the CM SAF R TOOLBOX

Monthly report of Surface Incoming Shortwave Radiation (SIS)

Application examples for the CM SAF R Toolbox using CM SAF Cloud, Albedo, Radiation (CLARA) datasets

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Contents

Definition and importance of SIS

Surface **I**ncoming **S**hortwave Radiation (**SIS**) - also known as surface irradiance - describes the **total amount of shortwave radiation that reaches the Earth‘s surface** (taking effects of the cloud‘s albedo into account)

Shortwave radiation is the radiant energy with wavelengths in the visible (VIS), near-ultraviolet (UV) and near-infrared (NIR) spectra emitted by the sun.

- **Wavelength range**: ~200-3000 nm
- **SI-Unit**: W/m^2

Definition and importance of SIS

Importance of SIS:

- SIS measurements form the basis for calculation of several other radiation quantities like the Surface Radiation Budget (SRB)
- Shortwave radiation is the main contributor of warming the Earth's surface and thus snow and ice melt

The CLARA dataset

- The **C**M SAF C**L**oud, **A**lbedo, **RA**diation (CLARA) dataset is a global data record including several cloud, surface albedo and surface radiation parameters.
- It is derived from measurements of the **Advanced Very High Resolution Radiometer (AVHRR)** onboard the polar orbiting NOAA and Metop satellites
- **Temporal resolution**: Monthly mean, daily mean, pentad mean
- **Spatial resolution**:
  - 0.25°x 0.25° for monthly and daily means (used here)
  - 0.05°x 0.05° for daily subsampled products

The CLARA dataset

Why do we choose this dataset?

- For this application examples, we analyze several locations all over the world (big spatial coverage needed)
  - ➢CLARA dataset provides global coverage

- In this project we focus on monthly means, anomalies, trends,..
  - ➢The temporal resolution (monthly) is suitable for these applications

Application exampels: Tip

- All data used in this project are accessible from EUMETSAT CM SAF, https://wui.cmsaf.eu
- After ordering and downloading the data as .tar-files, you can combine multiple files by rename them with the same order number, for example:

  ORD44786.tar → ORD44786.tar

  ORD44787.tar → ORD44786_1.tar

  ORD44788.tar → ORD44786_2.tar

  …. → ….

Application examples: long-term mean

a) Long-term mean of SIS in a specific month

Prepare

Required data: - Monthly, mean data (.tar files) for the preferred area
- Temporal coverage: 1991-01-01 to 2020-12-01

Important:

- If you want to combine multiple data records (e.g. CDR & TCDR), data need to have the same spatial and temporal resolution
- Avoid temporal overlap of the data

THEN: **Unzip and untar** the data for the time range 1991-01-01-2020-12-01

Application examples: long-term mean

a) Long-term mean of SIS in in a specific month

Analyze

- **Group of operators:** Monthly statistics
- **Operator**: Multi-year monthly means

↓

THEN: tick the box „do you want to apply another operator afterwards?”, apply operator and continue with the second operator:

↓

- **Group of operators:** Selection
- **Operator**: Select list of months

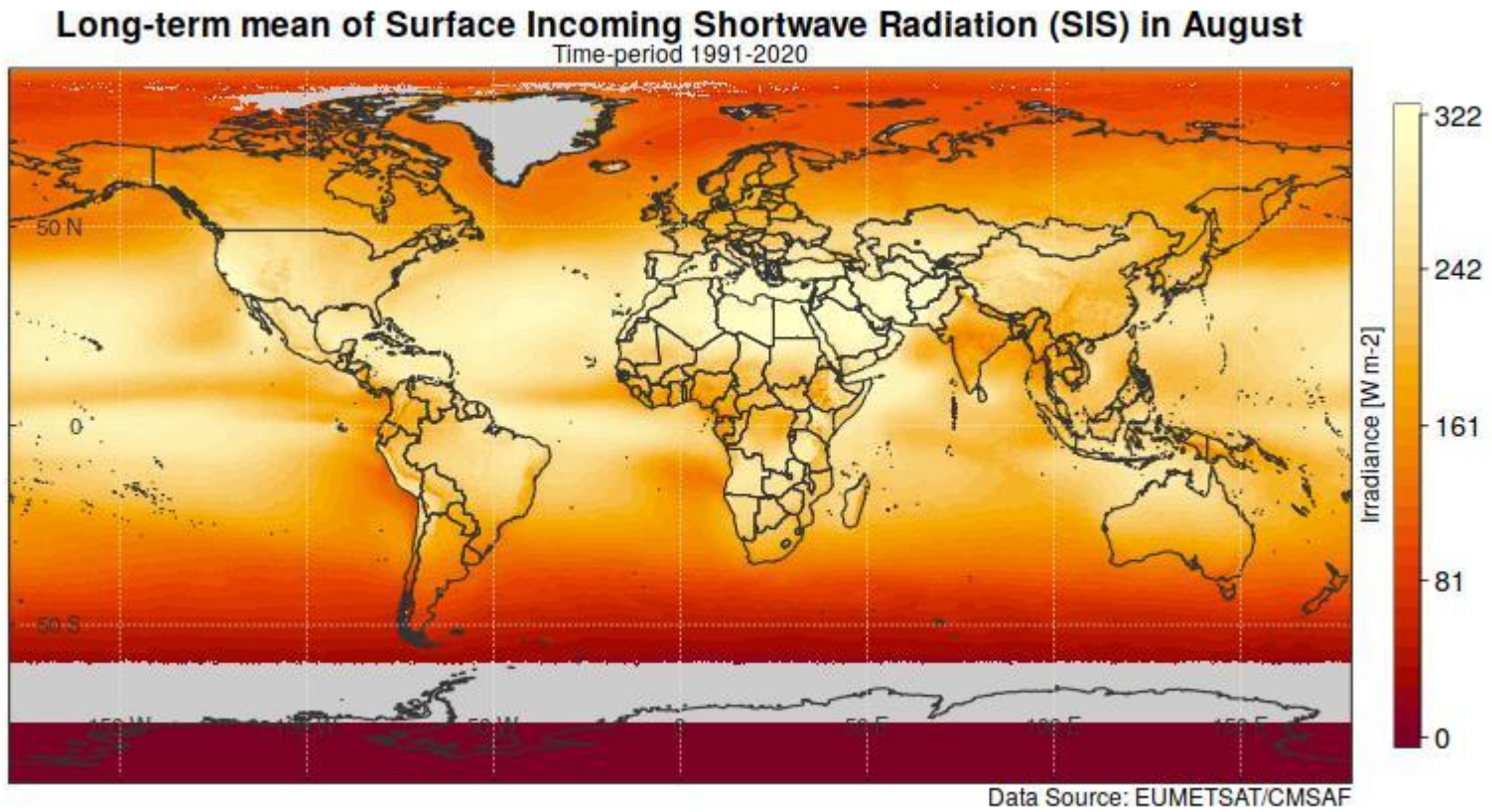
↓

Select the month you want to analyze, untick the box „do you want to apply another operator afterwards?” and apply the operator

Application examples: long-term mean

a) Long-term mean of SIS in a specific month

Visualize



Tip: vary the colorbar or the bordercolor to improve legibility

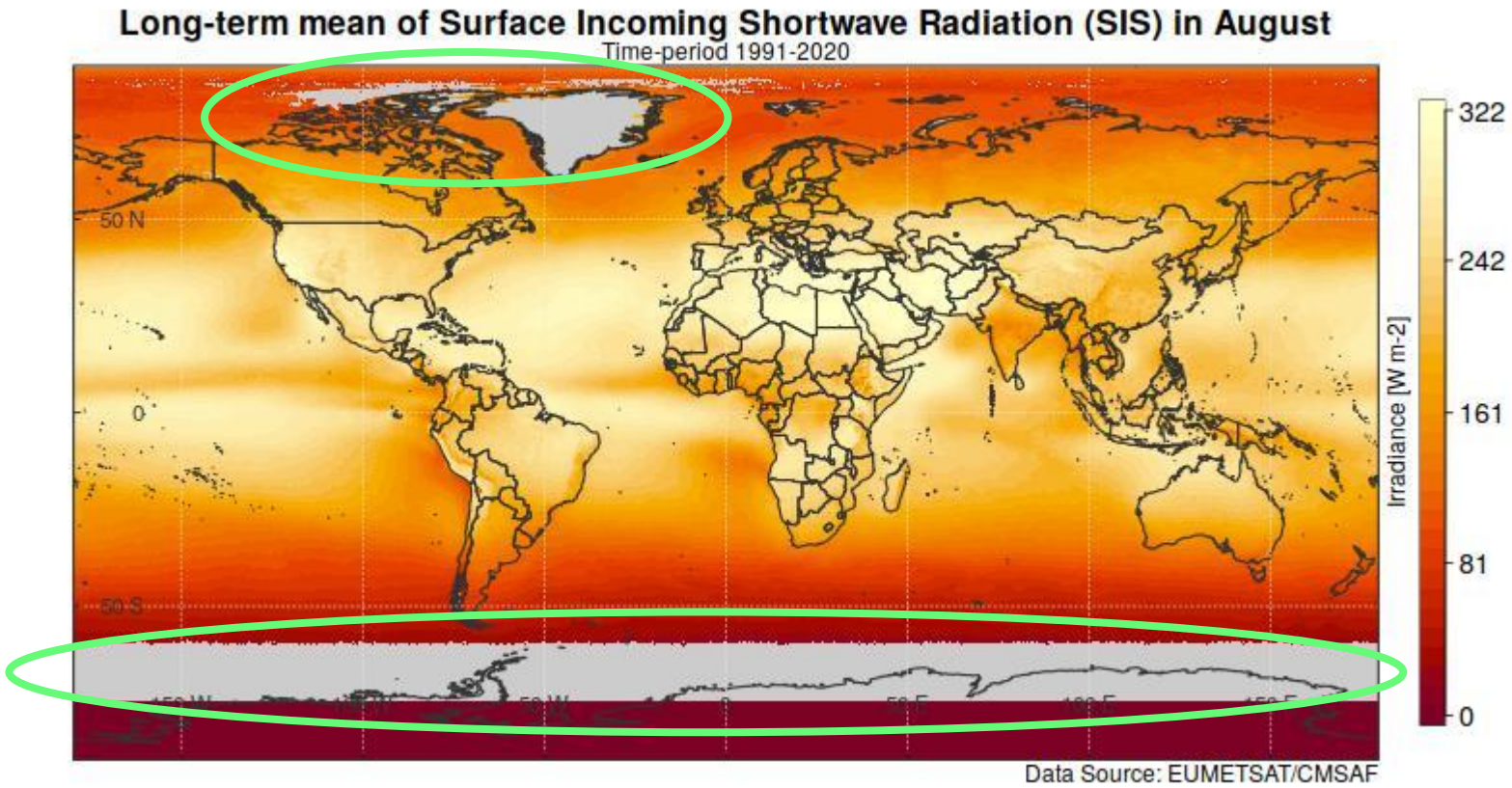
Result: Map of the global long-term mean of SIS in August over the time period 1991-2020

Application examples: long-term mean

a) Long-term mean of SIS in a specific month

Visualize

- Extremely low irradiance during June, July, August (winter on the southern hemisphere) results in lack of data in the very south
- Uncertainties in data retrieval caused by snow and ice masses result in data gaps at the poles



Result: Map of the global long-term mean of SIS in August over the time period 1991-2020

Application examples: Comparison of monthly means

b) Comparison of monthly means in South America

Prepare

Required data: - Monthly, mean data (.tar files) for the preferred area
- Temporal coverage: 2022-01-01 to 2022-07-01
(if you want to compare the months January till July of the year 2022)

Important:

- If you want to combine multiple data records (e.g. CDR & TCDR), data need to have the same spatial and temporal resolution
- Avoid temporal overlap of the data

THEN: **Unzip and untar** the data for the time range 2022-01-01-2022-07-01

Application examples: Comparison of monthly means

b) Comparison of monthly means

Analyze

- **Group of operators:** Monthly statistics
- **Operator**: Monthly mean

Visualize

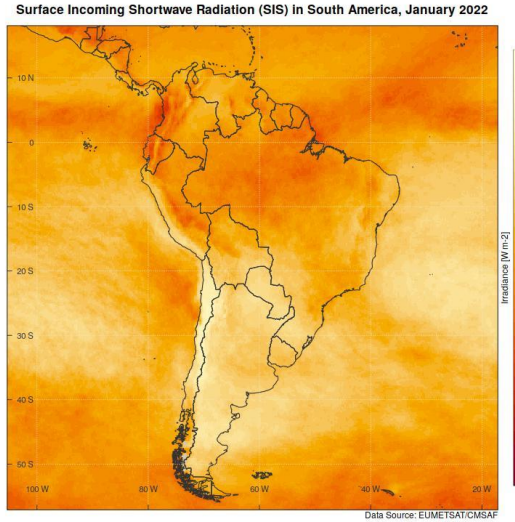
- You can either visualize the .nc file you just generated in the steps before or pick another file from your directory
- For each month you can select the fitting time step in the visualizer options and generate the plots one by one

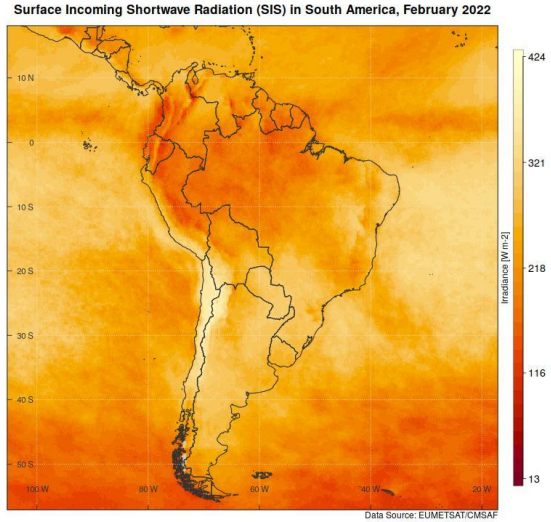
Application examples: Comparison of monthly means

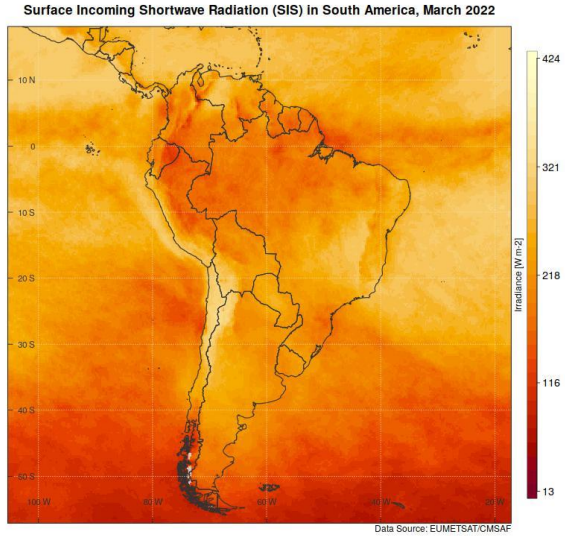
b) Comparison of monthly means

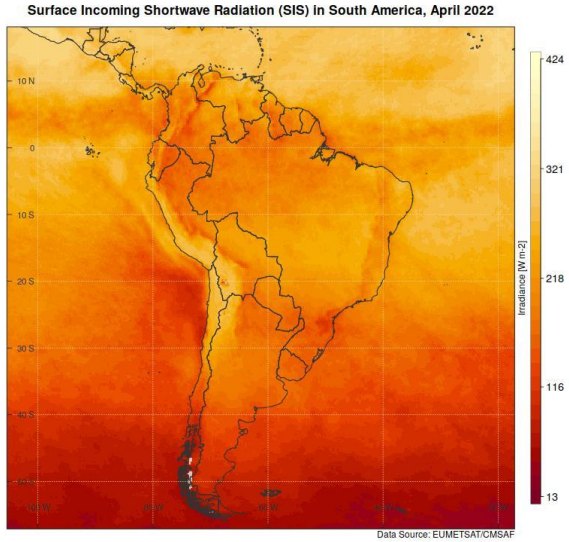
Visualize

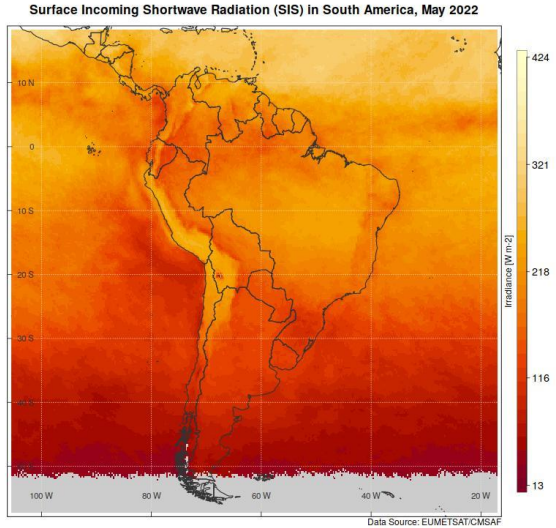
Result: Comparison of the monthly means January-July 2022

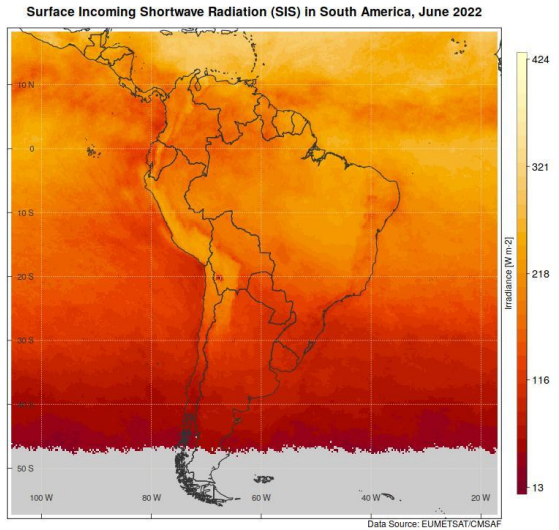


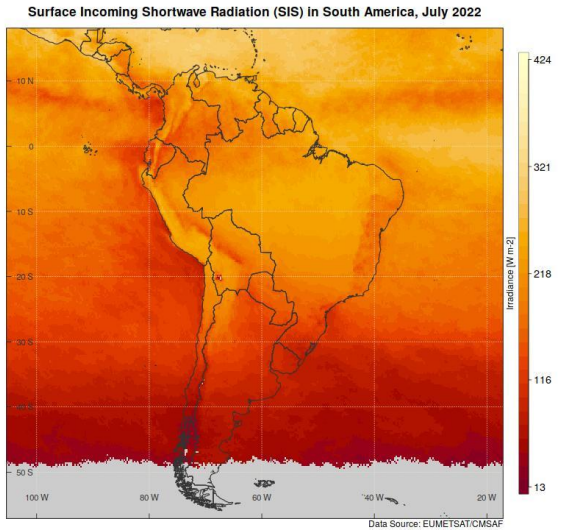










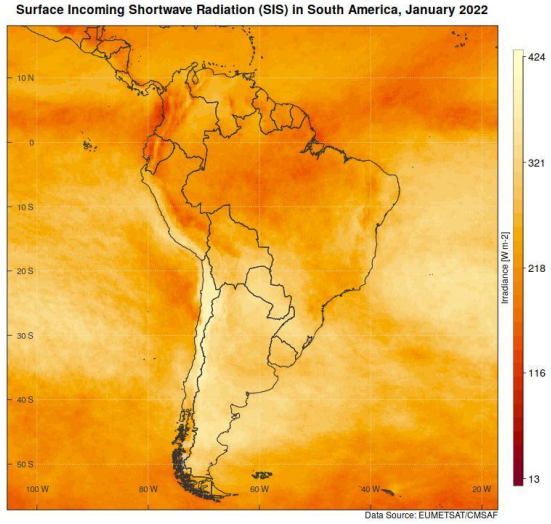


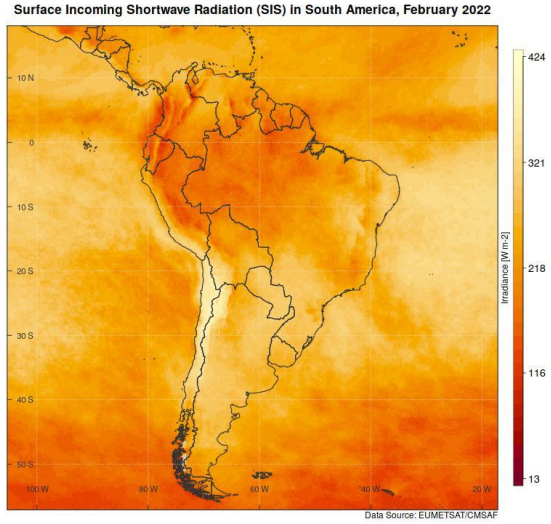
Application examples: Comparison of monthly means

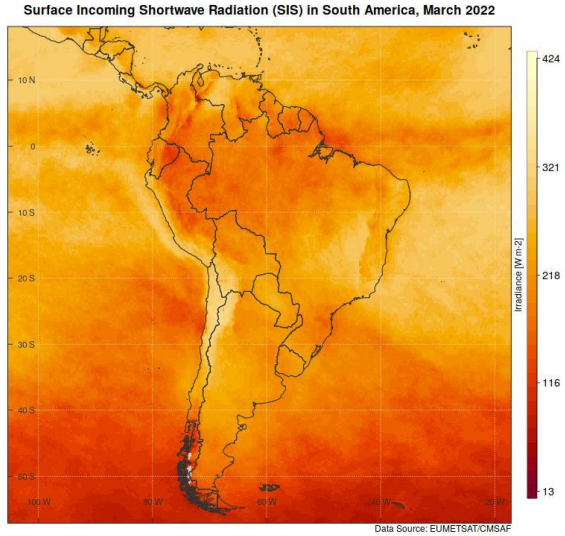
b) Comparison of monthly means

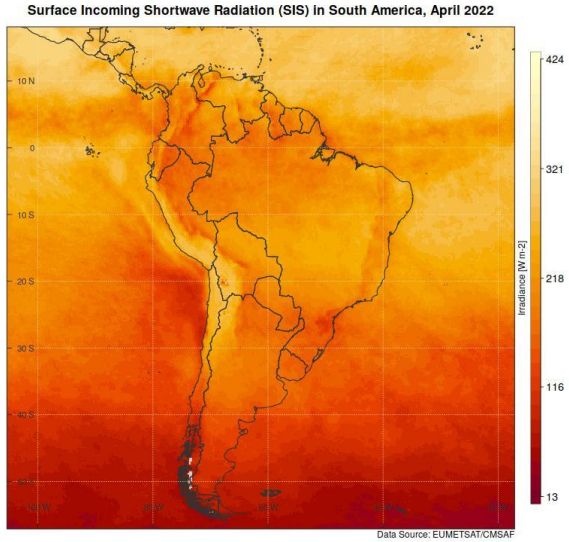
Visualize

Result: Comparison of the monthly means January-July 2022

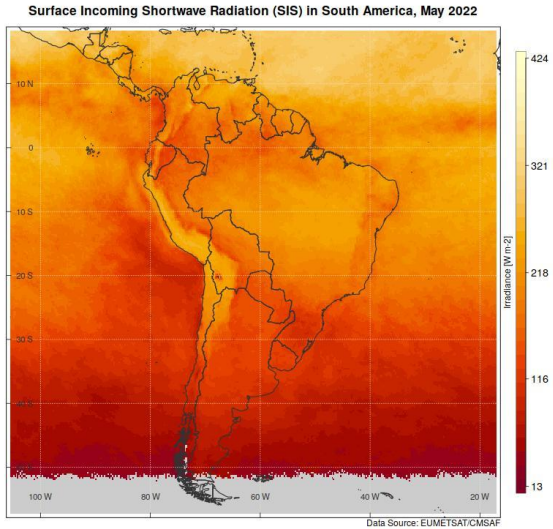


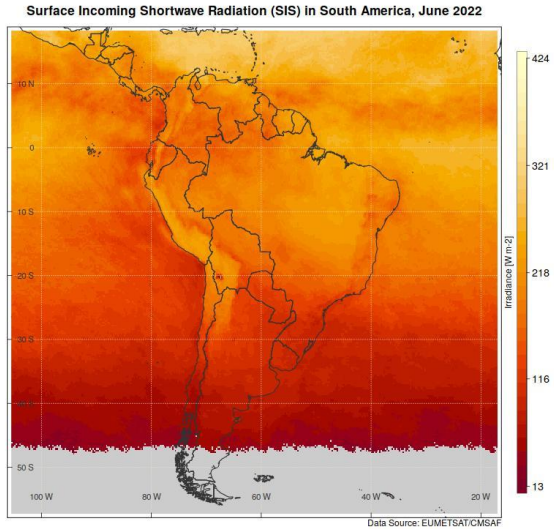


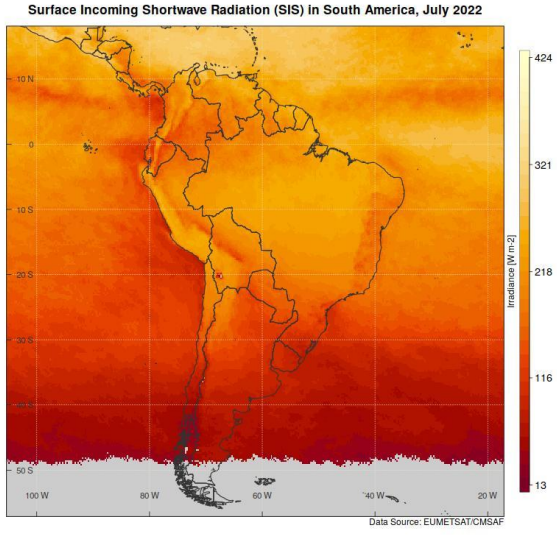




- At the Andes the monthly mean of SIS is significantly higher than in the rest of the country due to lower cloud fractional cover





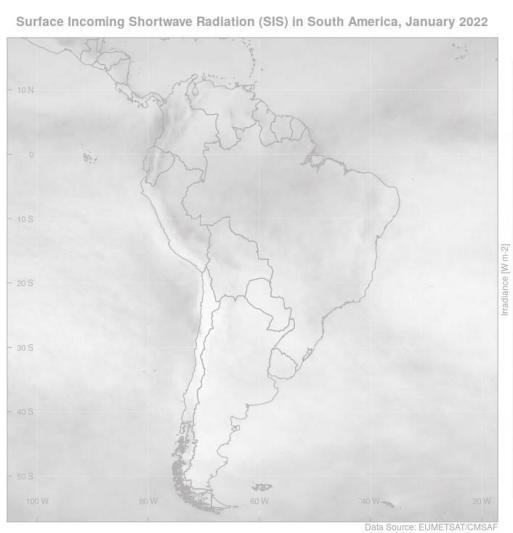


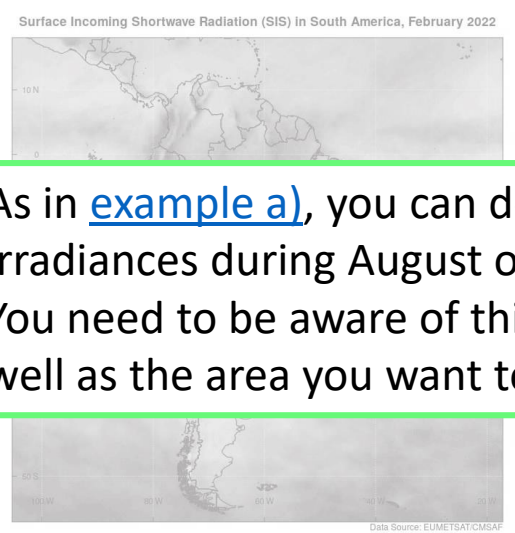
Application examples: Comparison of monthly means

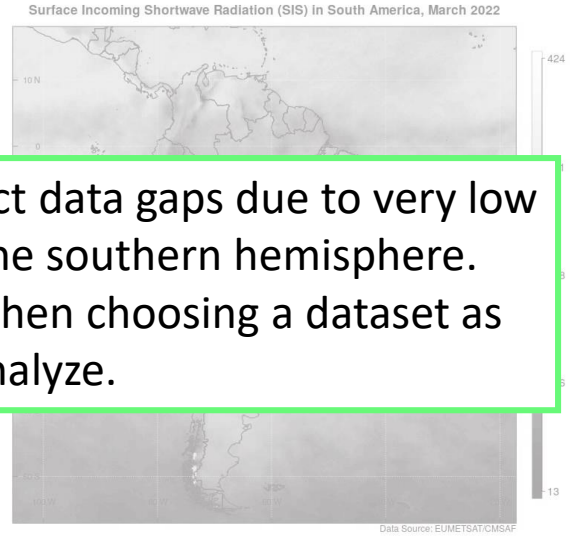
b) Comparison of monthly means

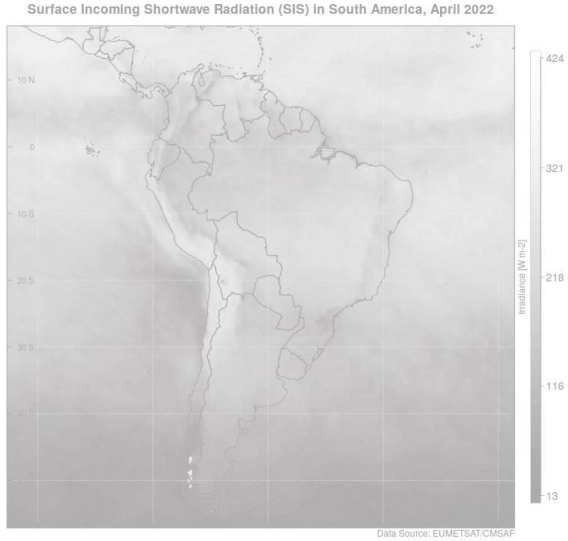
Visualize

Result: Comparison of the monthly means January-July 2022

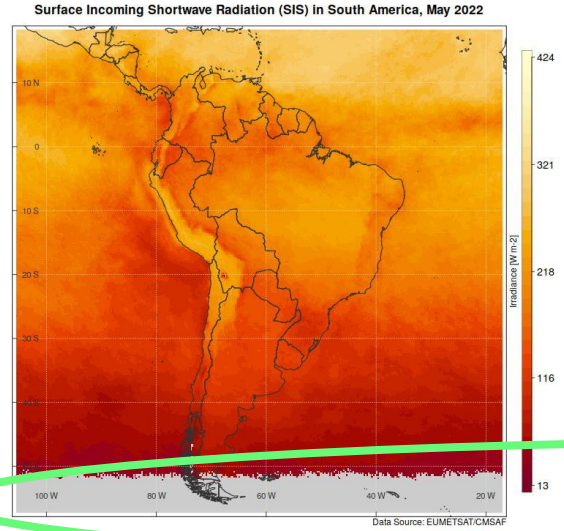


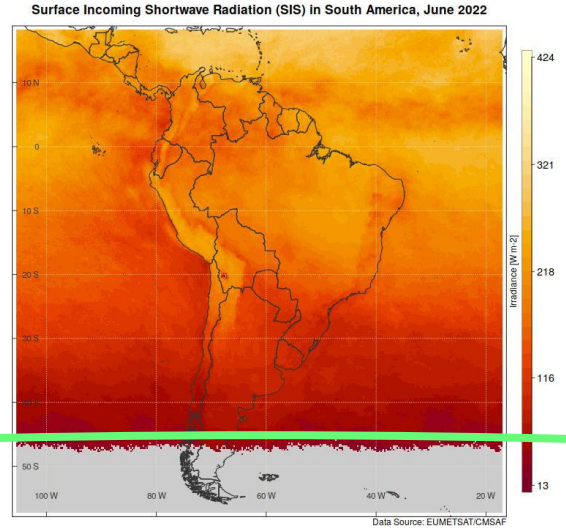


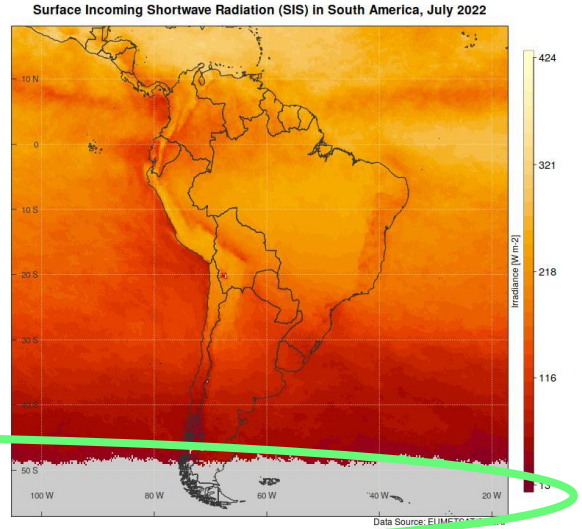




As in [example a)](), you can detect data gaps due to very low irradiances during August on the southern hemisphere. You need to be aware of this when choosing a dataset as well as the area you want to analyze.







Application examples: Global monthly anomaly in a specific month

c) Global monthly anomaly in a specific month

Prepare

Required data: - Monthly, mean data (.tar files) for the preferred area
- Temporal coverage: 1991-01-01 to 2022-09-01
(or latest available data of the current year)

Important:

- If you want to combine multiple data records (e.g. CDR & ICDR), data need to have the same spatial and temporal resolution
- Avoid temporal overlap of the data

Application examples: Global monthly anomaly in a specific month

c) Global monthly anomaly in a specific month

STEP 1: Generating the global long-term mean of the month (August)

Prepare

Unzip and untar data for the time range 1991-01-01-2020-01-01

! (if you already generated the long-term mean of the month in example a) you can directly skip to **STEP 2**)

Analyze

- **Group of operators**: Monthly statistics
- **Operator**: Multi-year monthly means

THEN: tick the box „do you want to apply another operator afterwards?", apply operator and continue with the second operator:

- **Group of operators**: Selection
- **Operator**: Select list of months

Select the month you want to analyze, untick the box „do you want to apply another operator afterwards?"

and apply the operator to create the global long-term mean of the month

Application examples: Global monthly anomaly in a specific month

c) Global monthly anomaly in a specific month

STEP 2: Generating the anomaly map

➡ Directly start from Analyze and choose the .nc-file from the prepare-section in the beginning „SIS_1991-01-01-2022-12-01.nc“

Analyze

- **Group of operators**: Selection
- **Operator**: Select list of months

⬇

Select the month you want to analyze, tick the box „do you want to apply another operator afterwards?”, apply the operator and continue with the second operator:

- **Group of operators**: Mathematical operator
- **Operator**: Substract values from another file

⬇

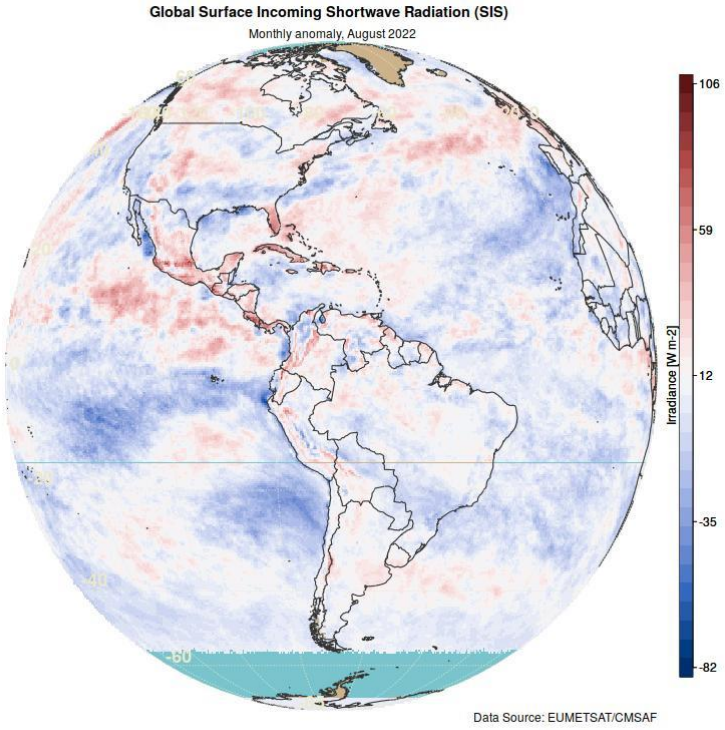
untick the box „do you want to apply another operator afterwards?”,

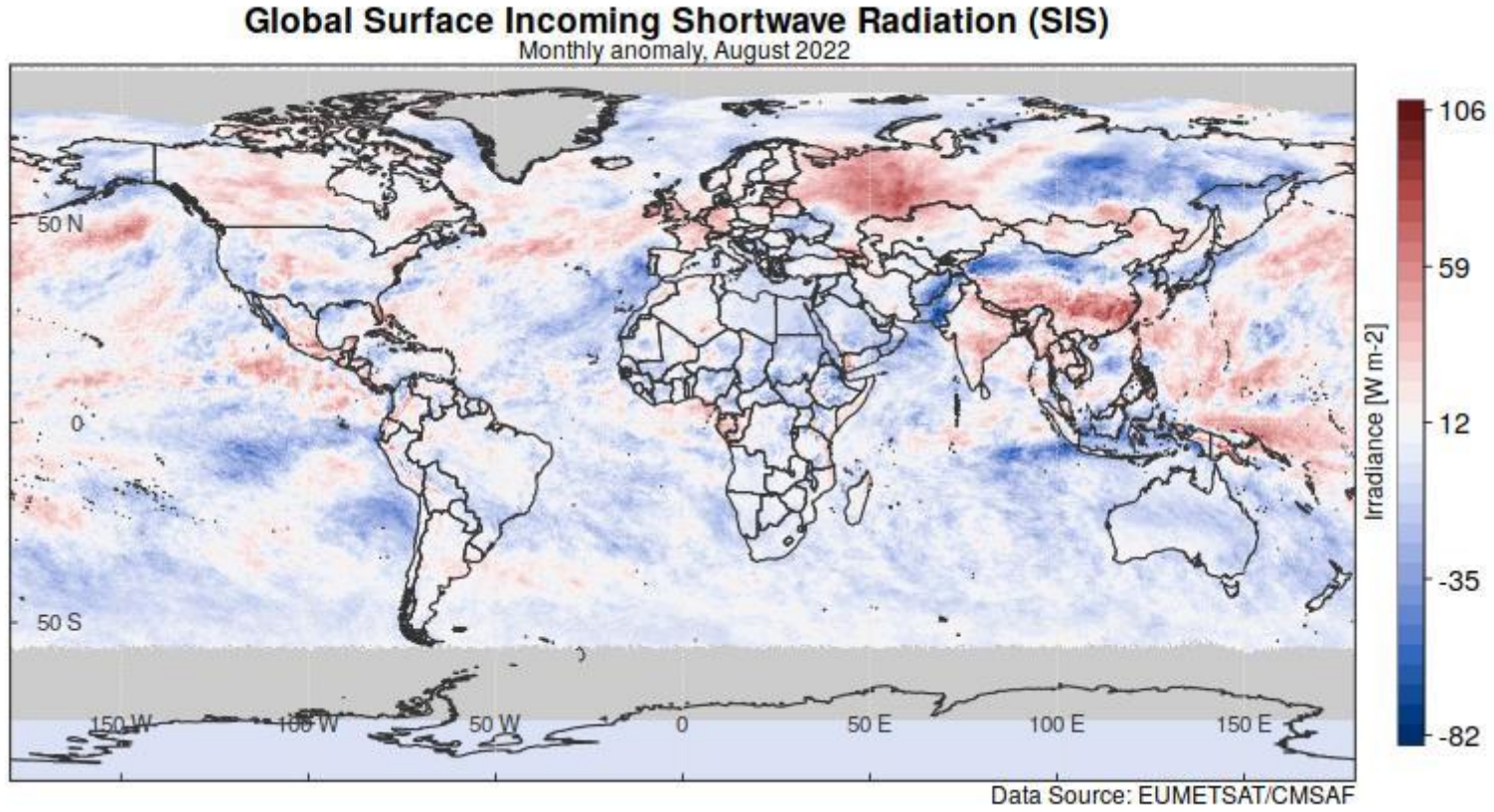
apply the operator and **choose the .nc-file „SIS_selmon…“ from Step 1**

Application examples: Global monthly anomaly in a specific month

c) Global monthly anomaly in a specific month

Visualize





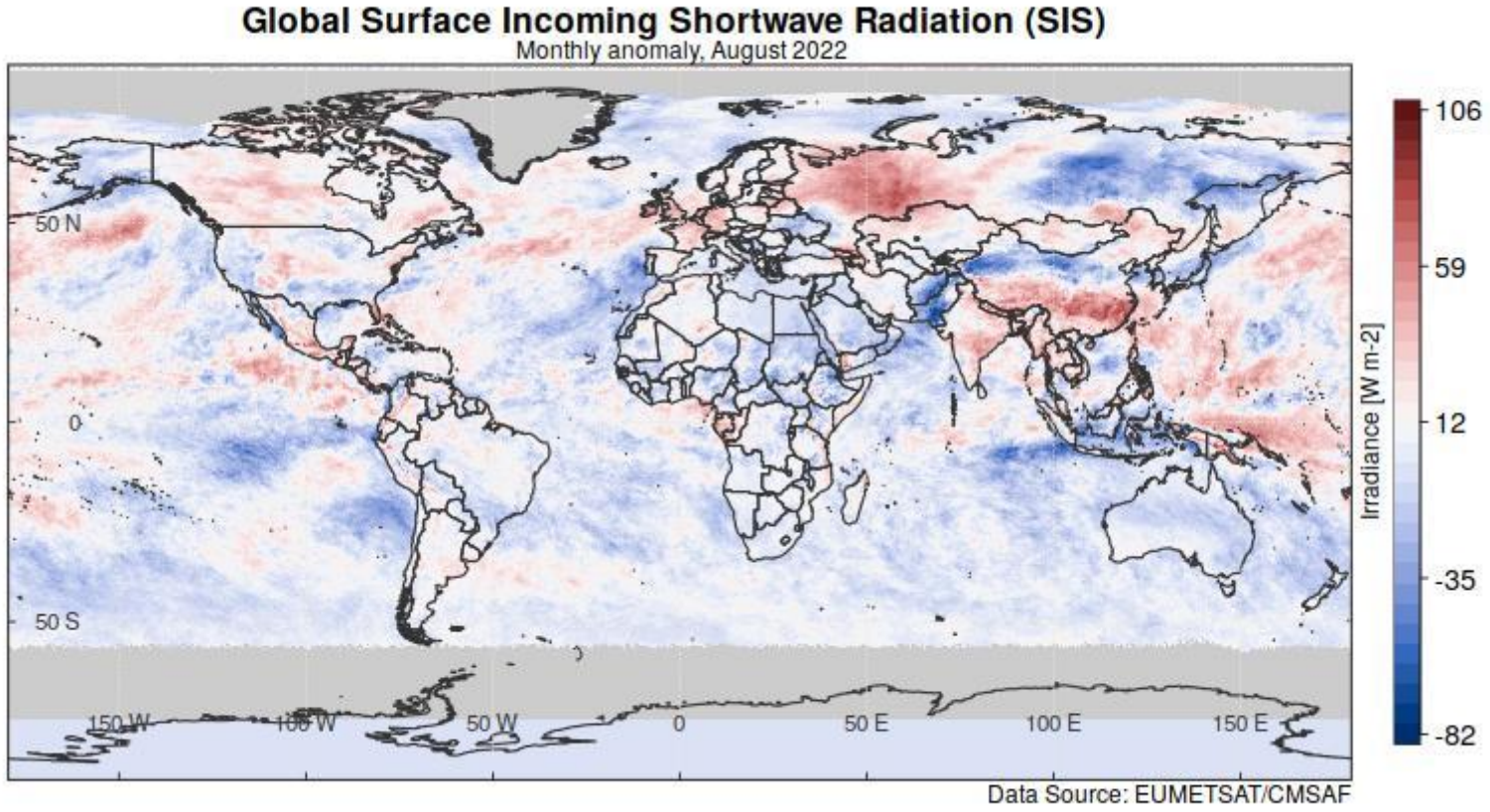
Result: Global monthly anomaly of SIS in August 2022.
In the visualizer options you can switch between rectangular (map on the right) and orthographic (map on the left) projection.

Application examples: Global monthly anomaly in a specific month

c) Global monthly anomaly in a specific month

Visualize

- Significant are the positive anomalies in central Europe as well as the strong gradients of SIS anomaly within Russia and China

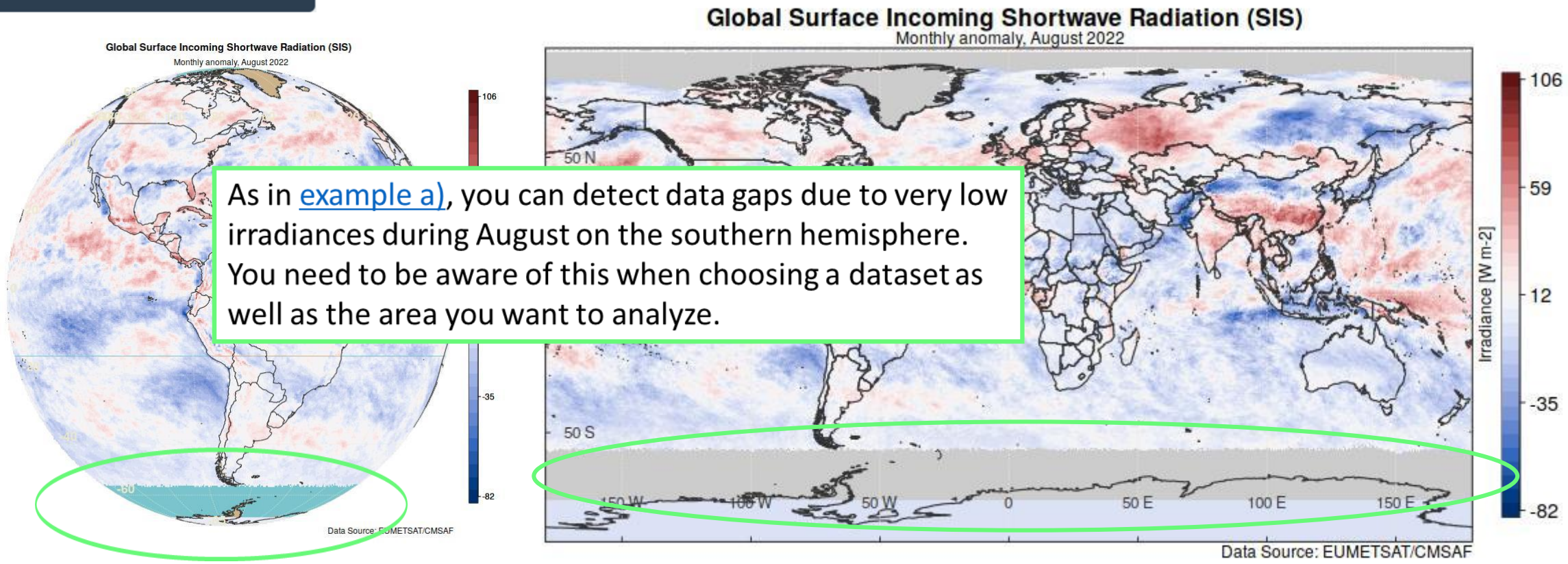


Result: Global monthly anomaly of SIS in August 2022.
In the visualizer options you can switch between rectangular (map on the right) and orthographic (map on the left) projection.

Application examples: Global monthly anomaly in a specific month

c) Global monthly anomaly in a specific month

Visualize



As in example a), you can detect data gaps due to very low irradiances during August on the southern hemisphere. You need to be aware of this when choosing a dataset as well as the area you want to analyze.

Result: Global monthly anomaly of SIS in August 2022.
In the visualizer options you can switch between rectangular (map on the right) and orthographic (map on the left) projection.

Application examples: Global seasonal anomaly

d) Global seasonal anomaly (here: summer 2022)

Prepare

Required data: see example c)

Important:

- If you want to combine multiple data records (e.g. CDR & ICDR), data need to have the same spatial and temporal resolution
- Avoid temporal overlap of the data

Application examples: Global seasonal anomaly

d) Global seasonal anomaly in summer 2022

STEP 1: Generating seasonal mean in the time period 1991-2020

Prepare

Unzip and untar data for the time range 1991-01-01-2020-12-01

Analyze

- **Group of operators**: Seasonal statistics
- **Operator**: Multi-year seasonal means

Applying the operator generates a .nc-file „SIS_yseasmean…“ for the seasonal means over the reference time span 1991-2020

Application examples: Global seasonal anomaly

d) Global seasonal anomaly in summer 2022

STEP 2: Generating the anomaly map

Prepare

Unzip and untar data for the time range 2022-06-01-2022-08-01

Analyze

- **Group of operators**: Temporal operators
- **Operator**: All-time mean

THEN: tick the box „do you want to apply another operator afterwards?", apply the operator and continue with the second operator:

- **Group of operators**: Mathematical operator
- **Operator**: Substract values from another file

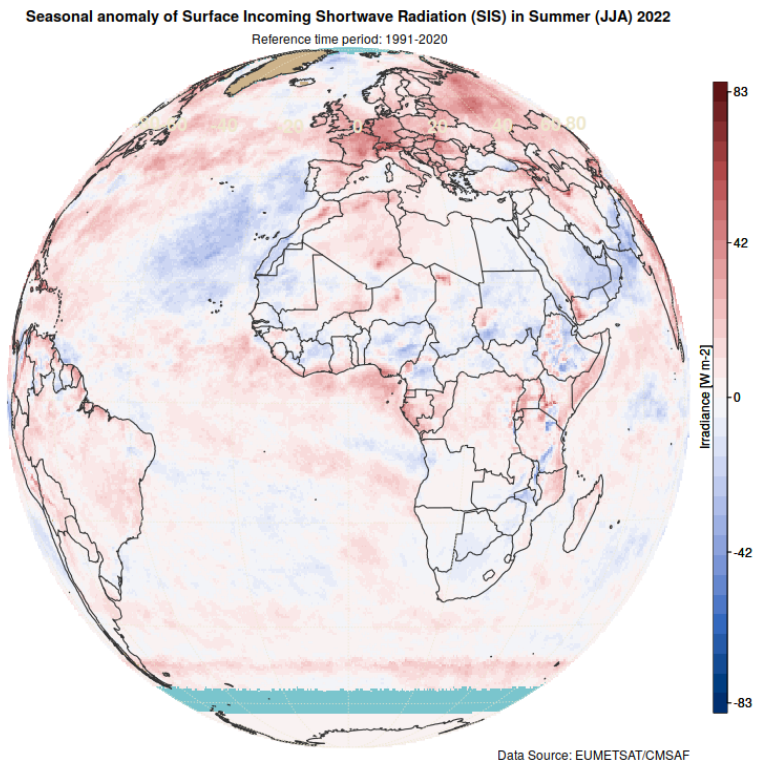
Apply the operator and choose the .nc file from Step 1

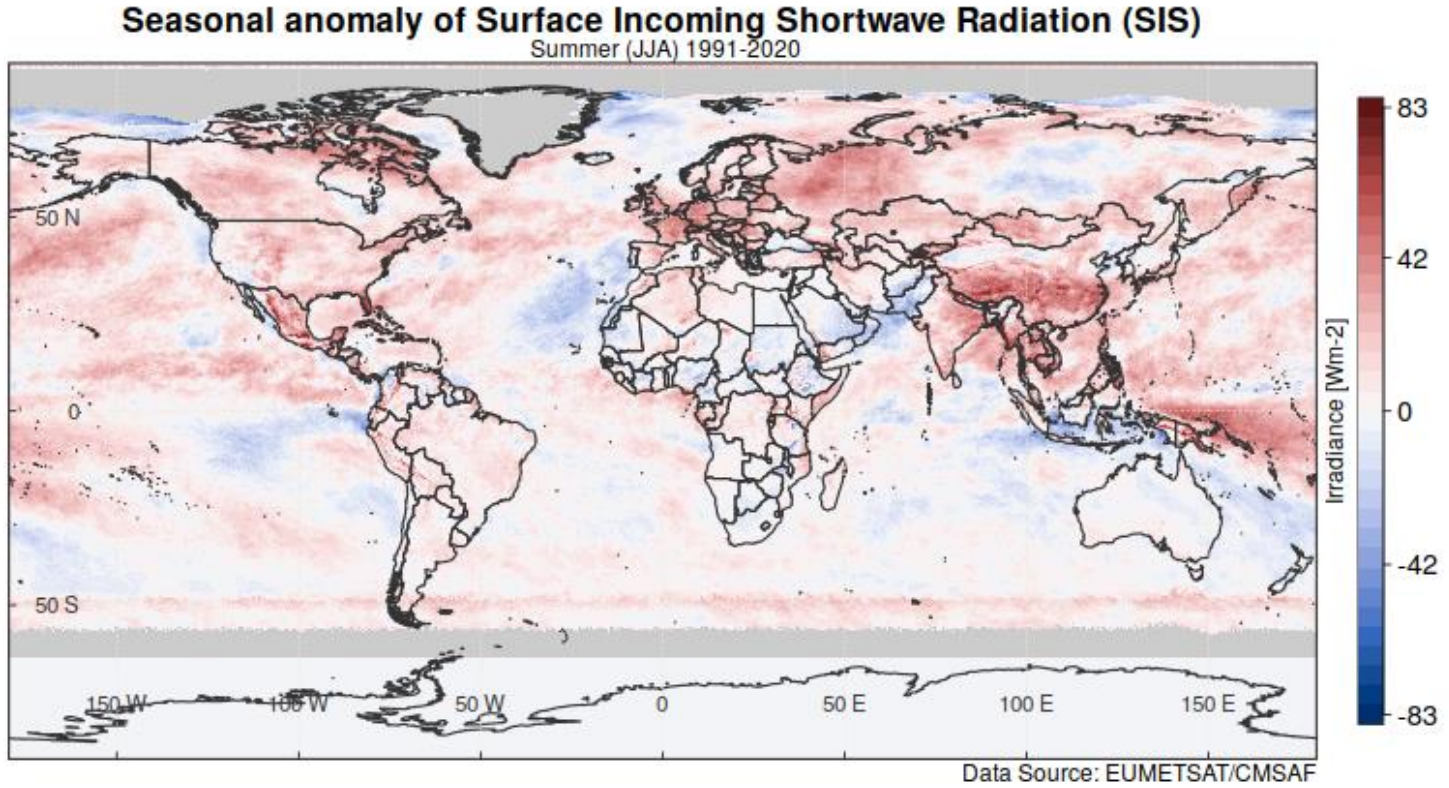
Visualize

Application examples: Global seasonal anomaly

d) Global seasonal anomaly in summer 2022

Visualize





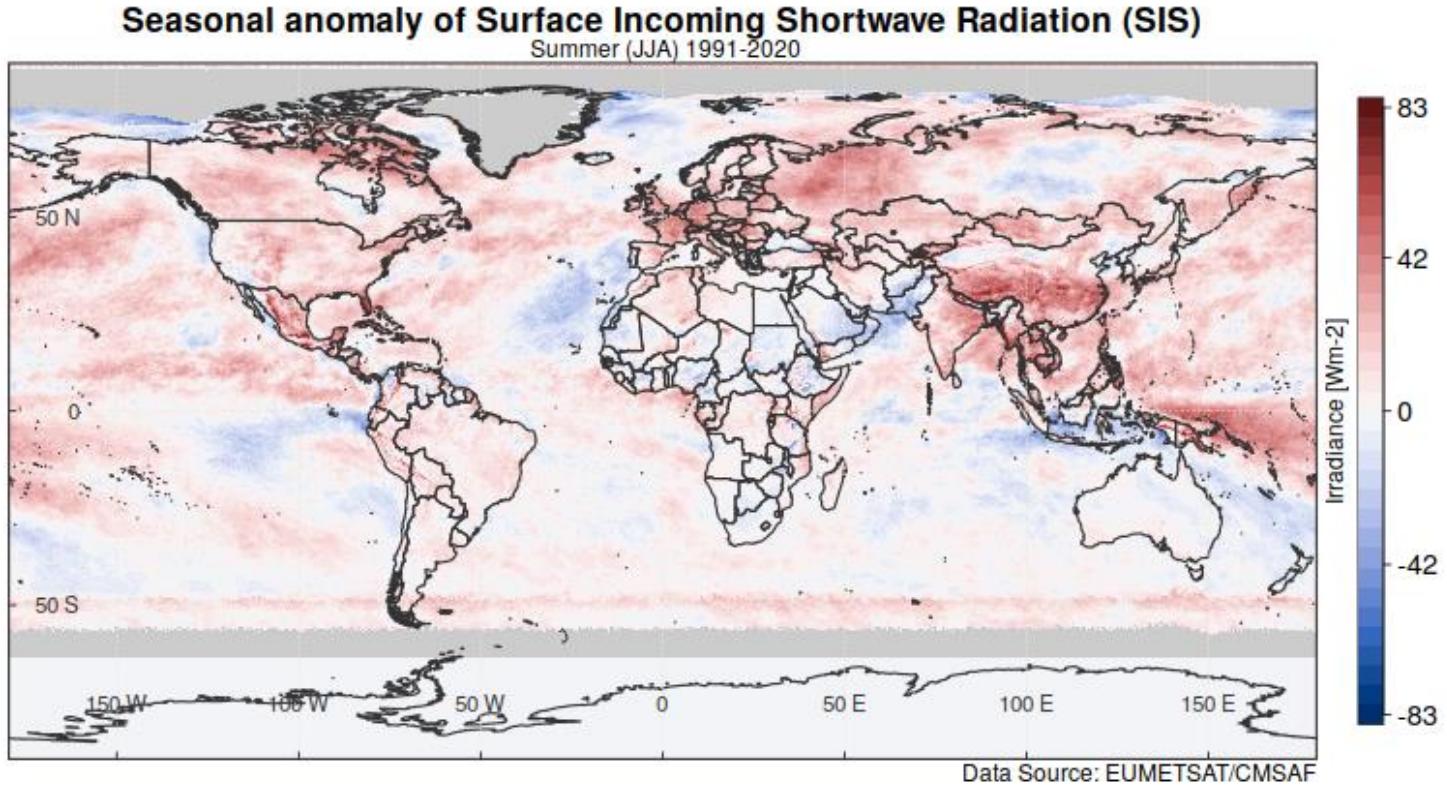
Result: Global seasonal anomaly of SIS in Summer (June, July, August) 2022.
In the visualizer options you can switch between rectangular (map on the right) and orthographic (map on the left) projection.

Application examples: Global seasonal anomaly

d) Global seasonal anomaly in summer 2022

Visualize

- Similar to the monthly anomaly map (example c)) you can detect extremely positive anomalies in central Europe, in America and in parts of Asia like India and southern China

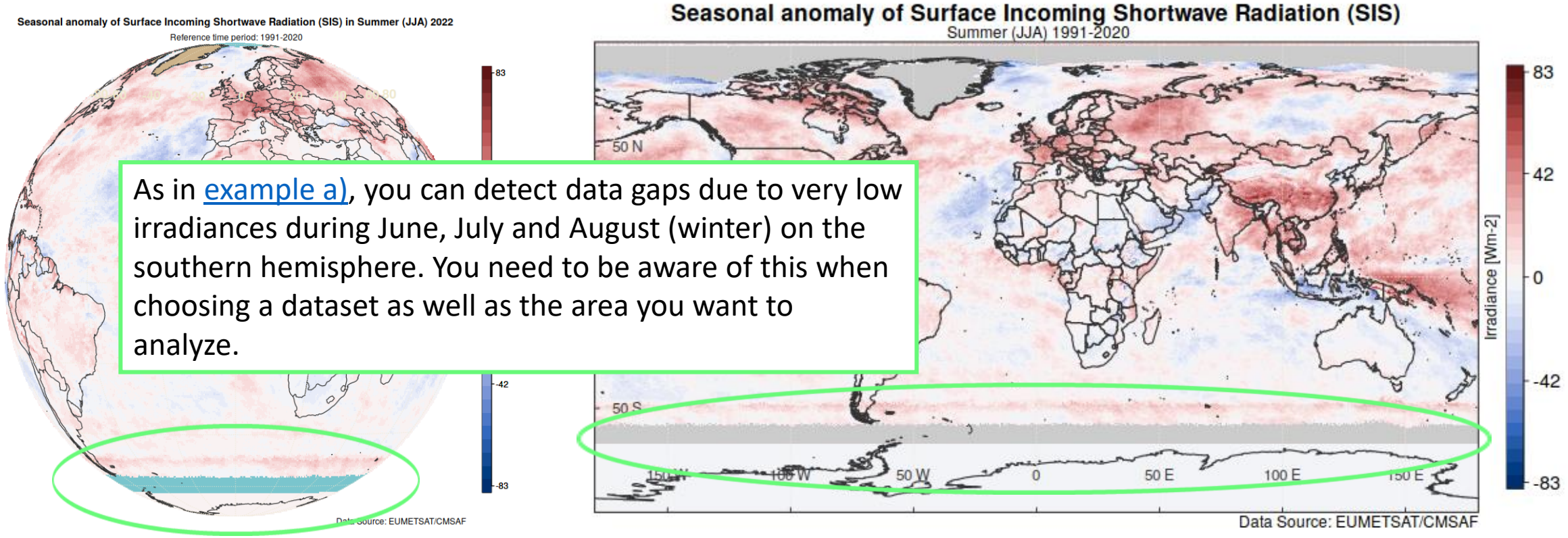


Result: Global seasonal anomaly of SIS in Summer (June, July, August) 2022.
In the visualizer options you can switch between rectangular (map on the right) and orthographic (map on the left) projection.

Application examples: Global seasonal anomaly

d) Global seasonal anomaly in summer 2022

Visualize



As in [example a)](), you can detect data gaps due to very low irradiances during June, July and August (winter) on the southern hemisphere. You need to be aware of this when choosing a dataset as well as the area you want to analyze.

Result: Global seasonal anomaly of SIS in Summer (June, July, August) 2022.
In the visualizer options you can switch between rectangular (map on the right) and orthographic (map on the left) projection.

Application examples: Time series

e) i. Time series: Monthly means in San José, Costa Rica

Prepare

Required data: see example a)

Important:

- If you want to combine multiple data records (e.g. CDR & ICDR), data need to have the same spatial and temporal resolution
- Avoid temporal overlap of the data

THEN: **Unzip and untar** the data for the time range 1991-01-01-2020-12-01

(if you already did this in example a), you can directly go to Analyze and choose the generated .nc-file „SIS_1991-01-01-2020-12-01.nc“

Application examples: Time series

e) i. Time series: Monthly means in San José, Costa Rica

Analyze

- **Group of operators**: Monthly statistics
- **Operator**: Monthly means

THEN: tick the box „do you want to apply another operator afterwards?”, apply operator and continue with the second operator:

- **Group of operators**: Selection
- **Operator**: Select data at given point

Enter the coordinates of the location you want to analyze (here: San José: lat: 9.785, lon: -84.125), untick the box „do you want to apply another operator afterwards?” and apply the operator

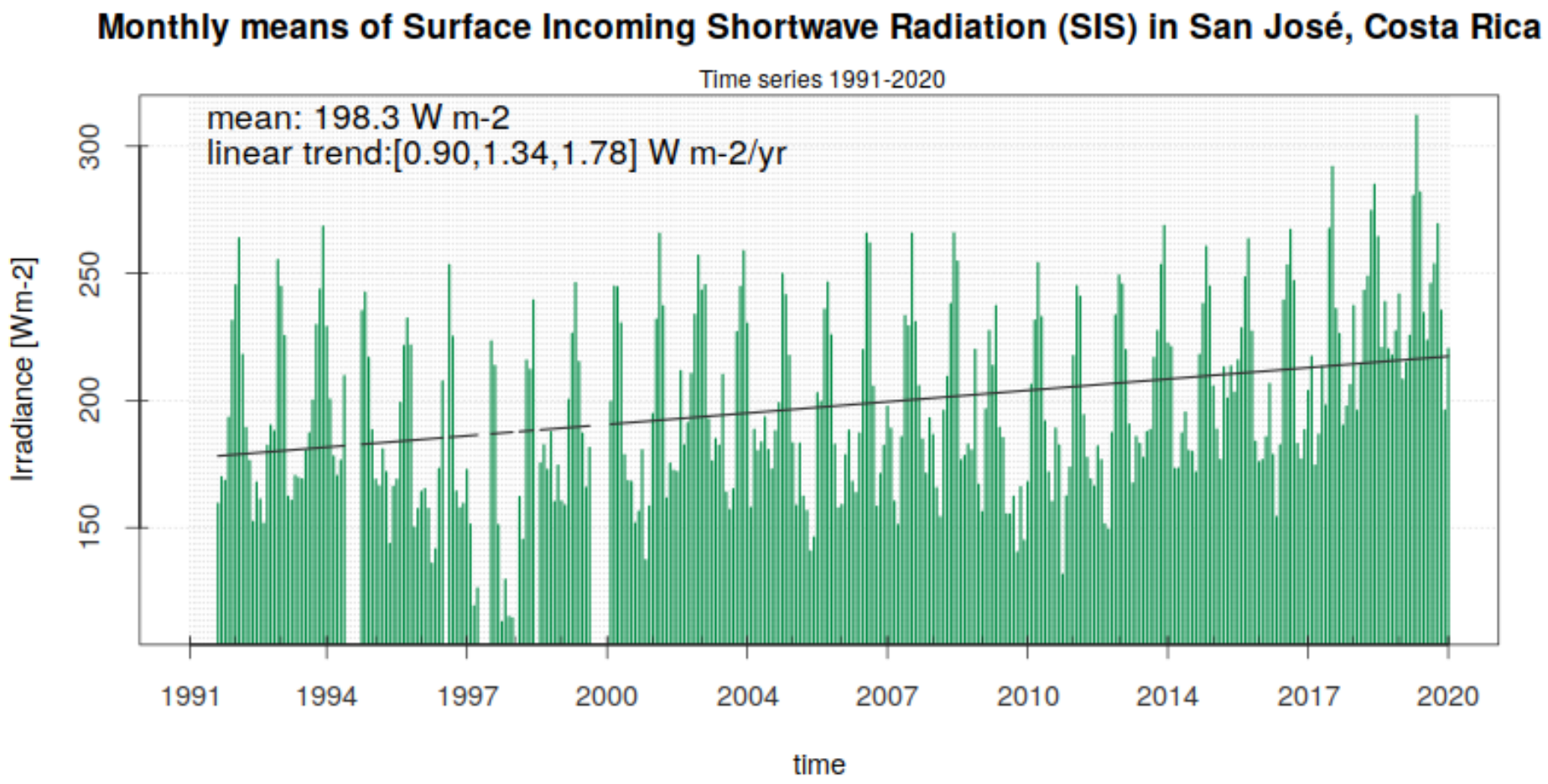
Application examples: Time series

In the visualizer options you can change the line type as well as adding a linear trend line or varying the x- and y-range

e) i. Time series: Monthly means in San José, Costa Rica

Visualize

- There is a strongly positive linear trend of the SIS monthly means between 1991 and 2020



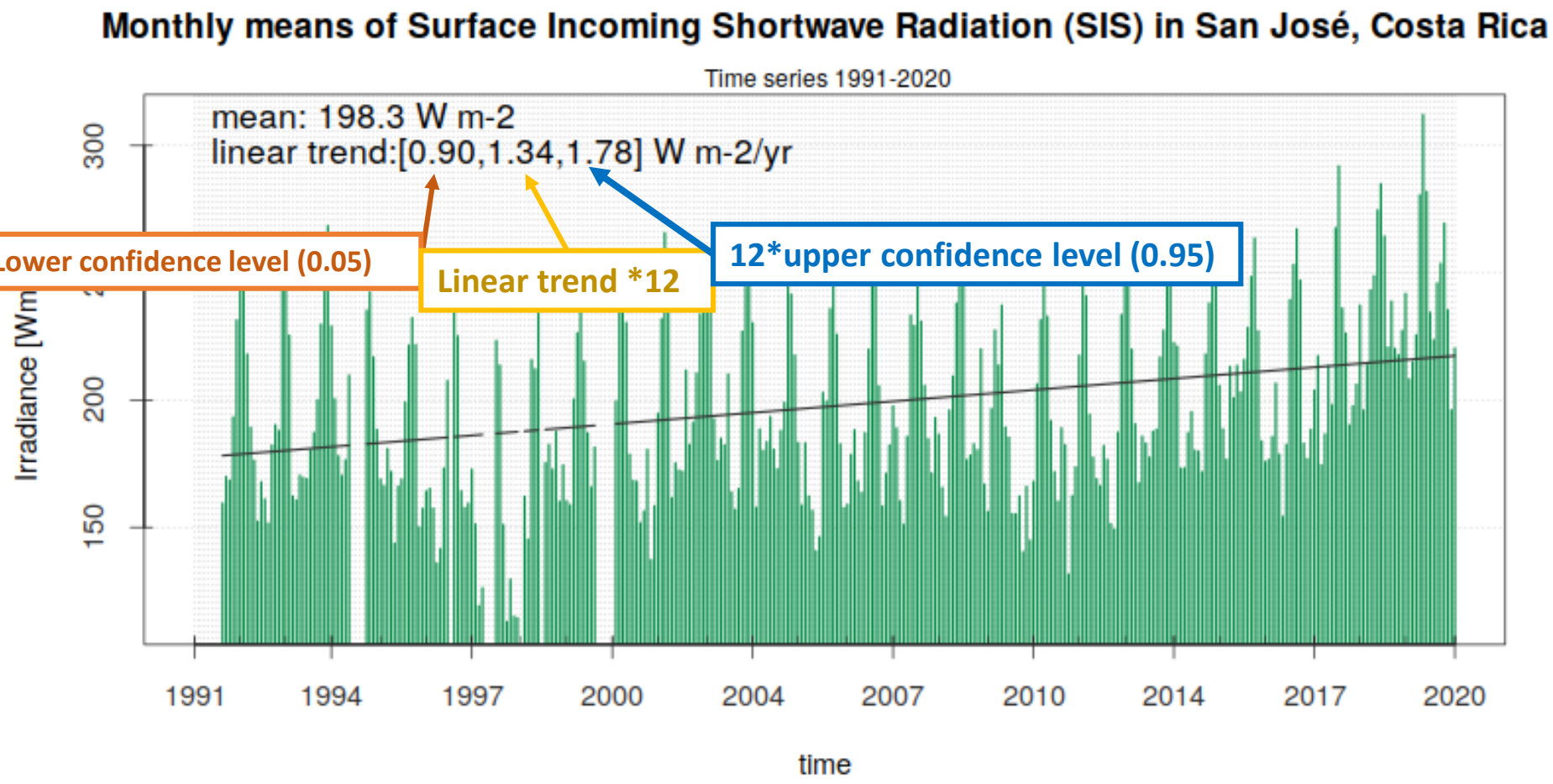
Application examples: Time series

In the visualizer options you can change the line type as well as adding a linear trend line or varying the x- and y-range

e) i. Time series: Monthly means in San José, Costa Rica

Visualize

- There is a strongly positive linear trend in the SIS monthly means between 1991 and 2020



Application examples: Time series

e) ii. Time series: Monthly anomalies in Porto Velho, Brazil

Prepare

Required data: - Monthly, mean data (.tar files) for the preferred area
- Temporal coverage: 1991-01-01 to 2020-12-01

Important:

- If you want to combine multiple data records (e.g. CDR & ICDR), data need to have the same spatial and temporal resolution
- Avoid temporal overlap of the data

THEN: **Unzip and untar** the data for the time range 1991-01-01-2020-12-01

➡ (if you already did this in example a), you can directly go to Analyze and choose the generated .nc-file „SIS_1991-01-01-2020-12-01.nc“

Application examples: Time series

e) ii. Time series: Monthly anomalies in Porto Velho, Brazil

Analyze

- **Group of operators**: Monthly statistics
- **Operator**: Monthly anomalies

↓

THEN: tick the box „do you want to apply another operator afterwards?”, apply operator and continue with the second operator:

↓

- **Group of operators**: Selection
- **Operator**: Select data at a given point

↓

Enter the coordinates of the location you want to analyze (here: Porto Velho: lat: -8.762, lon: -63.902), untick the box „do you want to apply another operator afterwards?” and apply the operator

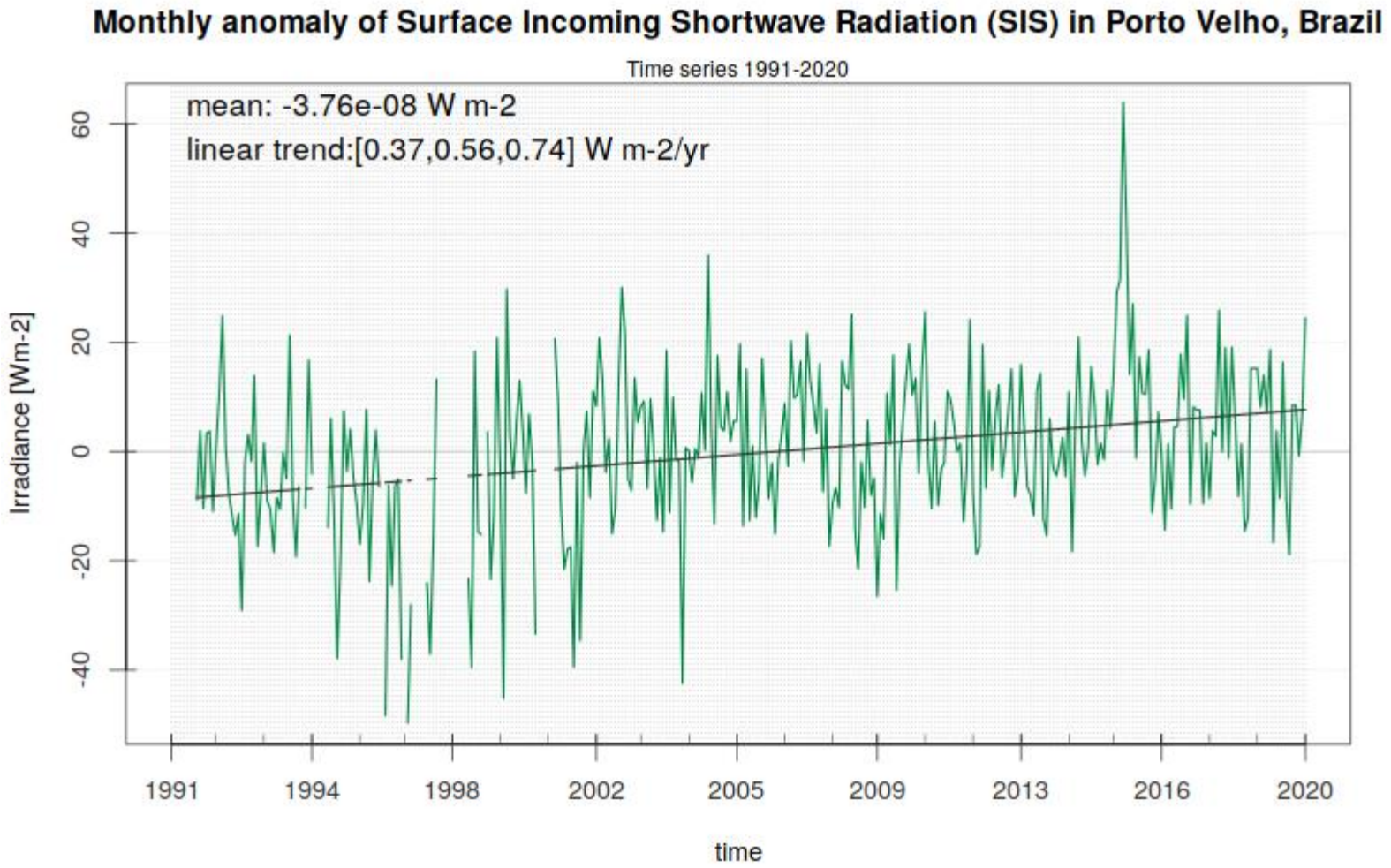
Application examples: Time series

In the visualizer options you can change the line type as well as adding a linear trend line or varying the x- and y-range

e) ii. Time series: Monthly anomalies in Porto Velho, Brazil

Visualize

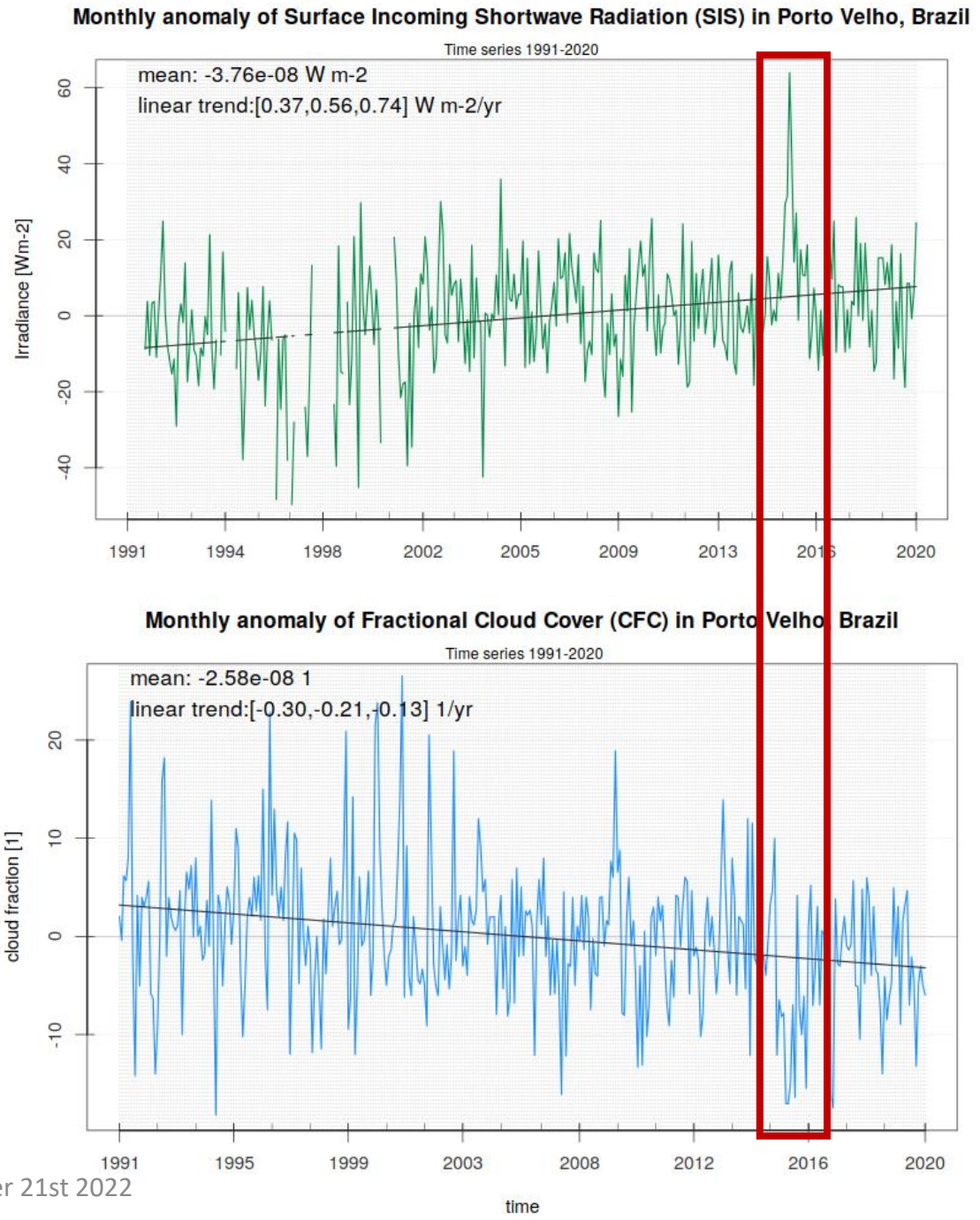
- Since 1991 the monthly anomalies of SIS increased significantly
- The highest positive anomalies occured during 2015 and are caused by….



Application examples: Time series

e) ii. Time series: Monthly anomalies in Porto Velho, Brazil

- The highest positive anomalies occured during 2015 and are caused by **negative anomalies of cloud fractional cover**
- Comparing the time series as well as the linear trends indicates: Decreasing CFC ⟹ increasing SIS



Application examples: Overall analysis

f) Overall analysis of SIS in San José, Costa Rica

Prepare → see example e)i

Analyze → see example e)i

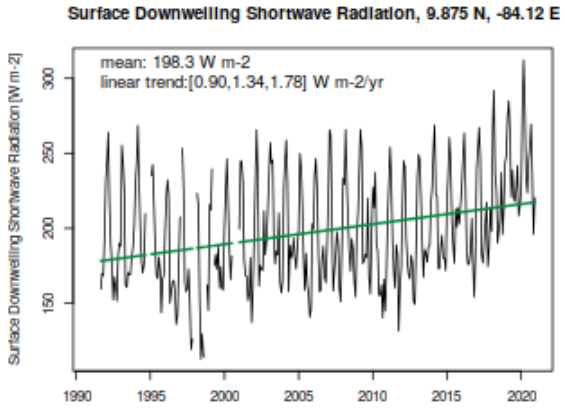
Visualize → After applying the operator you can tick the box „Analyze timeseries“ to get an overall analysis of the selected location

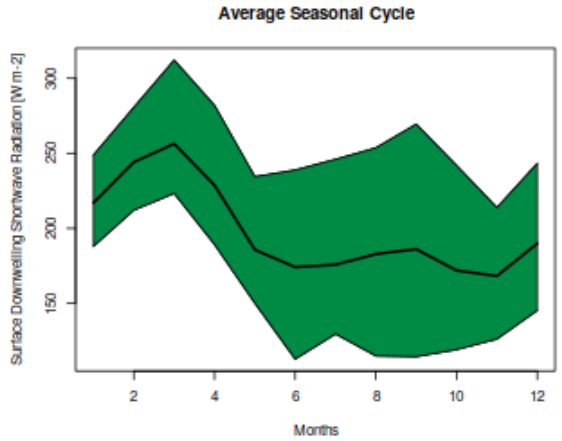
Application examples: Overall analysis

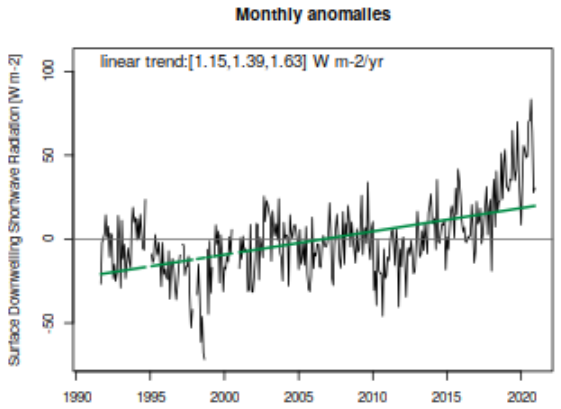
f) Overall analysis of SIS in San José, Costa Rica

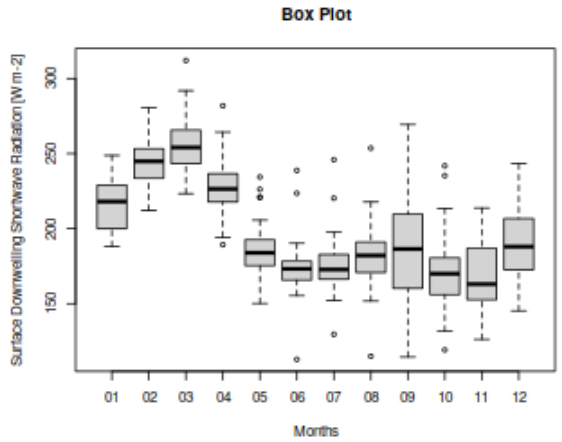
Visualize

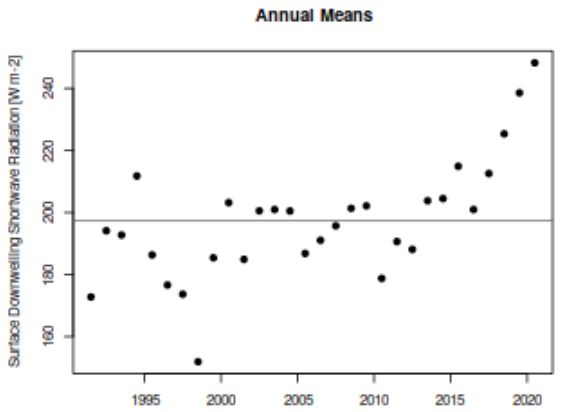
- Similar to the results in example e)i you can see a significantly positive trend of Surface Incoming Shortwave Radiation between 1991 and 2020

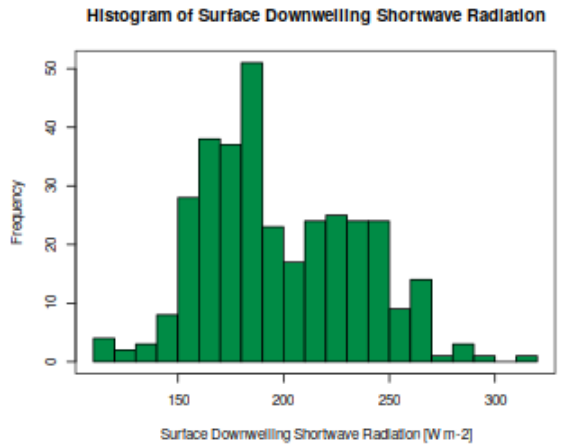










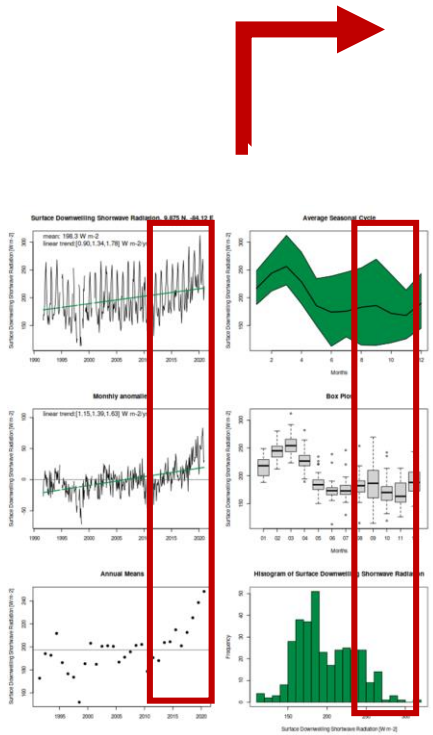


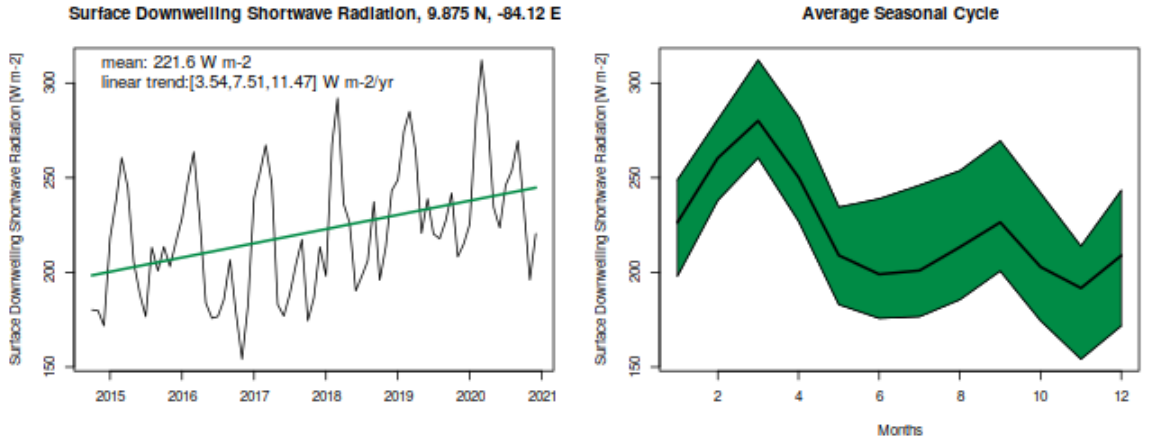
Application examples: Overall analysis

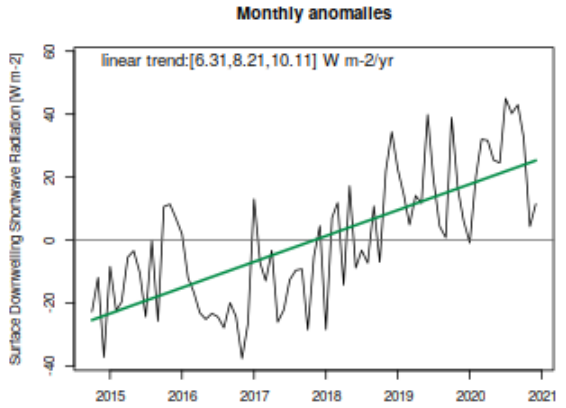
f) Overall analysis of SIS in San José, Costa Rica

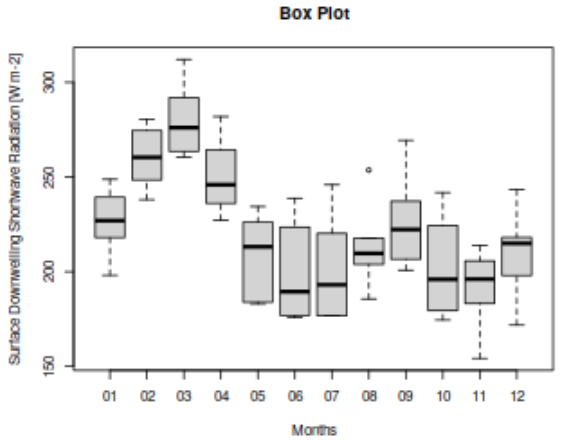
Visualize

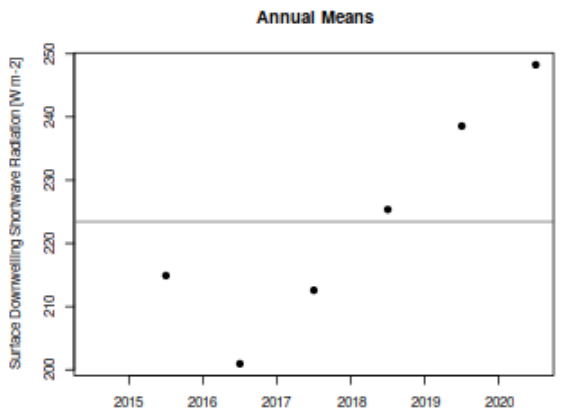
- By changing the x-range you can vary the time span of the overall analysis
- The positive linear trend of the SIS monthly means and anomalies is even more significant in the time span 2015-2020

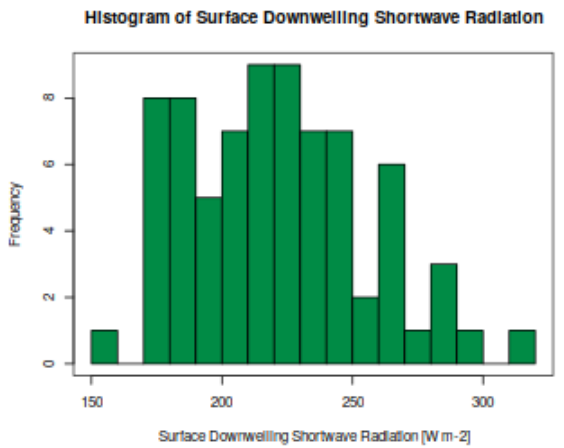












Application examples: Comparison to the climatology

g) Comparison of the current year to the climatology

Prepare

Required data: - Daily, mean data (.tar files) for the preferred area

- Temporal coverage: 1991-01-01 to 2022-09-30 (or the latest data of the current year)

Important:

- If you want to combine multiple data records (e.g. CDR & ICDR), data need to have the same spatial and temporal resolution
- Avoid temporal overlap of the data

THEN: **Unzip and untar** the data for the time range 1991-01-01-2022-09-30

Application examples: Comparison to the climatology

g) Comparison of the current year to the climatology

Important: These operators can only be applied using **daily data**!

Analyze

- **Group of operators:** Climate analysis
- **Operator**: Field mean plot **(1) OR** Anomaly map **(2)**

THEN: Select the country you want to analyze

Select the… - Date range (here: 2022-01-01 to 2022-09-30)

- Climatology start year: 1991; Climatology end year: 2020

and apply the operator

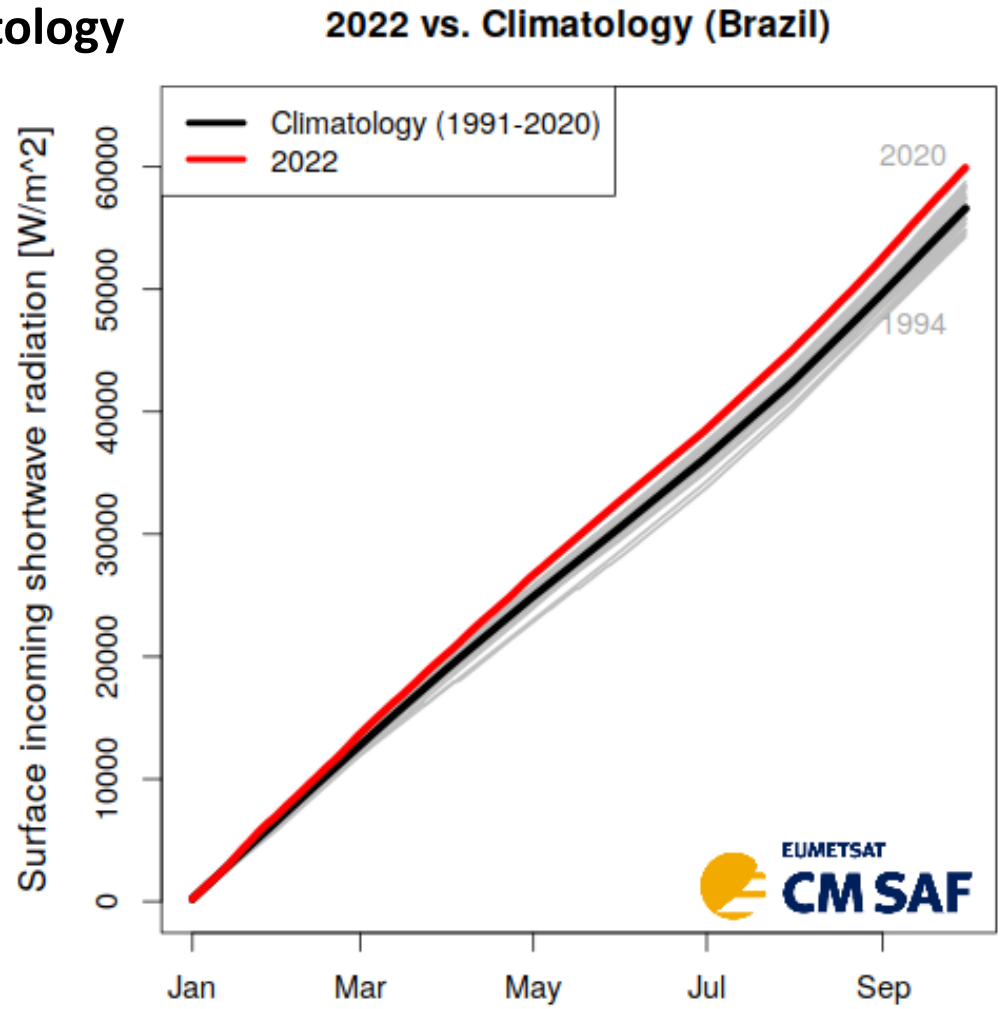
Application examples: Comparison to the climatology

g) Comparison of the current year to the climatology

Visualize

- The cumulated SIS of the current year (red) is significantly higher than the climatology in the time period 1991-2020 (black)

- In this reference time period even the highest cumulated SIS (in 2020) is lower than in 2022
  - ➢ **Tip:** When clicking on „Parameters“ in the visualize section, you can get more information such as the reference mean, maximum, minimum and ranking of all analyzed years



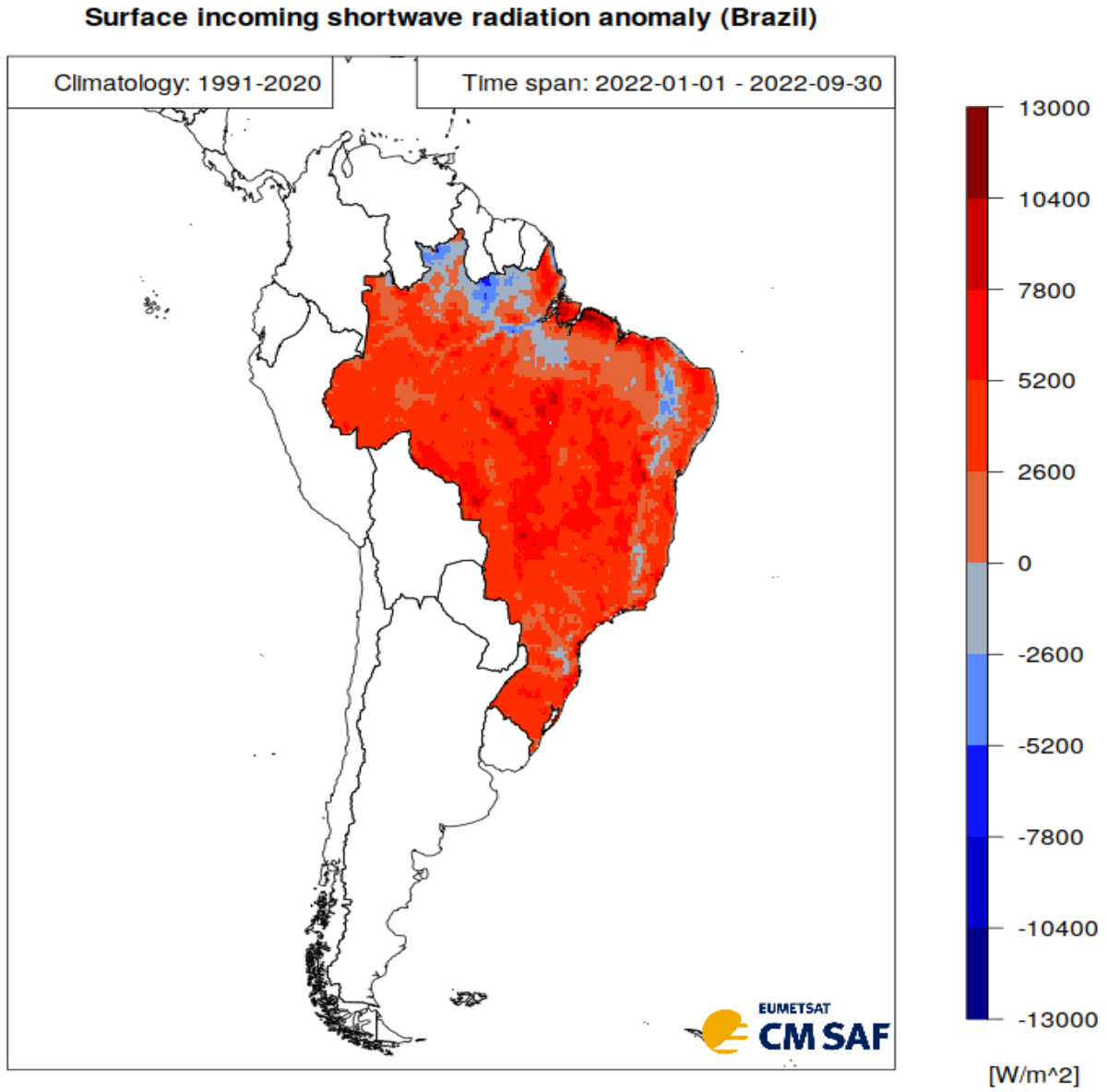
Result: Fieldmean plot **(1)** of the cumulated SIS in 2022 vs. In 1991-2020

Application examples: Comparison to the climatology

g) Comparison of the current year to the climatology

Visualize

- In the majority of Brazil there are positive anomalies of cumulated SIS in 2022
- Only in a few northern states like Roraima, Pará and the cumulated SIS was lower in 2022 than in the climatology 1991-2020



Result: Anomaly map **(2)** of the cumulated SIS in 2022 vs. In 1991-2020

Accessed data

- <u>Example a)-f):</u>
  - ”SIS-Surface incoming shortwave radiation, AVHRR on polar orbiting satellites, Monthly, Mean, Global” (TCDR)
    with temporal coverage 1991-01-01 to 2019-06-01
  - ”SIS-Surface incoming shortwave radiation, AVHRR on polar orbiting satellites, Monthly, Mean, Global” (ICDR)
    with temporal coverage 2019-07-01 to 2022-09-01
- <u>Example g):</u>
  - ”SIS-Surface incoming shortwave radiation, AVHRR on polar orbiting satellites, Daily, Mean, Global” (TCDR)
    with temporal coverage 1991-01-01 to 2022-09-30