contact training.cmsaf@dwd.de

- Monthly anomalies
- Monthly averages
- Monthly maxima
- Monthly means
- Monthly minima
- Monthly percentiles
- Monthly standard deviation
- Monthly sums
- Monthly variances
- Mean monthly daily variation
- Multi-monthly means
- Multi-monthly sums
- Multi-year monthly maxima
- Multi-year monthly means
- Multi-year monthly minima
- Multi-year monthly standard deviations
- Multi-year monthly sums
- Monthly number of timesteps above threshold
- Monthly number of timesteps below threshold
- Monthly number of timesteps equal threshold

Analyze



the CM SAF
R TOOLBOX

Prepare

Analyze

Visualize

EXIT

View or edit the user directory.

Please choose a variable
SDU

Select a group of operators
Climate Analysis

Select an operator.
Fieldmean plot

Do you want to accumulate the infile over time?
 Do you want to attach the data to that of an already existing file?

Please select a country
Germany

Longitude min: 5 Longitude max: 20
Latitude min: 45 Latitude max: 60

Select date range
2020-01-01 to 2020-07-14

Climatol. start year: 1991 Climatol. end year: 2020

Select plot format
graphic

Select output format

Short File Information

The file: /cmsaf/cmsaf-rad6/stkotho/TOOLBOX/output/mc_temp_0ld/SDU_1983-

Variable:
SDU

With following dimensions:
lon with length 301 (range 5 to 20)
lat with length 301 (range 45 to 60)
time with length 13710 (range 1983-01-01 to 2020-07-14)

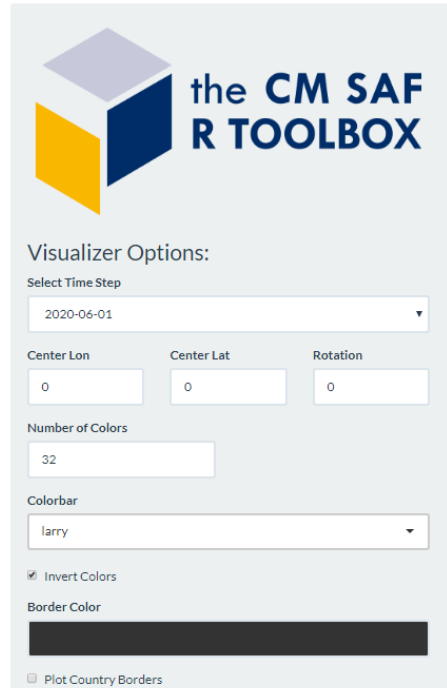
Operator Group Info

Climate Analysis
... analysis.
... data,
... results

- Absolute map
- Anomaly map
- Climatology map
- Fieldmean plot
- Fieldmean and anomaly map
- Stripes Plot
- Time Series Plot
- Trend Plot

Visualize

- Easy visualization of data
- Many options for adaptations
- Display of metadata and basic statistics



the CM SAF
R TOOLBOX

Visualizer Options:

Select Time Step
2020-06-01

Center Lon: 0 Center Lat: 0 Rotation: 0

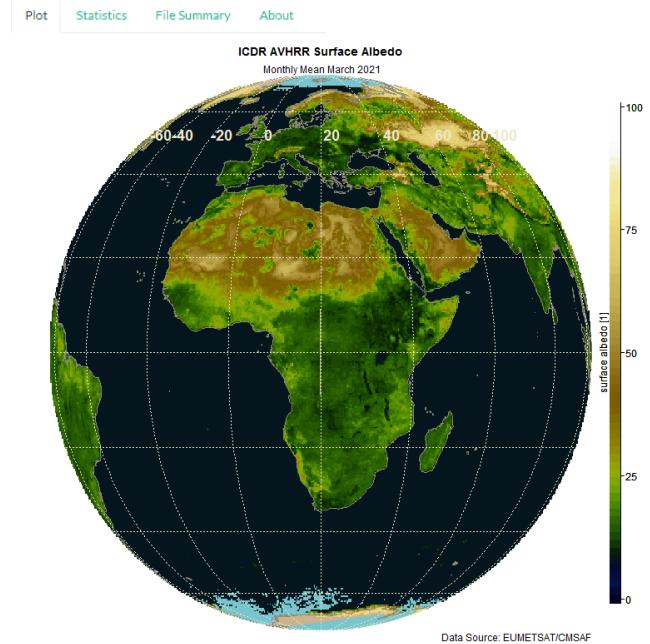
Number of Colors: 32

Colorbar: larry


Invert Colors

Border Color: [Dark Grey]

Plot Country Borders



Visualize



the CM SAF
R TOOLBOX

Visualizer Options:

Select Time Step
1983-01-01 - 2017-12-01

Plot region
 Show Zoom

Longitude
-15 to 30

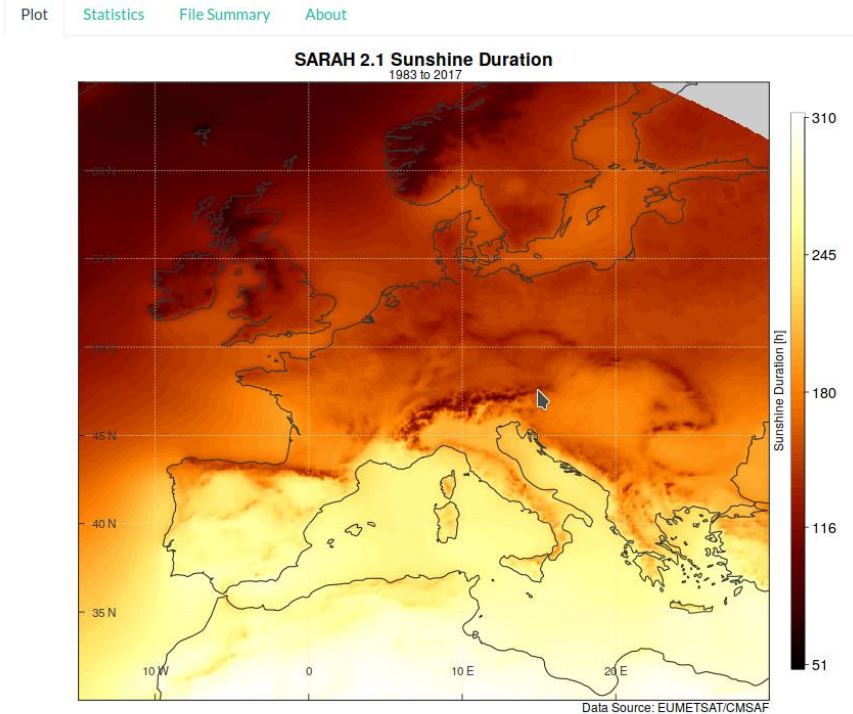
Latitude
30 to 65

Image Ratio
-0.9 0.1 0.9


Number of Colors: 64
Number of Ticks: 5

Colorbar

Invert Colors
Border Color



Visualize



the CM SAF
R TOOLBOX

Visualizer Options:

Select Time Step
1983-01-01 - 2017-12-01

Plot region
 Show Zoom

Longitude
-15 to 30

Latitude
30 to 65

Image Ratio
-0.9 0.1 0.9

Number of Colors: 64
Number of Ticks: 5

Colorbar

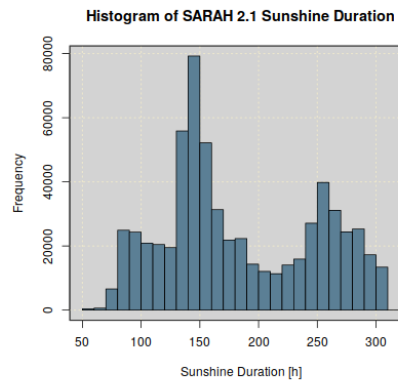
Invert Colors
Border Color

Plot **Statistics** File Summary About


Some numbers for the selected region.

Mean: 183
Median: 162
Standard deviation: 64
Maximum: 310
Minimum: 51
Unit: h

To save the histogram figure: right-click + save image as...



Visualize



the CM SAF
R TOOLBOX

Visualizer Options:

Select Time Step
1983-01-01 - 2017-12-01

Plot region
 Show Zoom

Longitude
-15 to 30

Latitude
30 to 65

Image Ratio
-0.9 0.1 0.9

Number of Colors: 64
Number of Ticks: 5

Colorbar
[Colorbar dropdown]

Invert Colors
Border Color

Plot Statistics **File Summary** About

Short File Info

The file: /cmsaf/cmsaf-rad6/stkotho/TOOLBOX/output/SDU_timmean144059.nc contains:

Variables:
SDU
time_bnds

With following dimensions:
lon with length 901 (range -15 to 30)
lat with length 701 (range 30 to 65)
time with length 1 (range 1983-01-01 to 1983-01-01)
nb2 with length 2 (range 0 to 1)

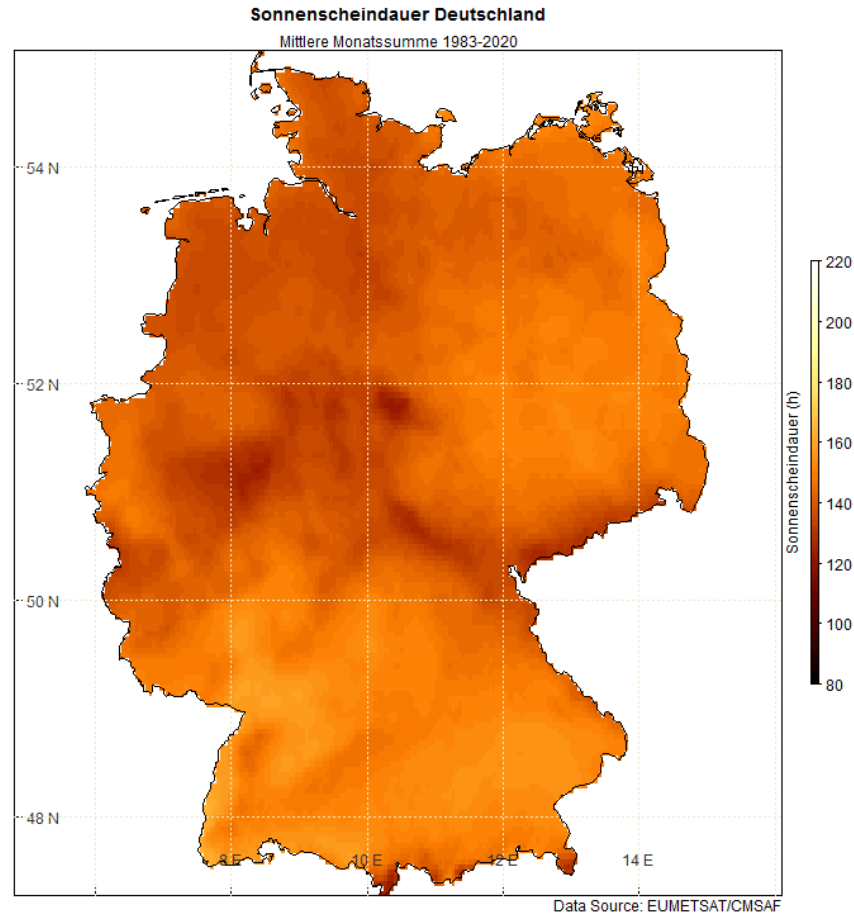
Detailed File Info

File /cmsaf/cmsaf-rad6/stkotho/TOOLBOX/output/SDU_timmean144059.nc (NC_FORMAT_NETCDF4):

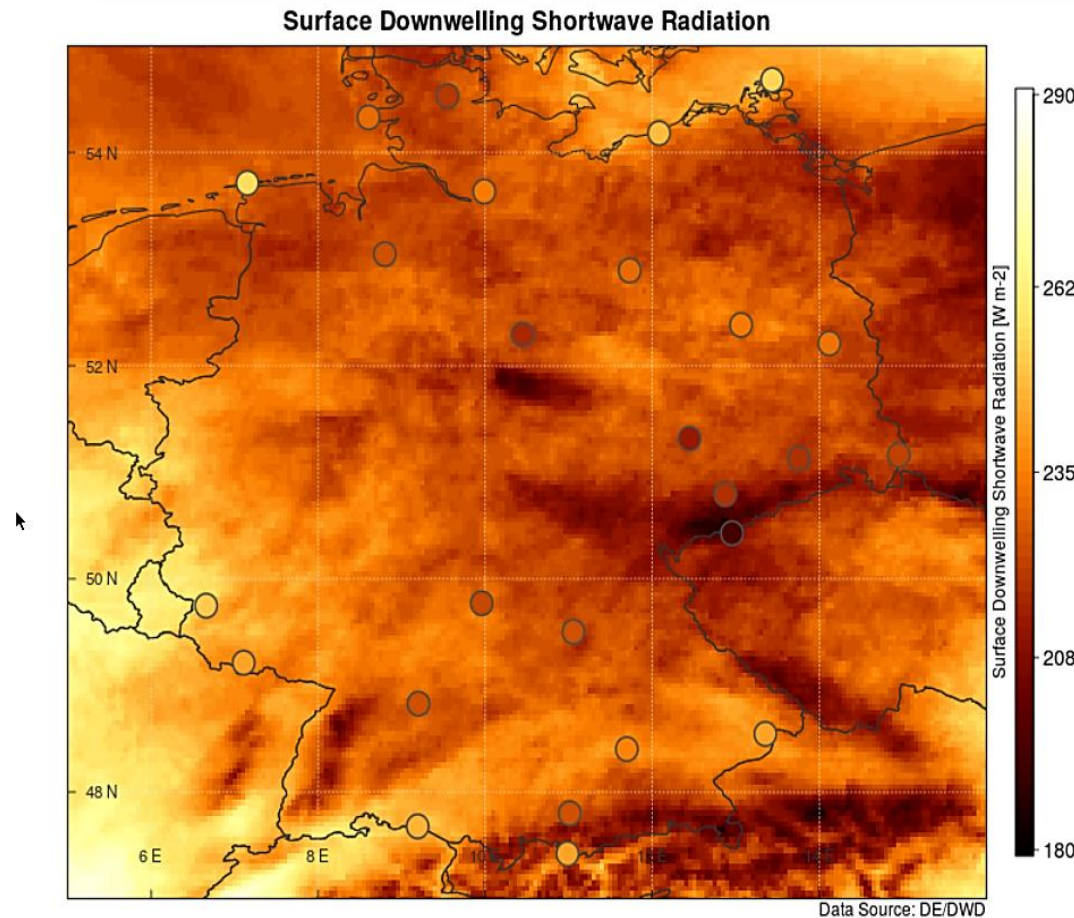
```
2 variables (excluding dimension variables):
  float SDU[lon,lat,time] (Chunking: [901,701,1]) (Compression: level 4)
    units: h
    _FillValue: -999
    standard_name: duration_of_sunshine
    long_name: Sunshine Duration
    cmsaf_info: cmsafops::timmean for variable SDU
  double time_bnds[nb2,time] (Chunking: [2,1])
    units: 1

4 dimensions:
  lon  Size:901
    units: degrees_east
    standard_name: longitude
    long_name: longitude
    axis: X
  lat  Size:701
    units: degrees_north
    standard_name: latitude
    long_name: latitude
    axis: Y
  time Size:1 *** is unlimited ***
    units: days since 1983-01-01 00:00:00
    long_name: time
    standard name: time
```

Visualize: Use Shapefiles

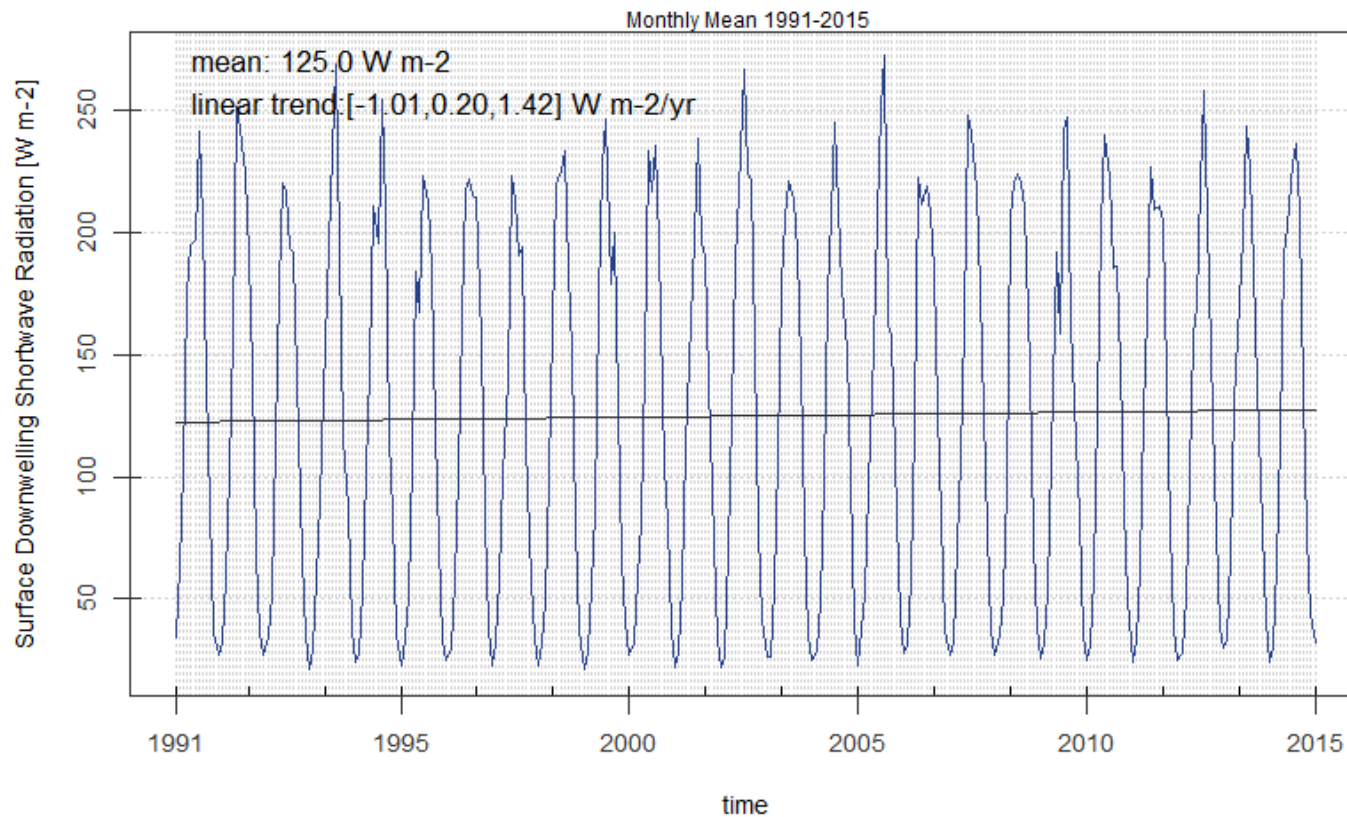


Visualize: Overlay Station Data

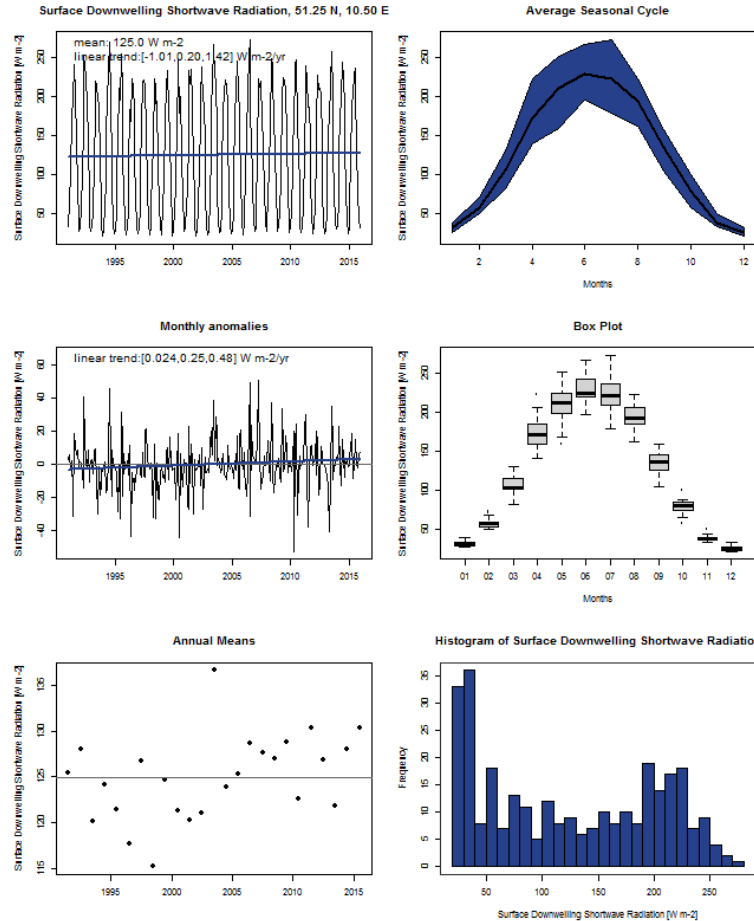


Visualize: Plot Time Series

Surface Downwelling Shortwave Radiation for Germany



Visualize: Analyze Time Series with One Click



Some Highlights: Multiple File Formats

The screenshot displays the CM SAF R Toolbox interface. A 'File format' dialog box is open, showing a dropdown menu with the following options: PNG, KML, GeoTiff, jpeg, and pdf. A 'Cancel' button is visible in the bottom right corner of the dialog. The background shows a map of cloud fraction with a color scale on the right ranging from 10.9 to 94.3. The map includes latitude and longitude markers (50 S, 150 W, 100 W, 50 W) and the text 'Data Source: EUMETSAT/CMSAF'. The interface also features various configuration options on the left, such as 'Border Color', 'Scale Range Min' (10,9), 'Scale Range Max' (94,3), 'Plot Country Borders', 'Plot R-Instat', 'Plot Own Location', 'Projection' (Rectangular), 'Title' (CLARA A2.1 Cloud Fraction), 'Subtitle', and 'Scale Caption' (cloud fraction [%]). 'Download' and 'Back' buttons are located at the bottom left of the interface.

Some Highlights: Compare Data

Please choose a variable

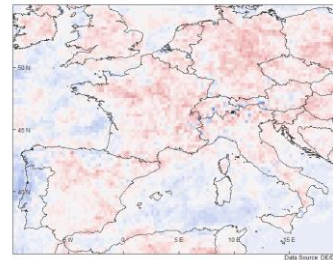
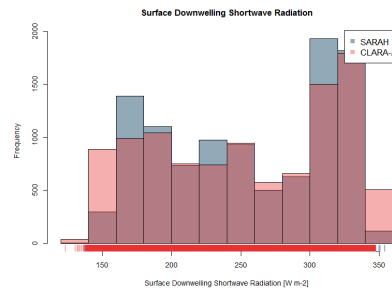
SIS

Select a group of operators

Compare Data

Select an operator.

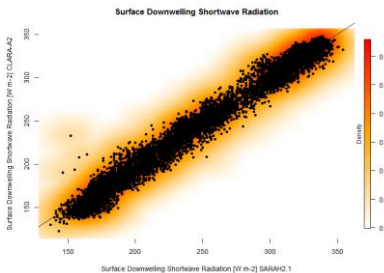
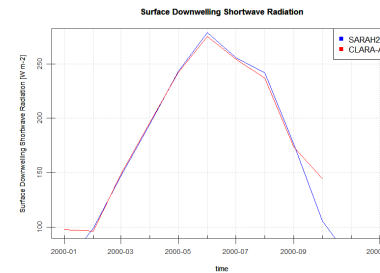
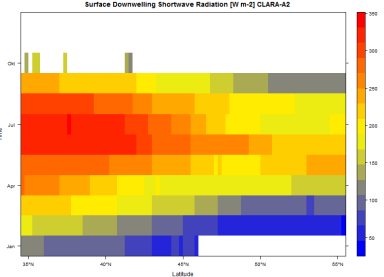
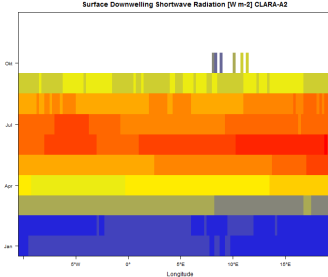
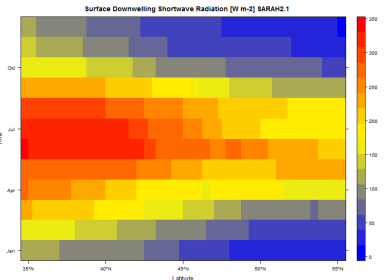
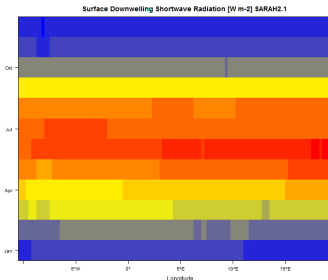
- Difference plot (absolute)
- Difference plot (relative)
- Scatterplot
- Histogram
- Side-by-Side plot
- Comparison of time series
- Hovmöller plot
- Show statistics



Plot Metrics File Summary About

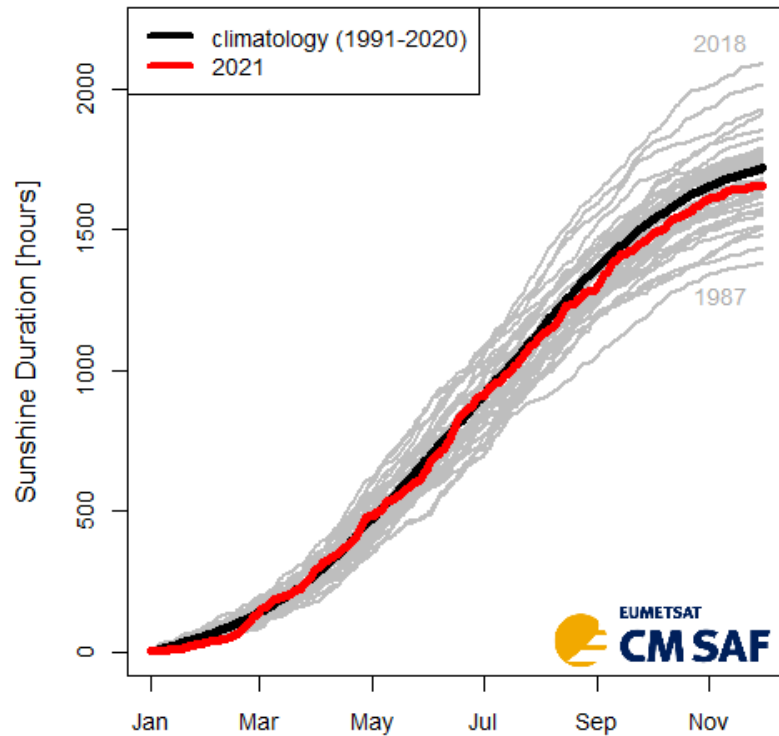
Metrics Compare Data

date.time	rmse	mae	bias	correlation
2000-01-01	8.506295	7.053025	5.9688141	0.9371886
2000-02-01	7.132968	5.547536	2.5749778	0.9886570
2000-03-01	6.740676	5.090336	1.9181380	0.9913958
2000-04-01	8.180659	6.407850	1.2038514	0.9783736
2000-05-01	9.898329	7.794798	0.9512247	0.9563417
2000-06-01	9.862399	7.963418	3.5929432	0.9804508
2000-07-01	10.206655	8.116911	1.7277837	0.9888991
2000-08-01	12.444698	9.866540	3.1271409	0.9638772
2000-09-01	10.003236	7.795496	1.7863850	0.9761946
2000-10-01	11.326240	8.042740	5.2107202	0.7978614
2000-11-01	NaN	NaN	NaN	NaN
2000-12-01	NaN	NaN	NaN	NaN

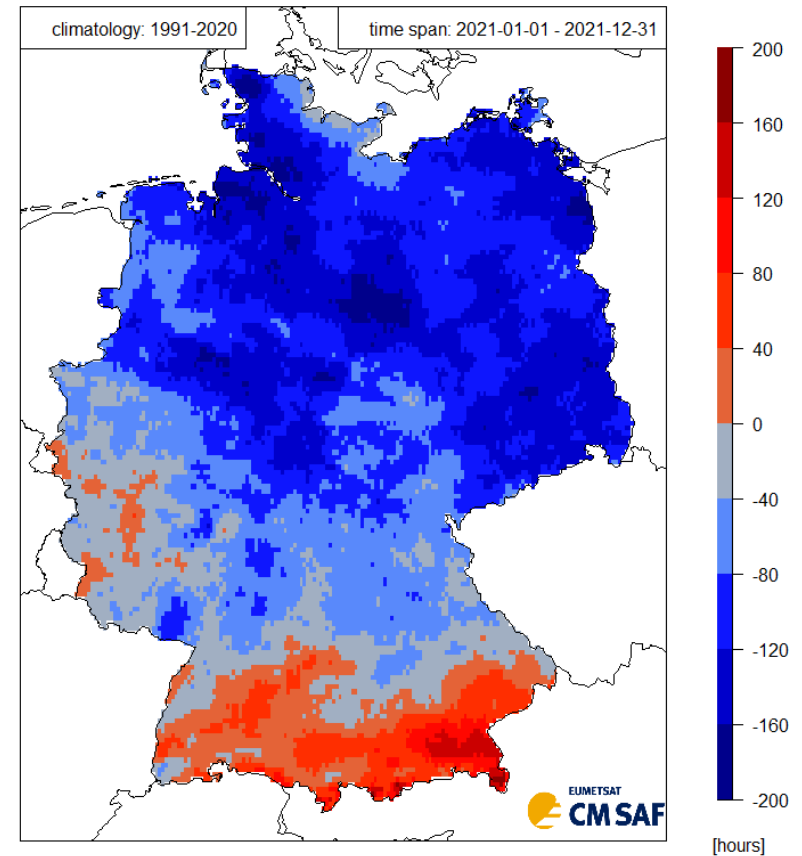


Some Highlights: Climate Analysis

2021 vs. climatology (Germany)

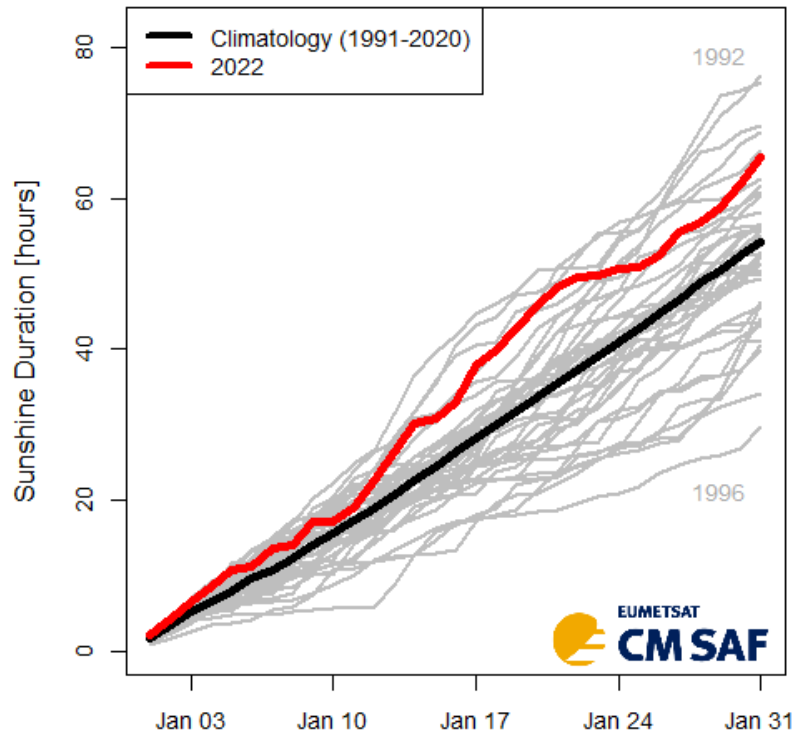


Sunshine Duration anomaly (Germany)

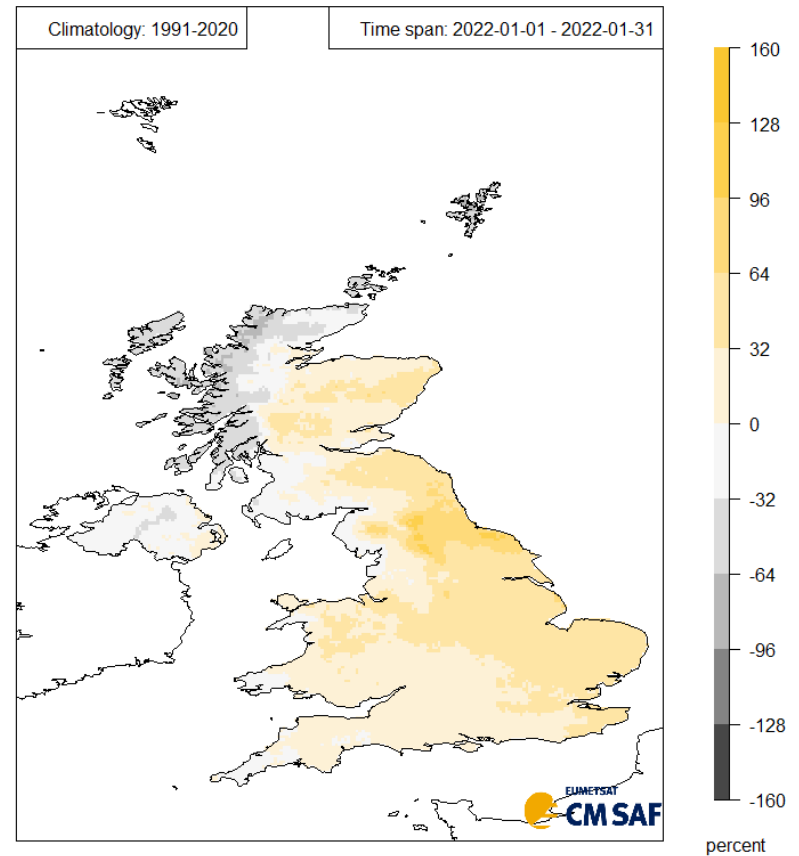


Some Highlights: Climate Analysis

2022 vs. Climatology (United Kingdom)

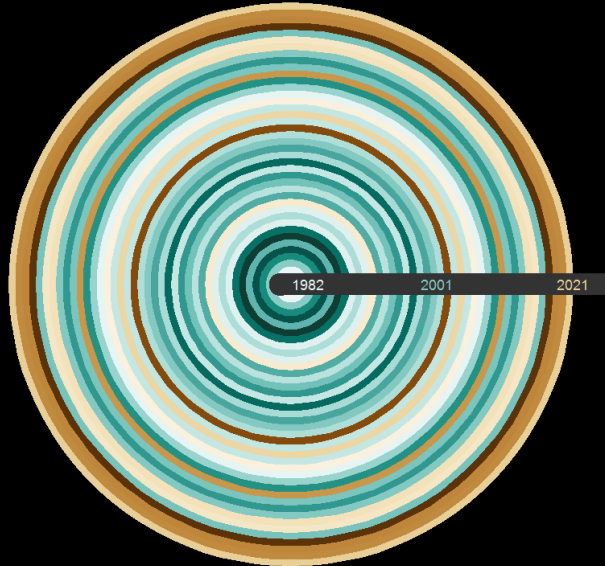


Sunshine Duration anomaly (United Kingdom)

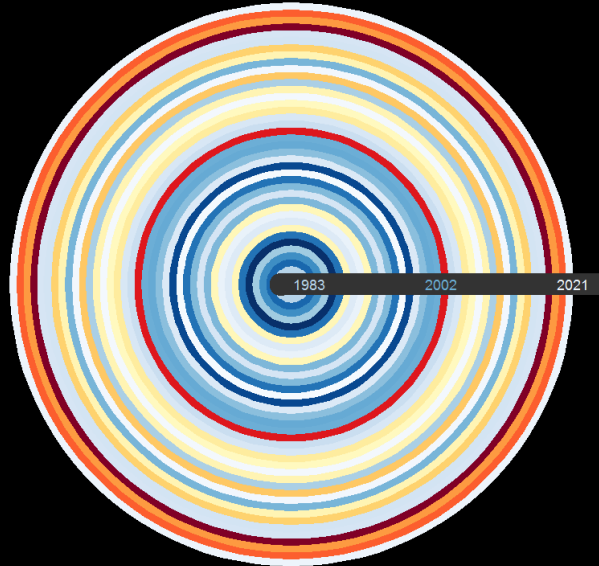


Some Highlights: Climate Analysis

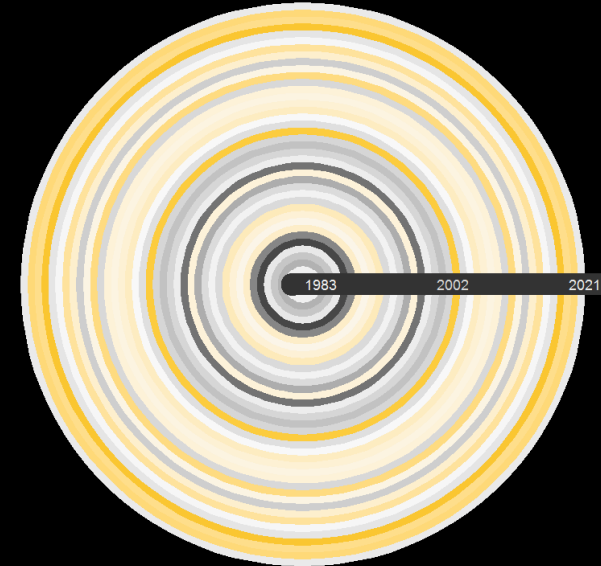
cfv change in Germany since 1982 (Reference: 1991 - 2021)



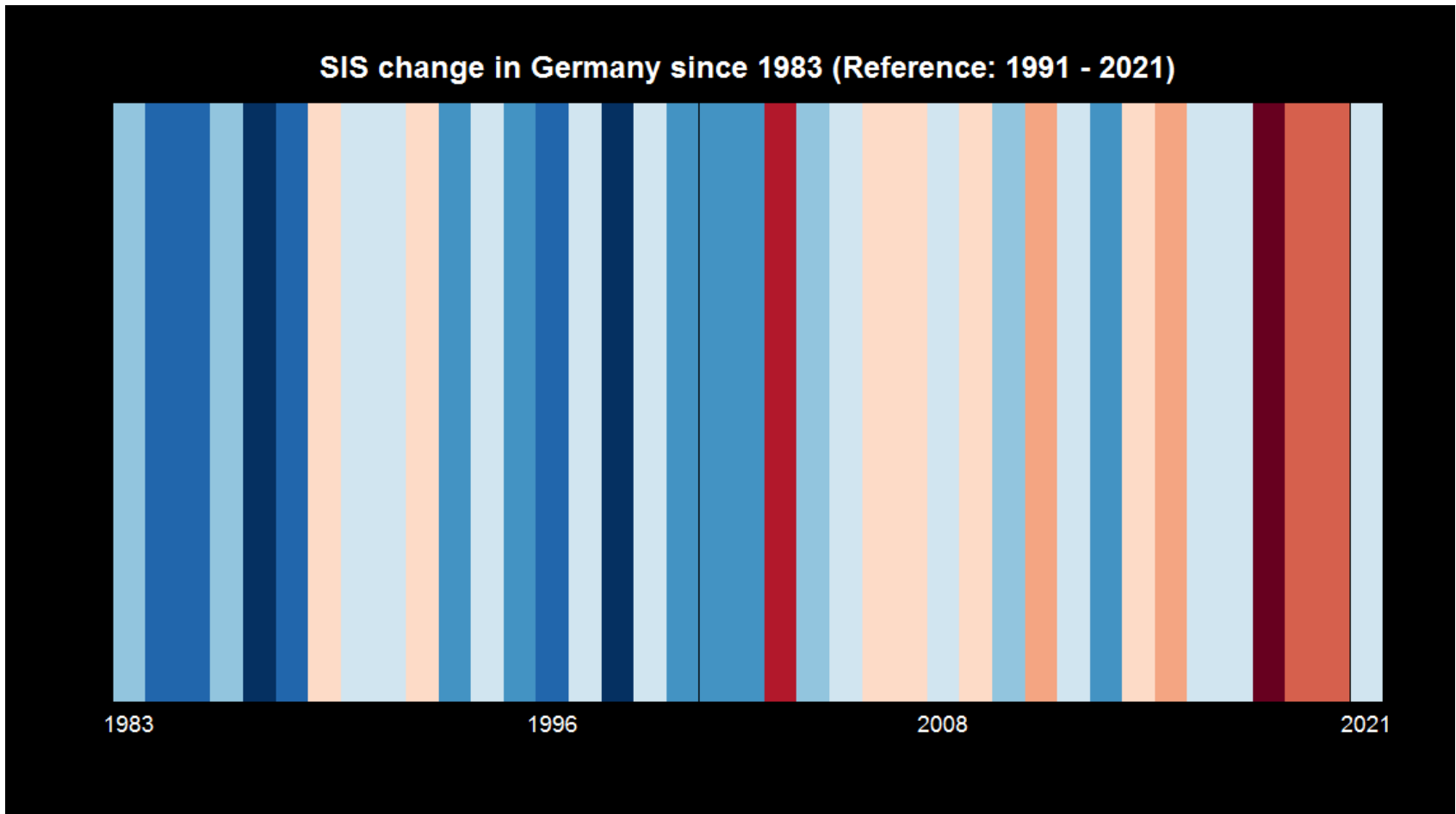
SIS change in Germany since 1983 (Reference: 1991 - 2021)



SDU change in Germany since 1983 (Reference: 1991 - 2021)



Some Highlights: Climate Analysis



Support

➔ If you need help using the Toolbox have a look at our manuals, Youtube videos, the Toolbox paper, Q&A document, Cheat Sheets, flyer, etc.

➔ www.cmsaf.eu/R_toolbox

➔ contact.cmsaf@dwd.de

