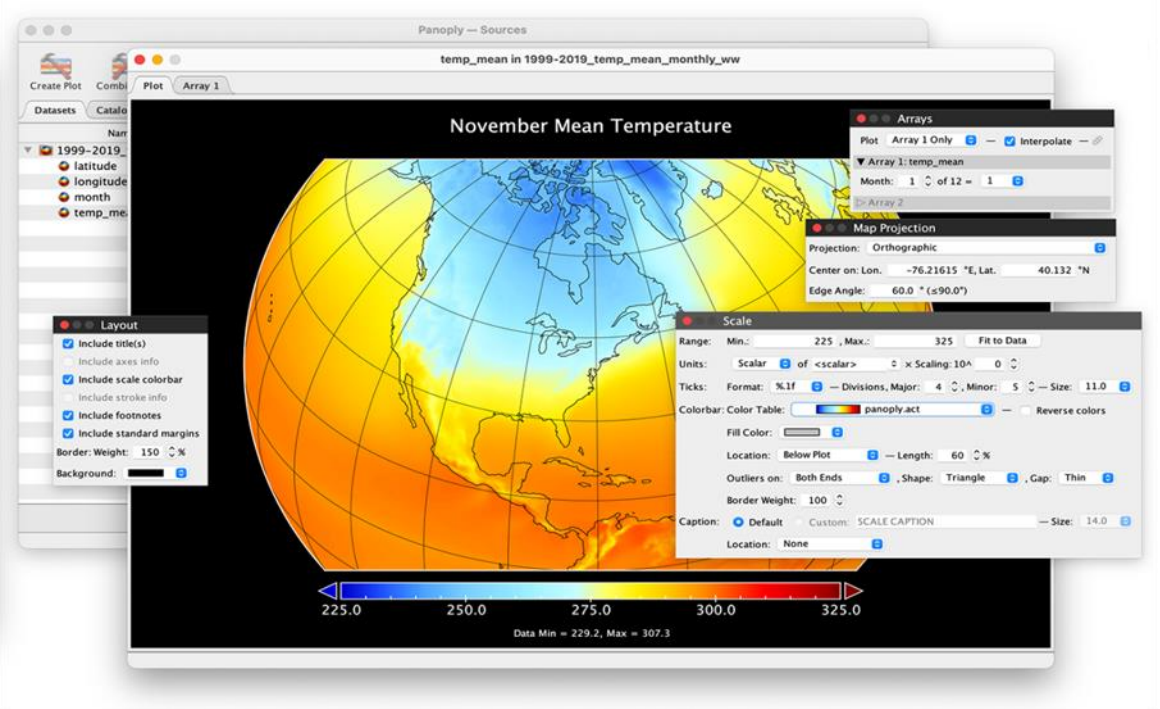
HAROKOPIO UNIVERSITY OF ATHENS
DEPARTMENT OF GEOGRAPHY

ATMOSPHERE AND CLIMATE DYNAMICS GROUP (ACDG)
http://meteoclima.gr

Panoply: A data visualization starter guide

Petros Katsafados and Pavlos Batsios



2026

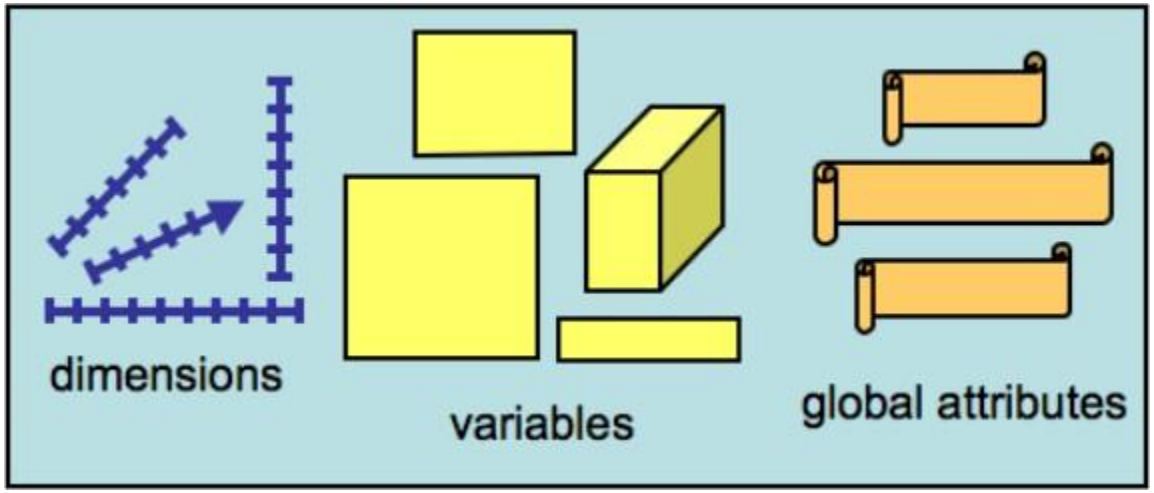
netCDF format for climate data

What are netCDF data?

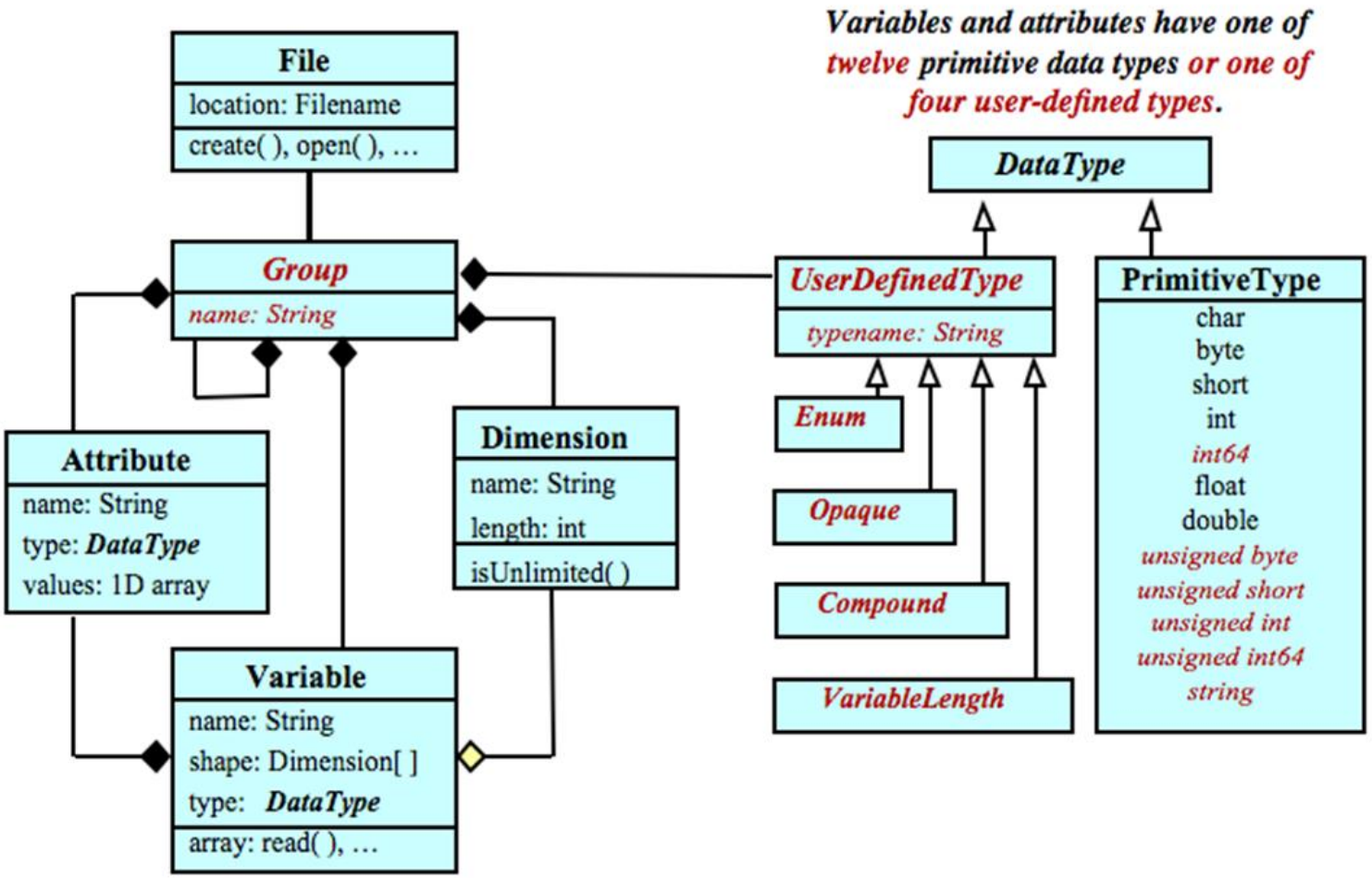
Network Common Data Form (NetCDF) is a file format that stores multidimensional (variable) scientific data, such as temperature, humidity, pressure, wind speed and direction. Each of these variables can be displayed via a dimension (for example, time)

netCDF format for climate data

The Structure of NetCDF files (based on the "Classic" format)
NetCDF files are containers for Dimensions, Variables, and Global Attributes



A netCDF file has a **path name** and possibly some **dimensions, variables, global** (file-level) **attributes**, and **data values** associated with the variables. Sometimes we refer to netCDF files more abstractly as datasets.



A file has a top-level unnamed group. Each group may contain one or more named subgroups, user-defined types, variables, dimensions, and attributes. Variables also have attributes. Variables may share dimensions, indicating a common grid. One or more dimensions may be of unlimited length.

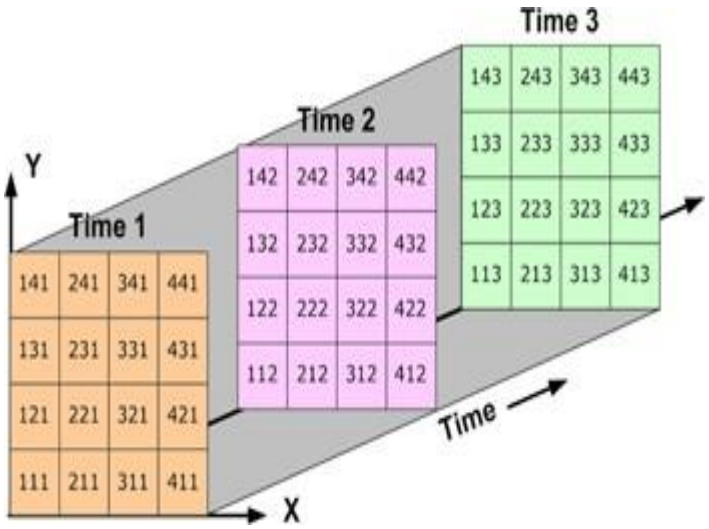
netCDF format for climate data

The data in a NetCDF file is stored in table form.
For example, the variation of temperature over time at a location is stored as a one-dimensional array. The temperature above an area at a given time is stored as a two-dimensional array.

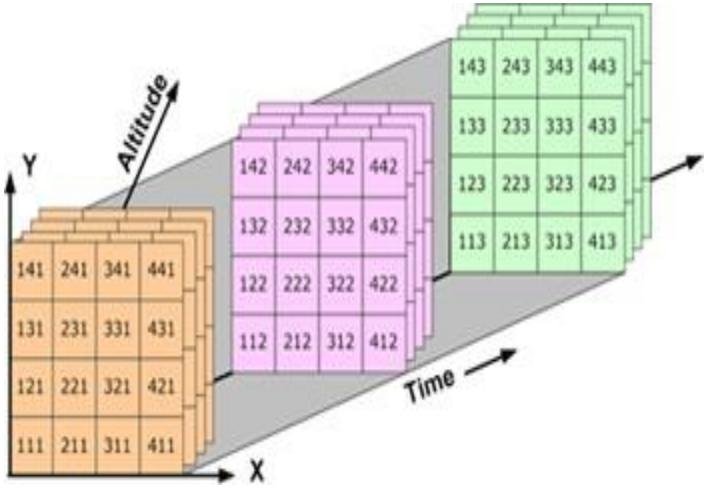
Three-dimensional (3D) data, such as the temperature over a region that varies over time, or four-dimensional (4D) (temperature over an area that varies over time and depending on the altitude) are stored as a series of two-dimensional arrays.

netCDF format for climate data

NetCDF data storage



Three-dimensional data: data over an area that varies over time.



Four-dimensional data: data over an area that varies over time and according to altitude.

netCDF format for climate data

An easier way to view NetCDF: CDL

CDL (Common Data Language) is a human-readable text notation used to describe the structure and contents of netCDF datasets. It represents netCDF objects—such as dimensions, variables, attributes, and data—in a plain text format that is easy for people to read and write.

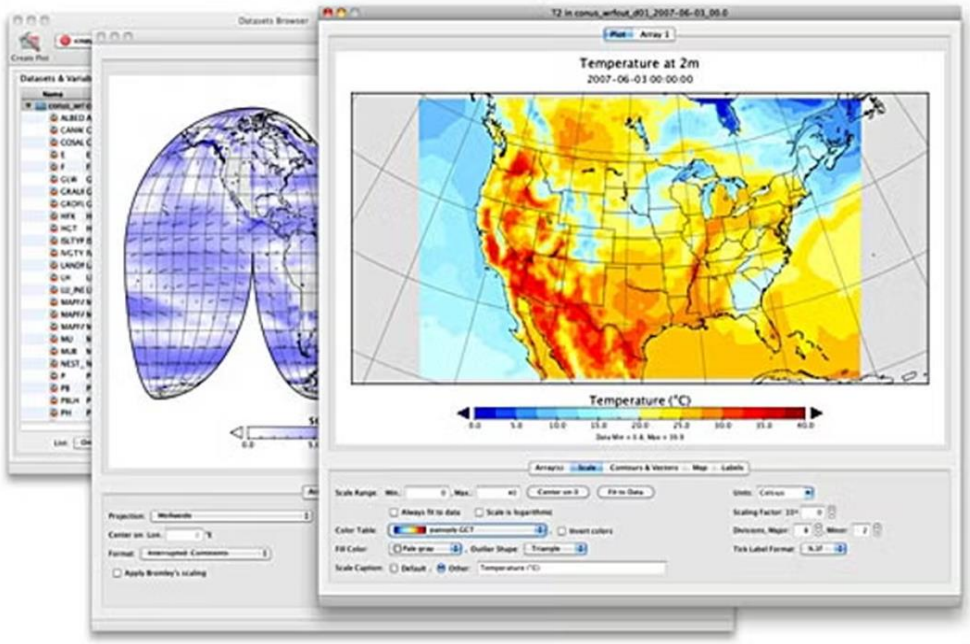
```
netcdf filename {
dimensions:
        lat = 3 ;
        lon = 4 ;
        time = UNLIMITED ; // (2 currently)

variables:
        float lat(lat) ;
                lat:long_name = "Latitude" ;
                lat:units = "degrees_north" ;
        float lon(lon) ;
                lon:long_name = "Longitude" ;
                lon:units = "degrees_east" ;
        int time(time) ;
                time:long_name = "Time" ;
                time:units = "days since 1895-01-01" ;
                time:calendar = "gregorian" ;
        float rainfall(time, lat, lon) ;
                rainfall:long_name = "Precipitation" ;
                rainfall:units = "mm yr-1" ;
                rainfall:missing_value = -9999.f ;

// global attributes:
                :title = "Historical Climate Scenarios" ;
                :Conventions = "CF-1.0" ;

data:
 lat = 48.75, 48.25, 47.75;
 lon = -124.25, -123.75, -123.25, -122.75;
 time = 364, 730;
 rainfall =
   761, 1265, 2184, 1812, 1405, 688, 366, 269, 328, 455, 524, 877,
   1019, 714, 865, 697, 927, 926, 1452, 626, 275, 221, 196, 223;
}
```

Coordinate variable

Variable attribute

Global attribute

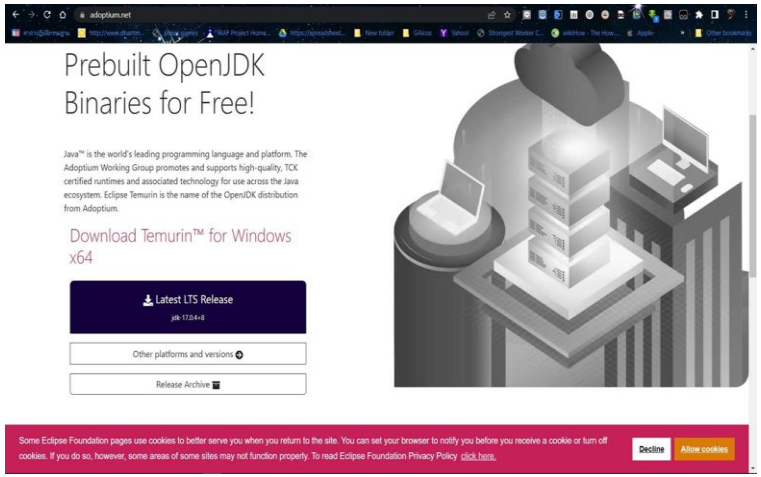
Introducing **Panoply**



Panoply is a powerful and user-friendly tool developed by NASA Goddard Institute for Space Studies for visualizing scientific data stored in netCDF format. Panoply allows users to open, explore, and visualize netCDF data through a simple graphical interface, making it much easier to analyze patterns, trends, and relationships within the data.

In this presentation, we will learn what Panoply is, its key features, and how it can help transform raw scientific data into meaningful visual insights.

Software requirements



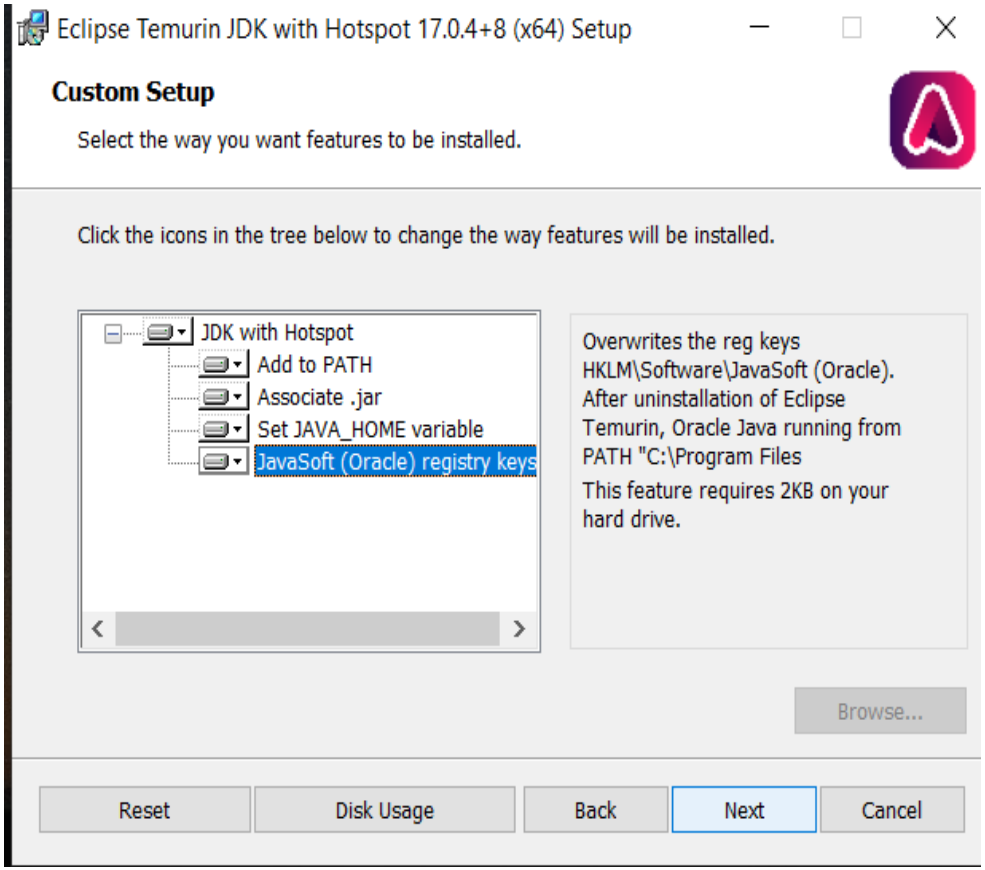
- Java version 11 or later
- Panoply via https://www.giss.nasa.gov/tools/panoply/download
- Please elect the option that is compatible with your operation system

Java installation

- We suggest downloading Java installation from https://adoptium.net
- On the home page, you can directly download the latest version of Java (Java 17 is compatible with Panoply)

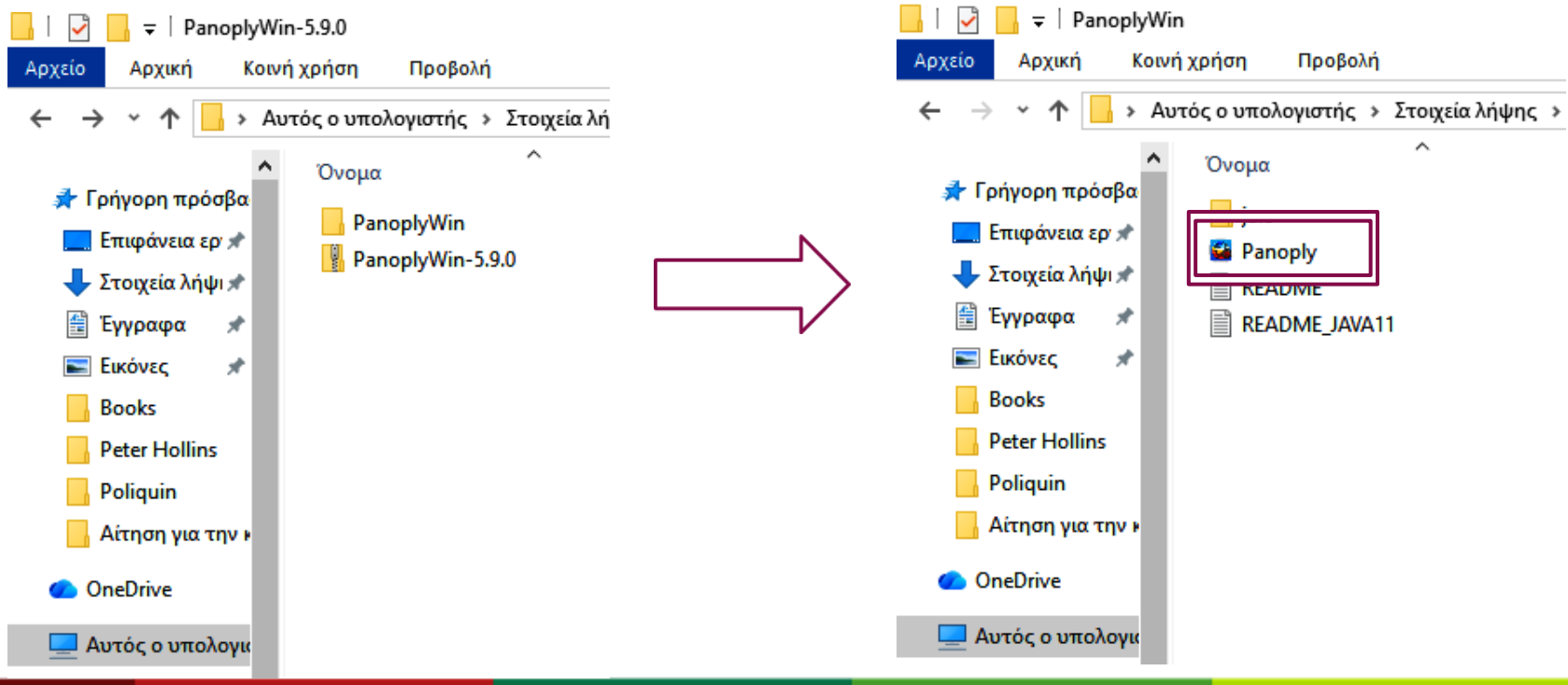
For Windows users

- On the installation prompt, please select all the options available.

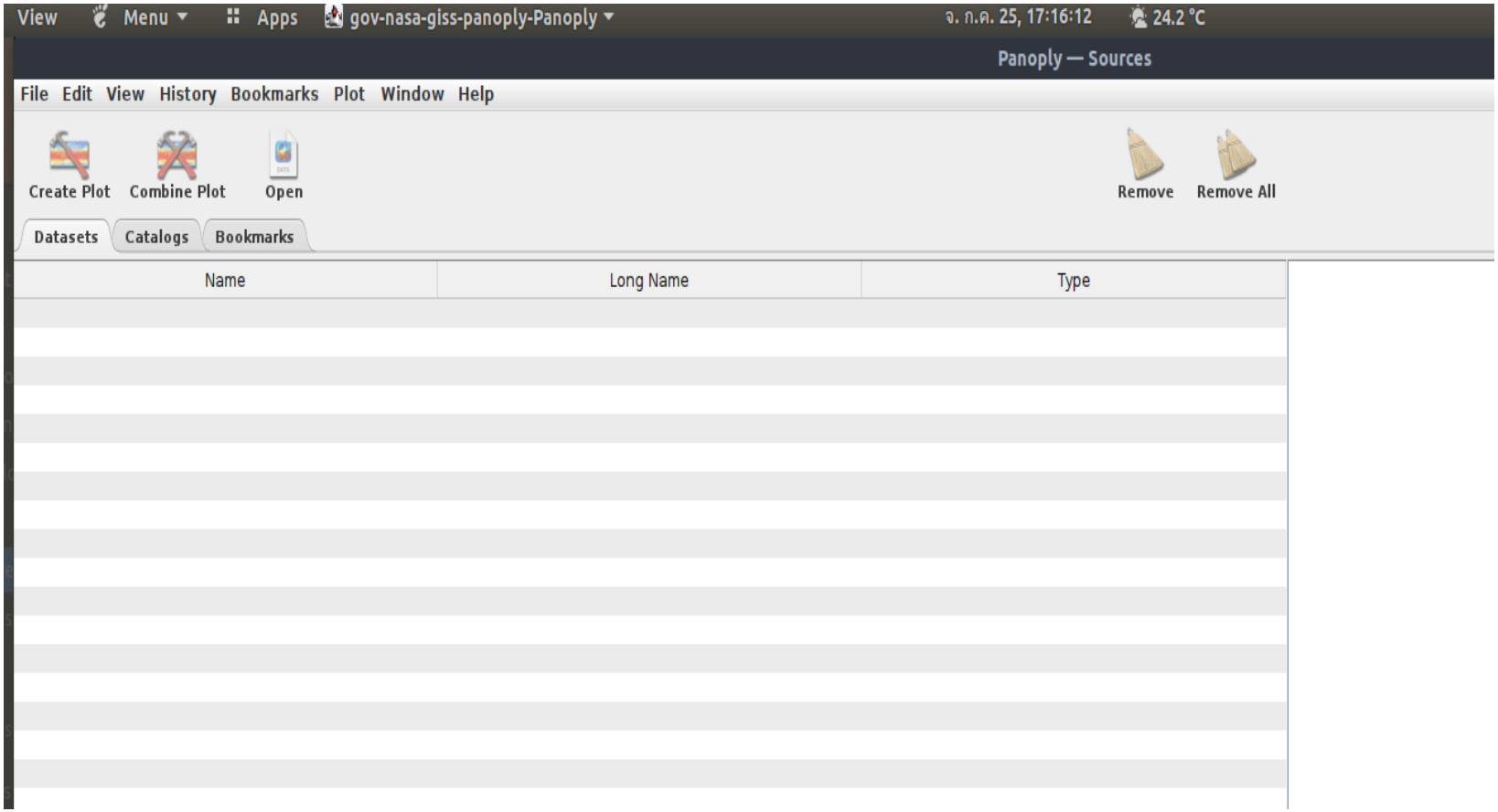


Using Panoply (for Windows)

- Extract "PanoplyWin-5.9.0.zip" into your working directory
- Browse the directory "PanoplyWin-5.9.0" then go to "PanoplyWin"
- Run the file "Panoply.exe"

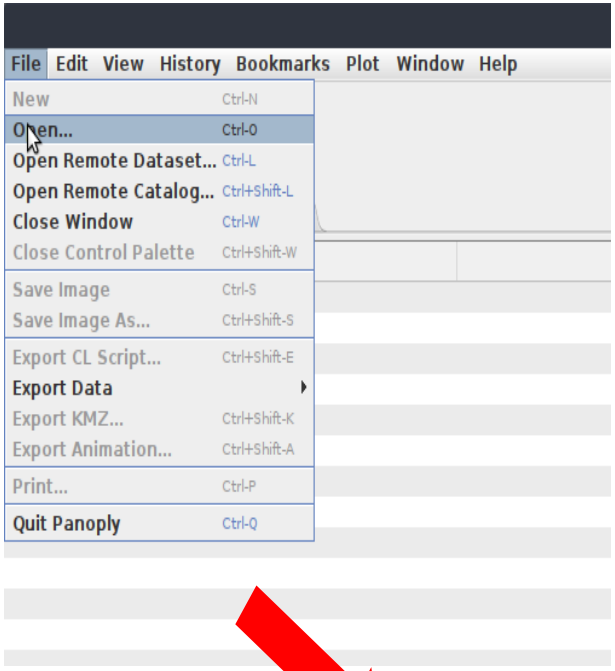


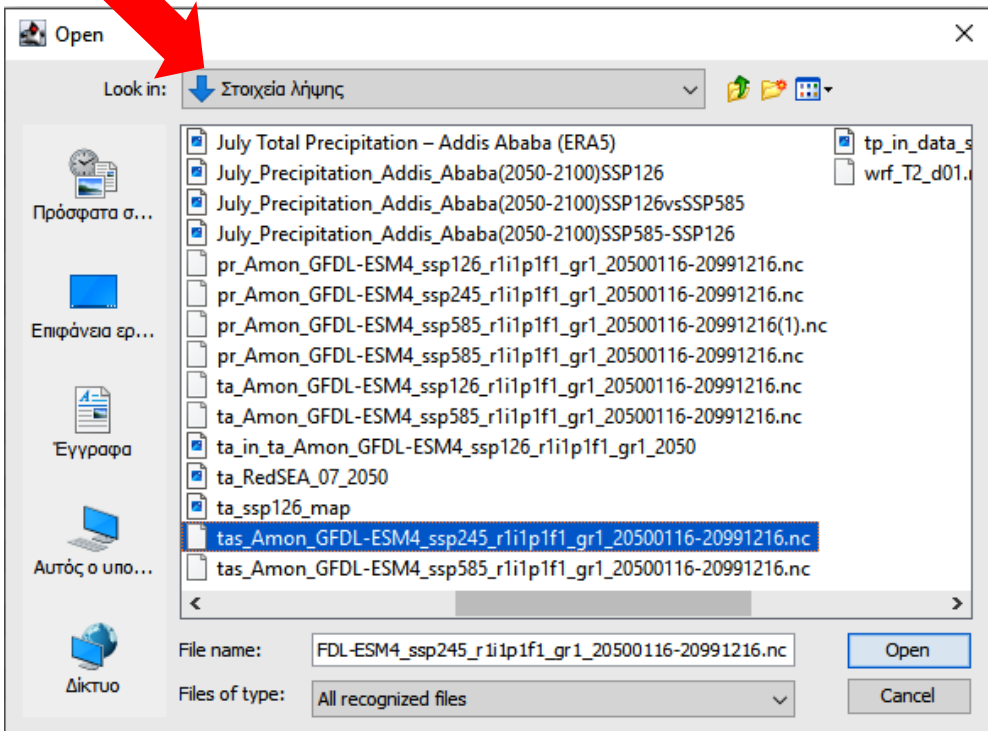
Panoply - prompt window



Open file

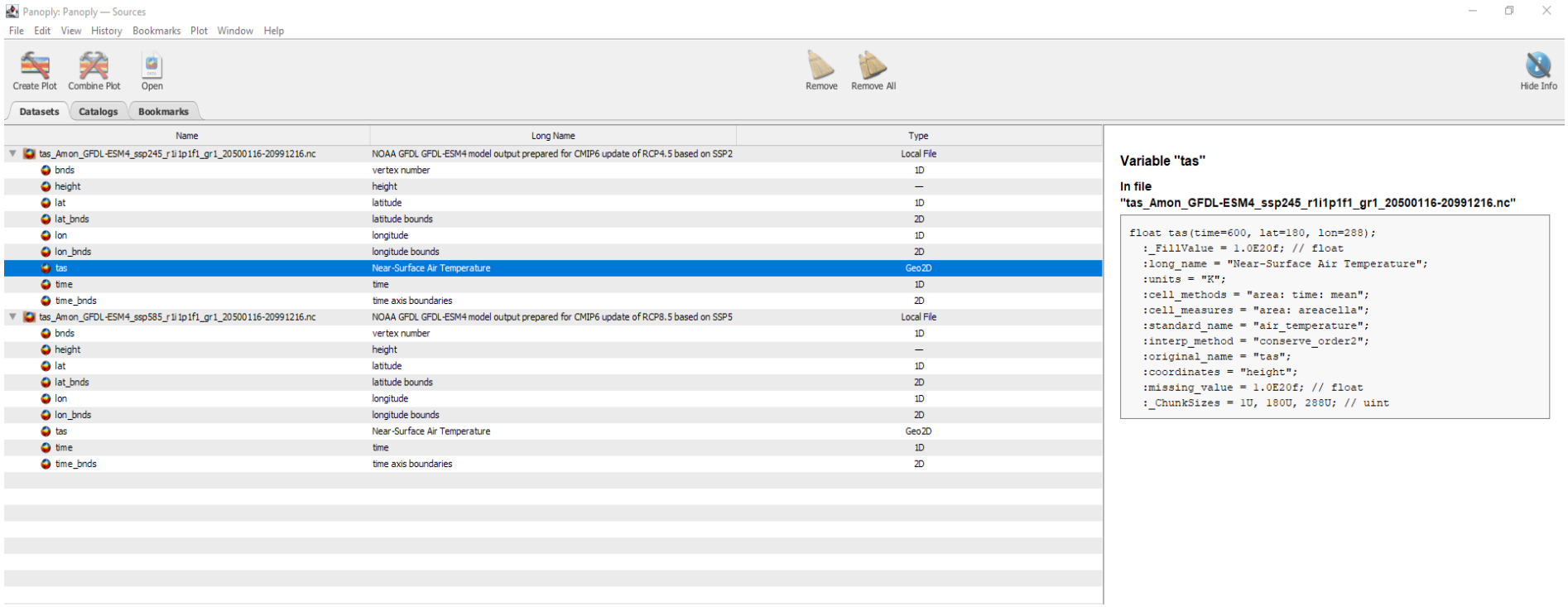
- Click "File" and select "Open"
- Select "tas_Amon_GFDL ESM4_ssp245_r1i1p1f1_gr1 _20500116-20991216.nc" and "tas_Amon_GFDL-ESM4_ssp585_r1i1p1f1_gr 1_20500116-20991216.nc" from your download directory. The datasets represent the **SSP245** and **SSP585** climate change scenarios from the IPCC's Shared Socioeconomic Pathways (SSPs).





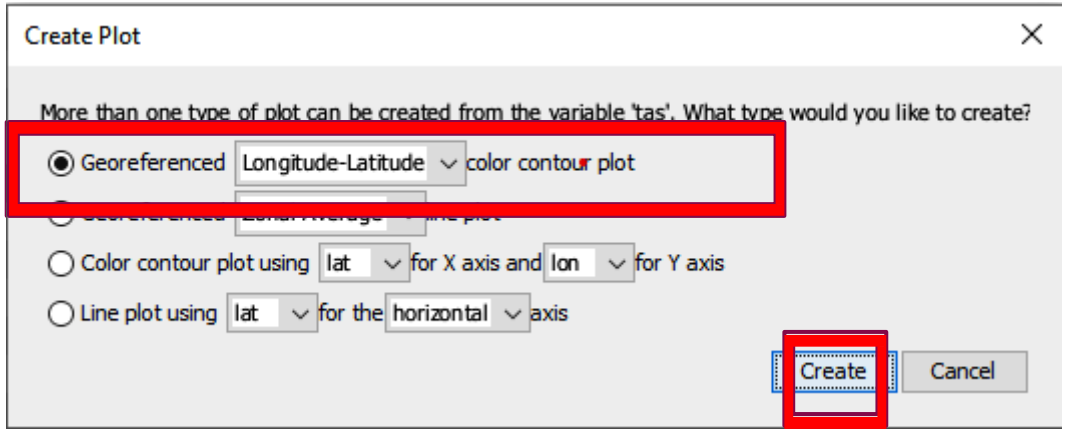
Data tables are presented in the left panel.

The right panel contains the information of the selected table.



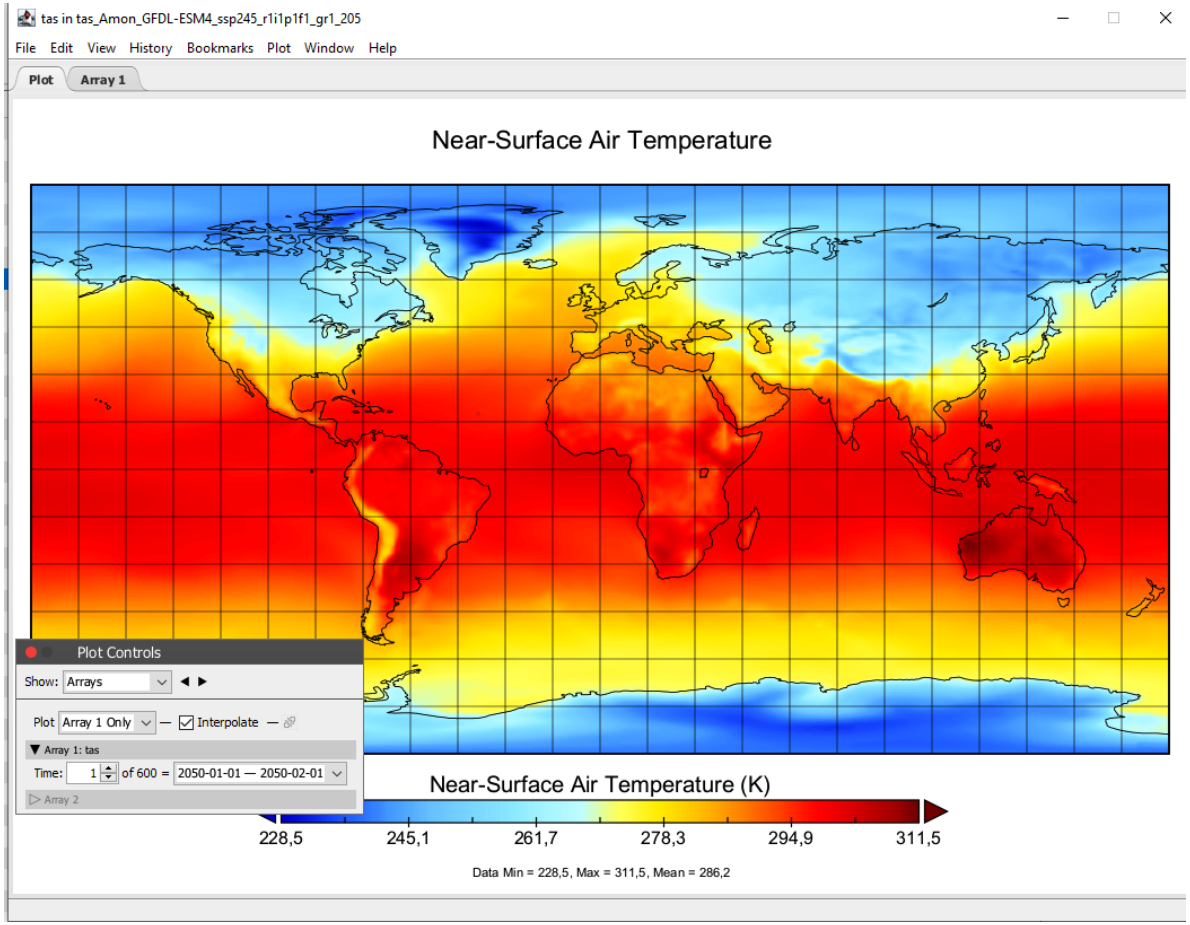
Example: Air Temperature plot

- In column "Name" search for "ta - Air Temperature"
- Create plot by:
  - Double click on "tas" or
  - On menu bar, click "plot" then select "create plot" or
  - Right click on row "tas" then select "create plot"
  - On pop-up window select "Georeferenced Longitude-Latitude color contour plot" (The 1st row) then "create"



Window menu – plot manipulation

- Selecting options from "Window" tap in the menu bar.
- There are 4 windows in this example
  - Arrays – data selection
  - Scale – for plot manipulation: color scheme, data limit, tick length, etc.
  - Map projection -- change projection, map center
  - Grid – manipulate grid size, lines

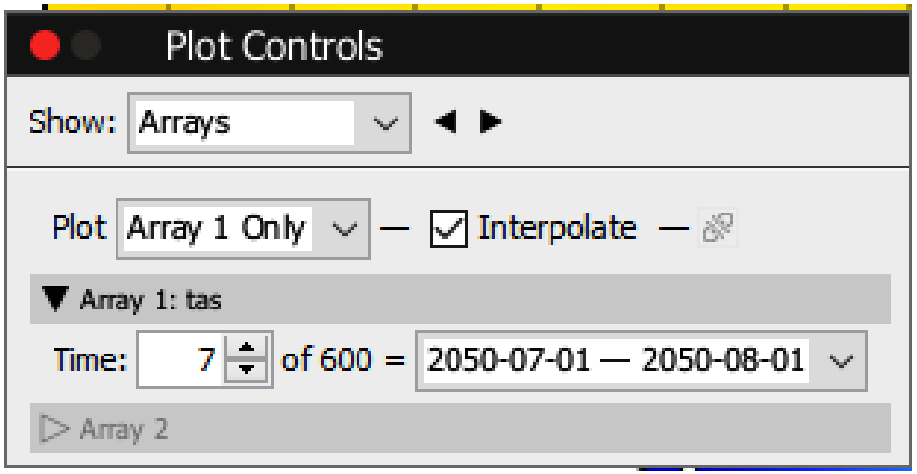


Zoom-in and out

- Hold "ctrl + alt" keys then press
- "+" key to zoom-in the magnified region will center at the specified coordinate in the "Map Projection" panel
- "-" key to zoom-out, again, the scaled image is centered at the specified coordinate

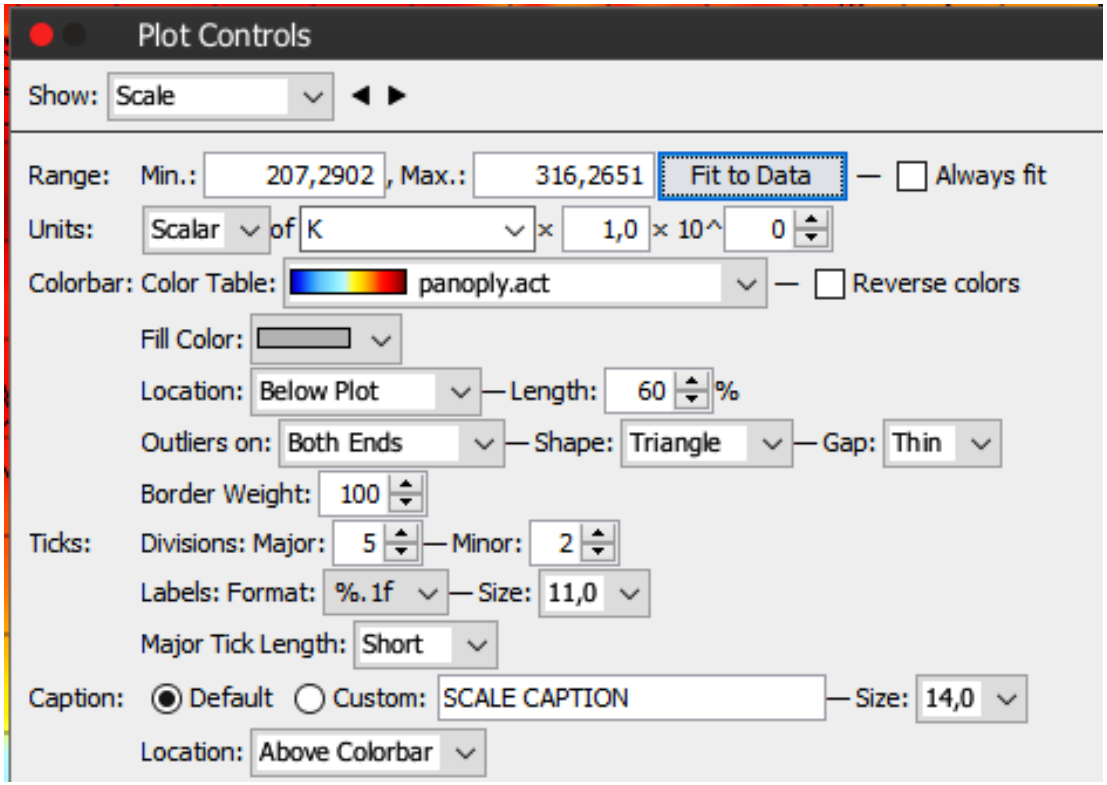
Arrays and Scale panels

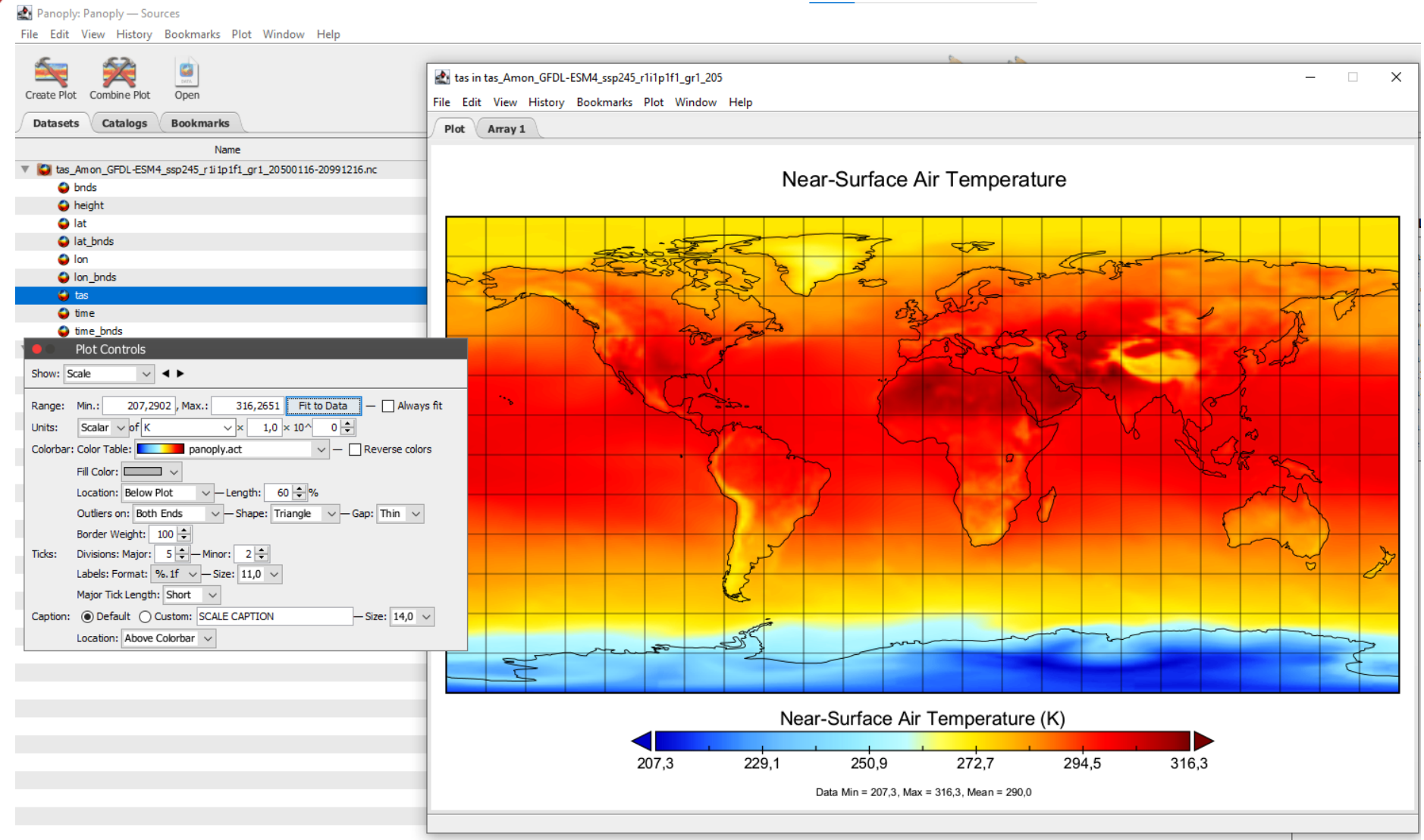
1. At “Plot Controls", under Array 1:tas you can select the data at specific time bin.
For our exercise we select Time 7 (July 2050)



Arrays and Scale panels

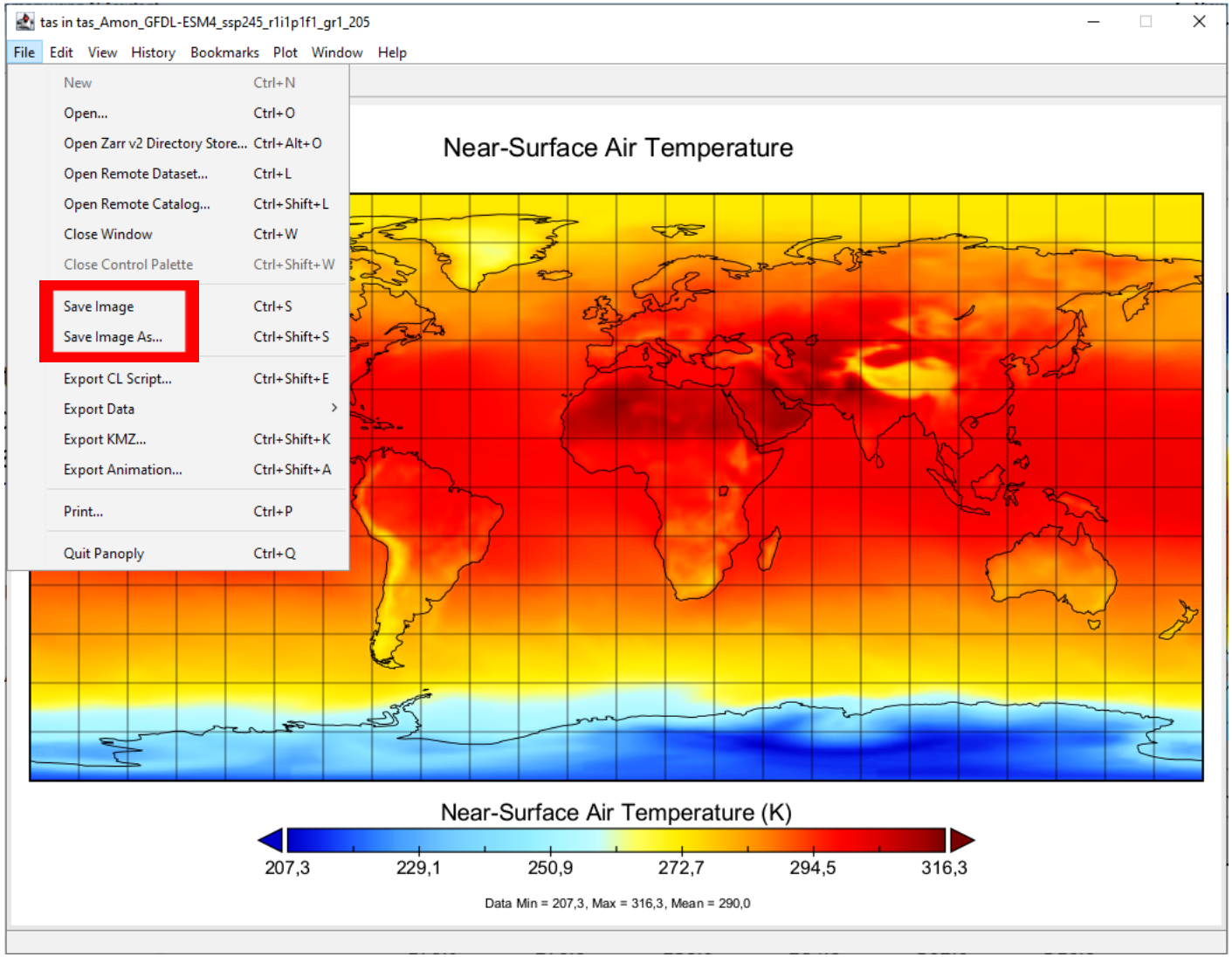
- Scale
- Range: adjust min-max range for data display. This parameter needs to be adjusted for correct display.
- A quick input is to click "Fit to Data" which will choose min-max value from the specified time-bin and table slice.
- The other options can be changed according to your preferences. Change the values and see the according results.



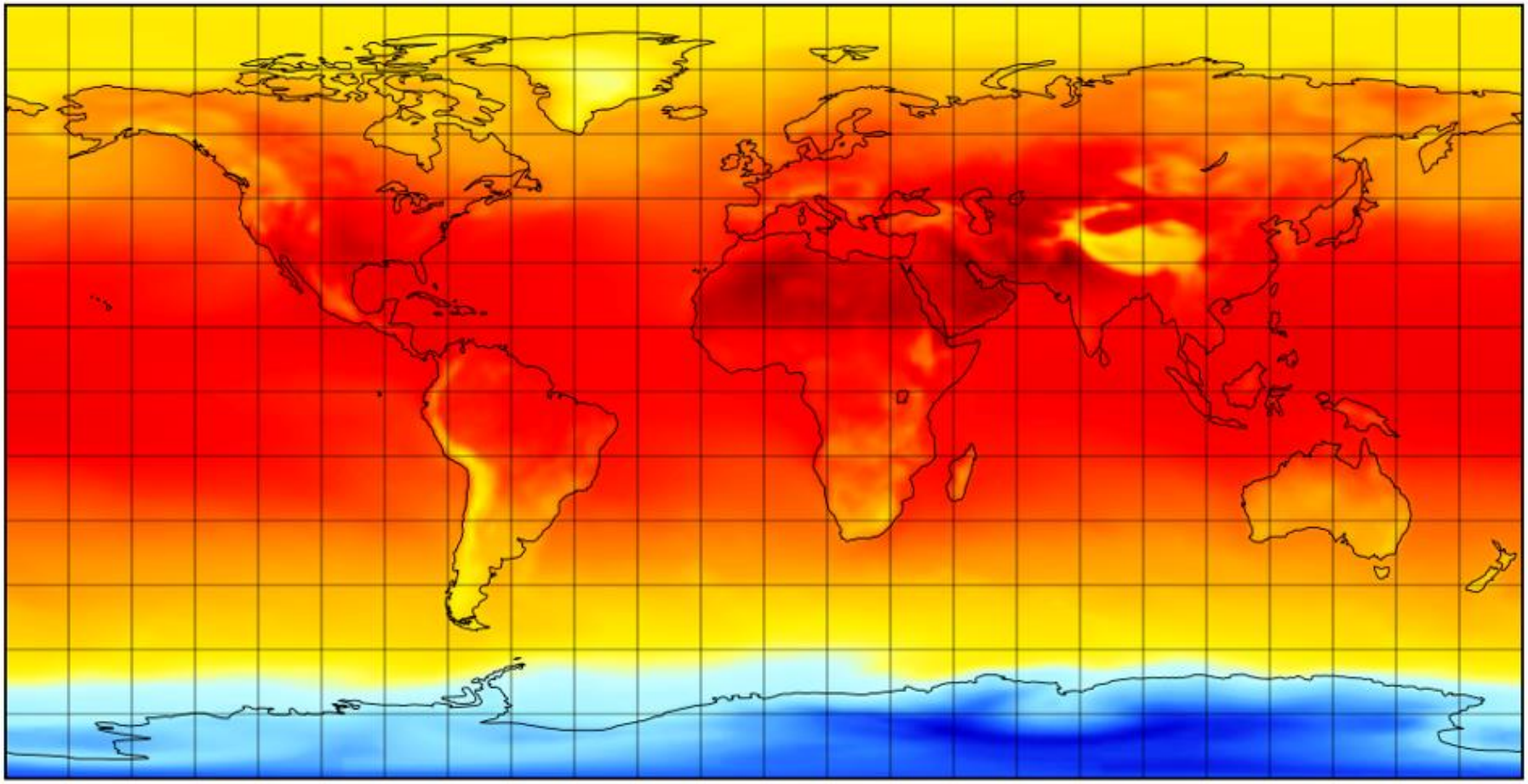

Panoply: Panoply — Sources
File Edit View History Bookmarks Plot Window Help
Create Plot
Combine Plot
Open
Datasets
Catalogs
Bookmarks
Name
tas_Amon_GFDL-ESM4_ssp245_r1i1p1f1_gr1_20500116-20991216.nc
bnds
height
lat
lat_bnds
lon
lon_bnds
tas
time
time_bnds
Plot Controls
Show: Scale
Range: Min.: 207,2902 Max.: 316,2651 Fit to Data Always fit
Units: Scalar of K × 1,0 × 10^ 0
Colorbar: Color Table: panoply.act Reverse colors
Fill Color:
Location: Below Plot Length: 60 %
Outliers on: Both Ends Shape: Triangle Gap: Thin
Border Weight: 100
Ticks: Divisions: Major: 5 Minor: 2
Labels: Format: %.1f Size: 11,0
Major Tick Length: Short
Caption: Default Custom: SCALE CAPTION Size: 14,0
Location: Above Colorbar
tas in tas_Amon_GFDL-ESM4_ssp245_r1i1p1f1_gr1_205
File Edit View History Bookmarks Plot Window Help
Plot
Array 1
Near-Surface Air Temperature
Near-Surface Air Temperature (K)
207,3
229,1
250,9
272,7
294,5
316,3
Data Min = 207,3, Max = 316,3, Mean = 290,0

Save Plot

- Once you are satisfied with the graphic(s), you can save it as image (default format .jpeg).
- On the File menu of the plot window, you can select Save As and choose the format



Near-Surface Air Temperature



Near-Surface Air Temperature (K)

207,3 229,1 250,9 272,7 294,5 316,3

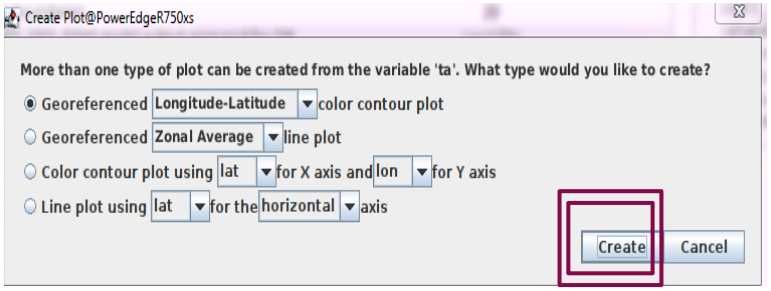
Data Min = 207,3, Max = 316,3, Mean = 290,0

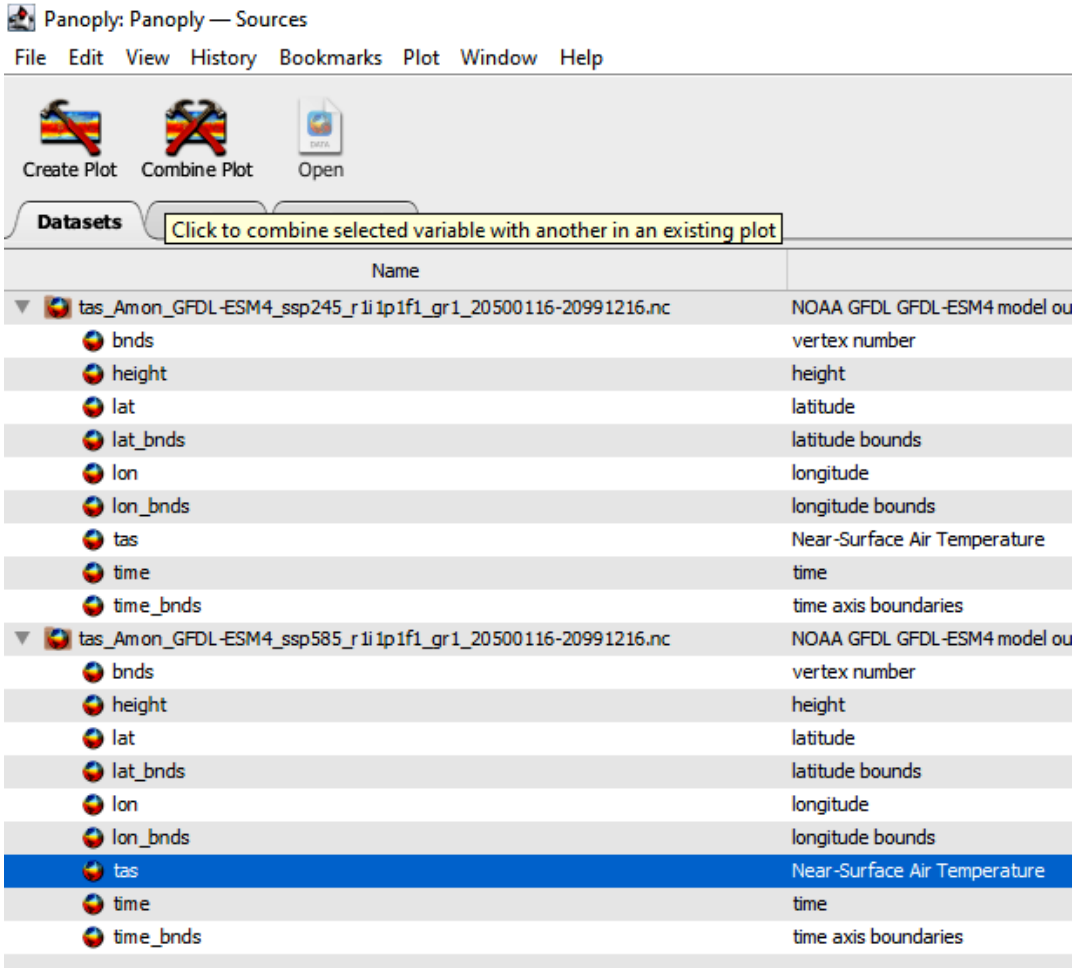
Comparing Data Using Combination Plots in Panoply

- Open Your First Dataset
- Click the data set you wish to Plot (1).
- Click Create Plot (2)

Select the variables that you wish to display.

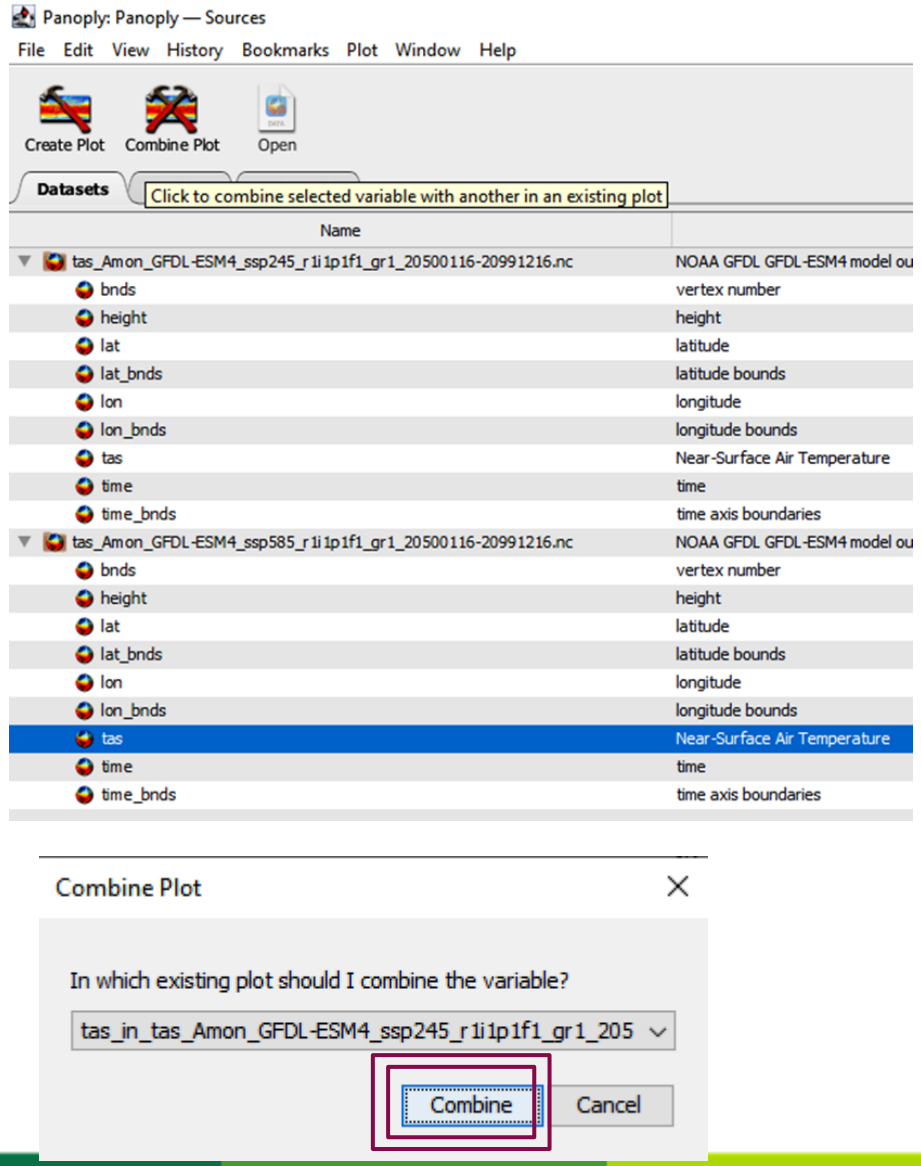
- Click Create.

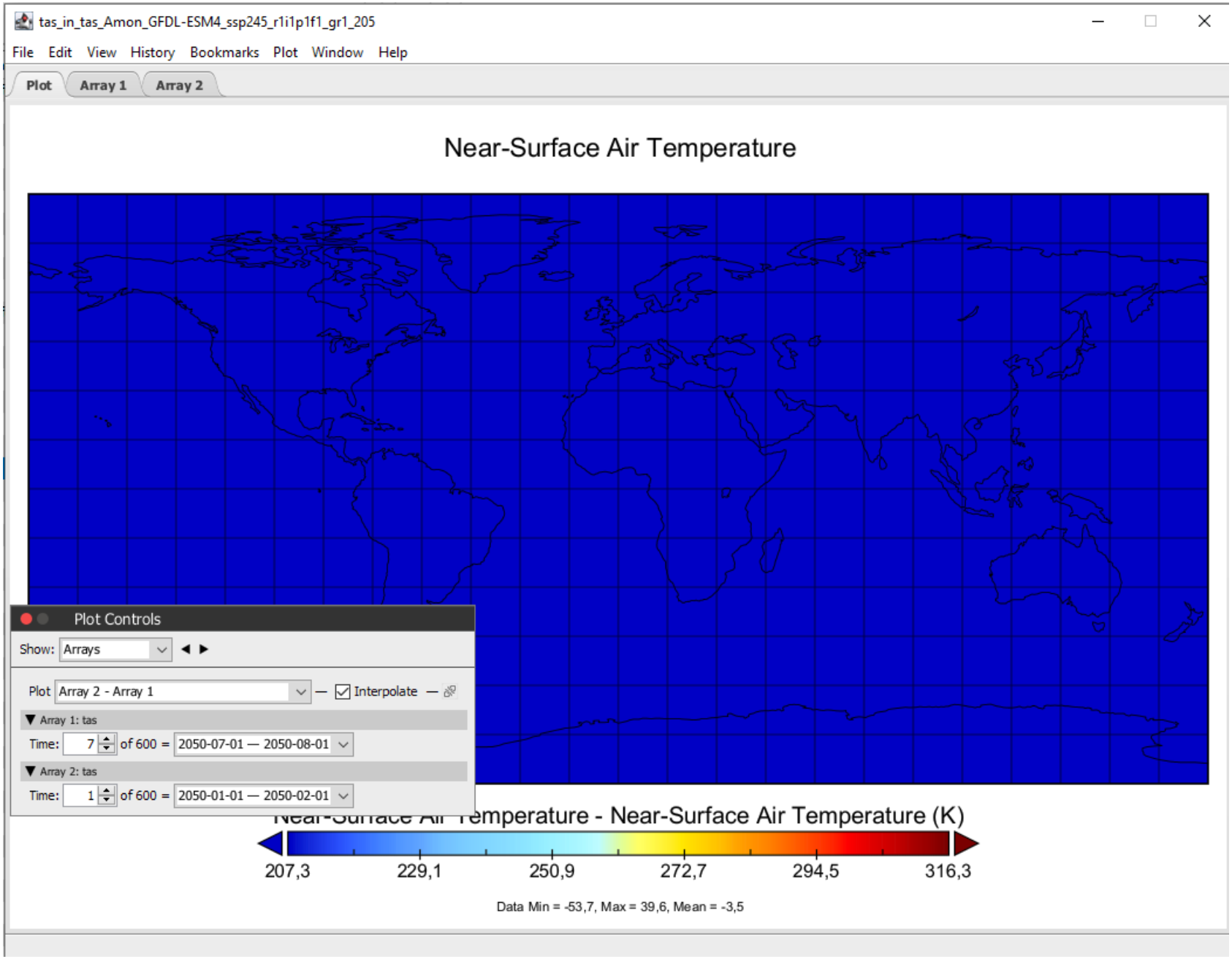




Comparing Data Using Combination Plots in Panoply

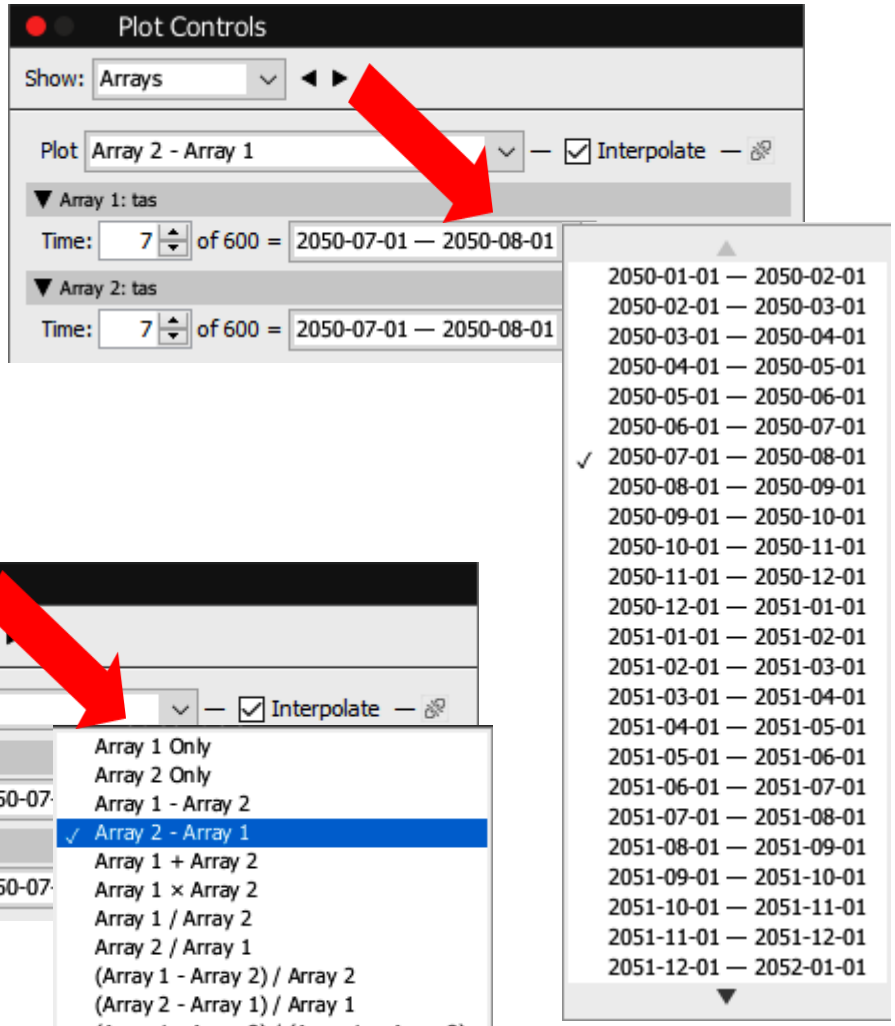
- Open Your Second Dataset or Select the Same Dataset from the Panoply Sources Browser
- Click the data set you wish to Plot (1). *Note: This can be the same dataset or different datasets with the same units (parameters can vary).*
- Click Combine Plot (2). Select the plot with which to combine the variable (i.e., the plot you opened in the first step.)
- Click Combine.



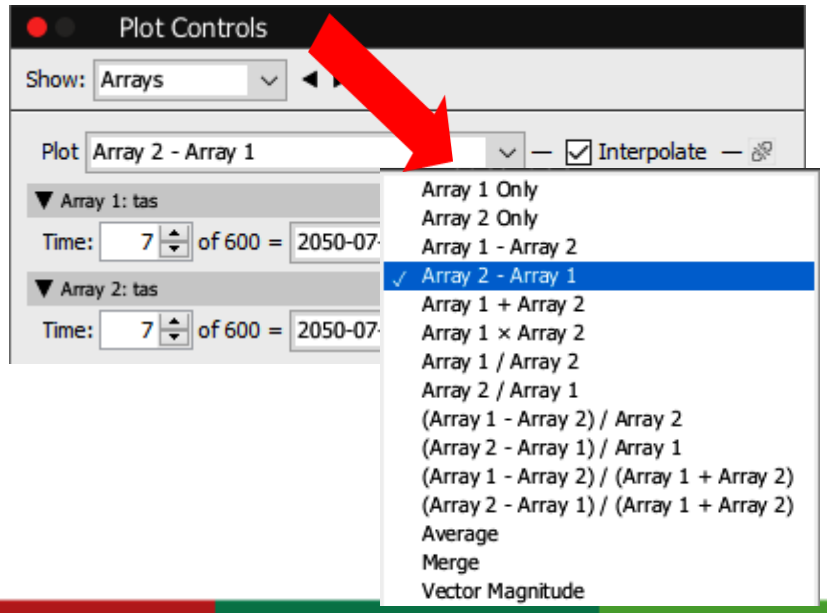

tas_in_tas_Amon_GFDL-ESM4_ssp245_r1i1p1f1_gr1_205
File Edit View History Bookmarks Plot Window Help
Plot Array 1 Array 2
Near-Surface Air Temperature
Plot Controls
Show: Arrays
Plot Array 2 - Array 1 — Interpolate —
Array 1: tas
Time: 7 of 600 = 2050-07-01 — 2050-08-01
Array 2: tas
Time: 1 of 600 = 2050-01-01 — 2050-02-01
Near-Surface Air Temperature - Near-Surface Air Temperature (K)
207,3 229,1 250,9 272,7 294,5 316,3
Data Min = -53,7, Max = 39,6, Mean = -3,5

Comparing Data Using Combination Plots in Panoply

- On the Array(s) tab, select dates to compare (both for Array 1 and Array 2). Here we choose July 2050.

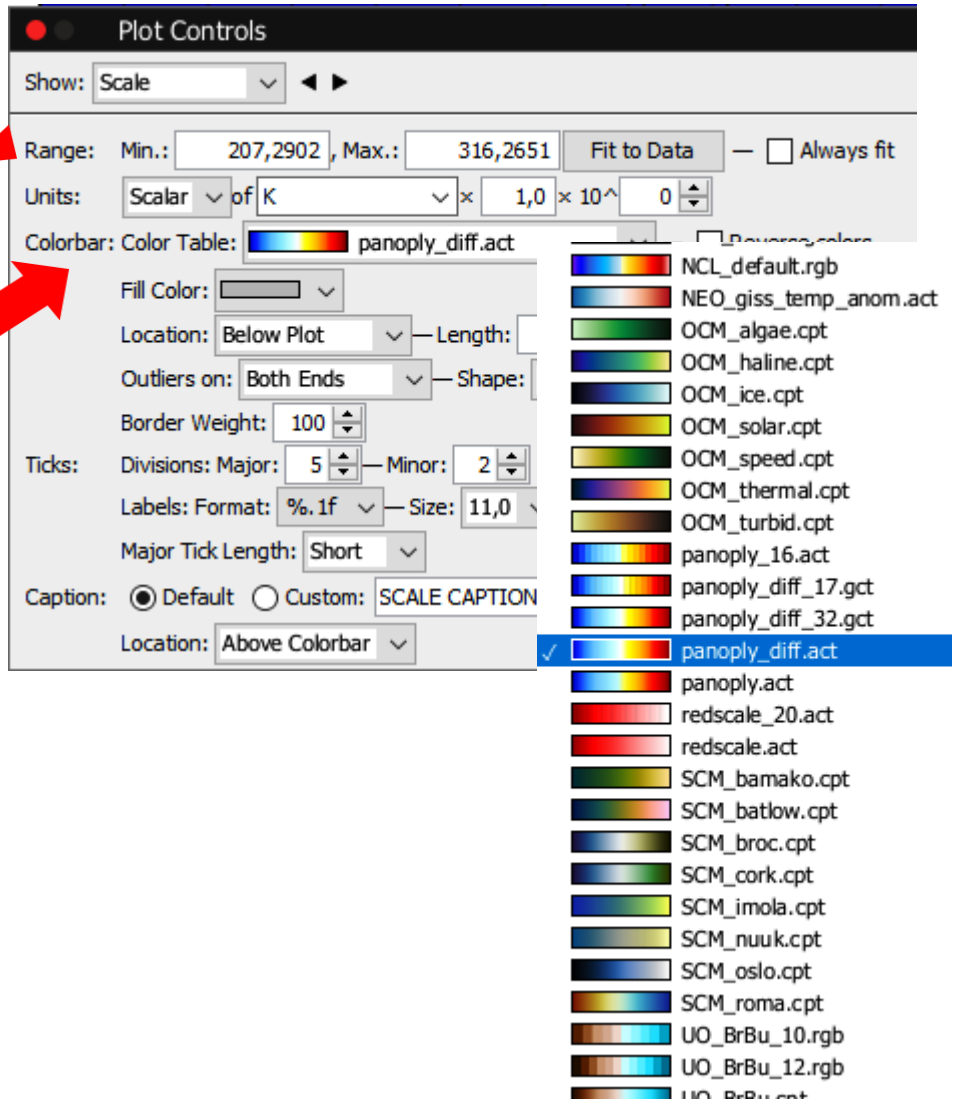


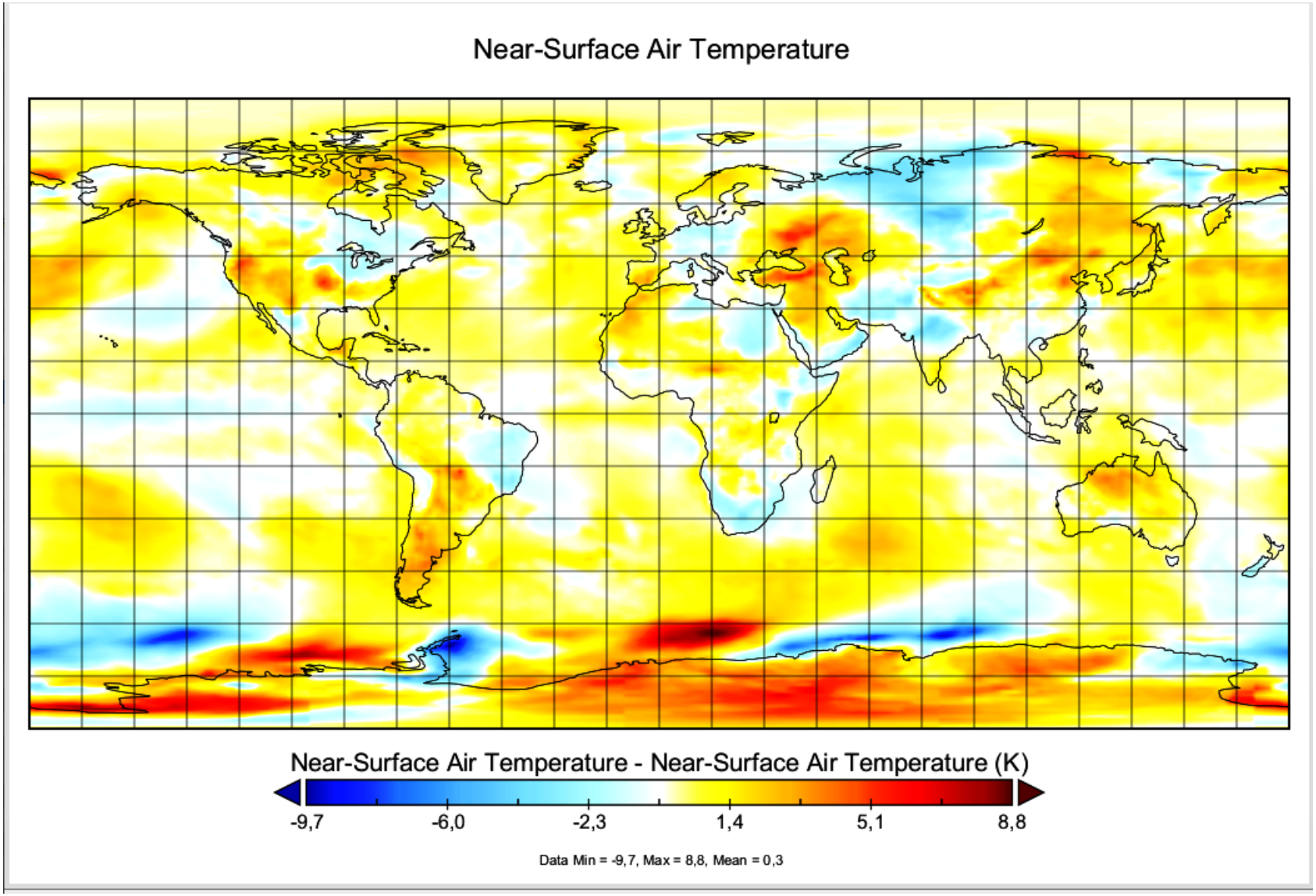
- On the Array(s) tab, select how you want to combine the datasets from the drop down menu.



Comparing Data Using Combination Plots in Panoply

- On the Scale tab, adjust min-max range for data display.
- Tip: On the Color Table we choose an option with white color representing zero which is more preferable for difference plots. Change the values and see the according results.

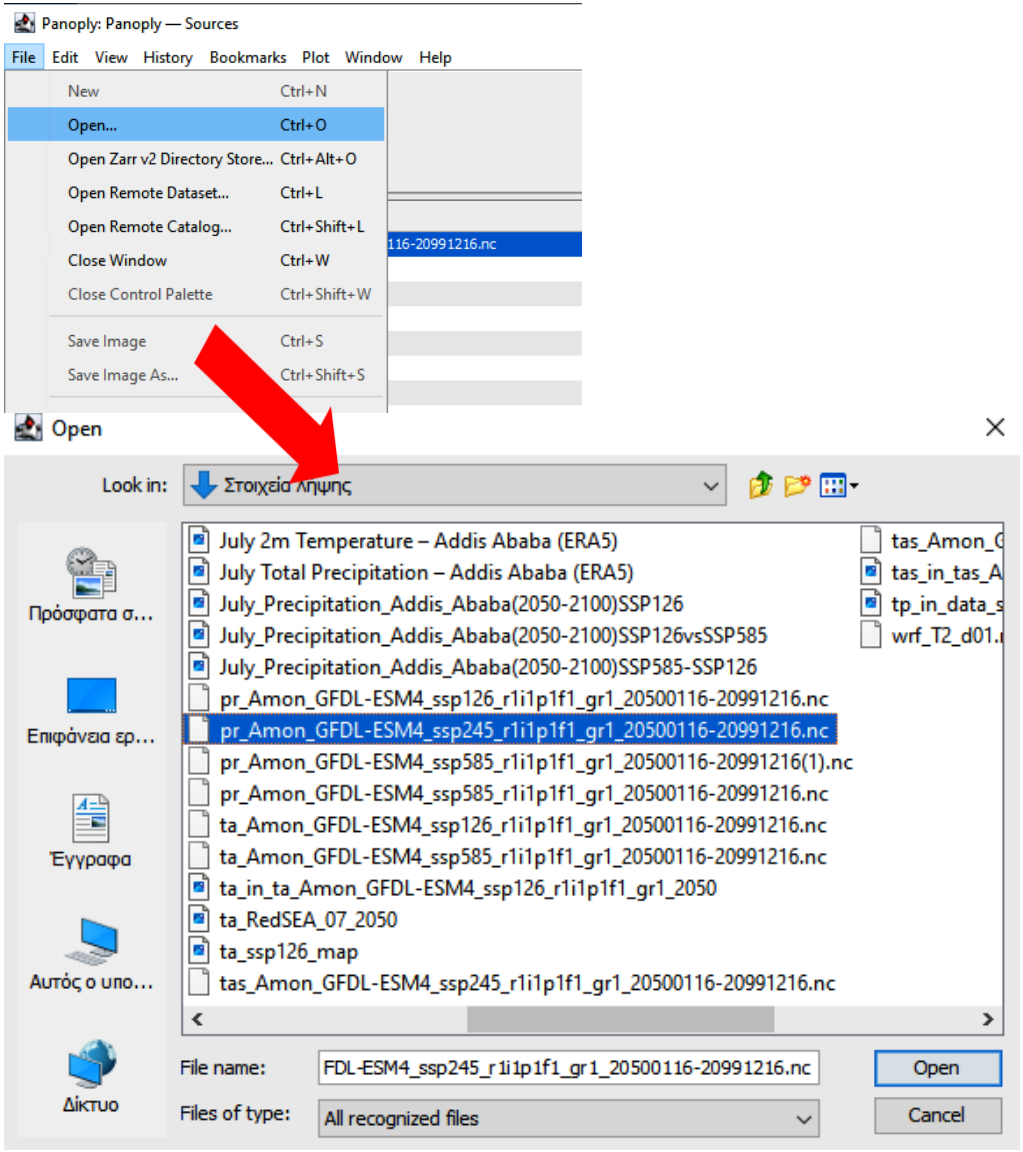



Near-Surface Air Temperature
Near-Surface Air Temperature - Near-Surface Air Temperature (K)
-9,7
-6,0
-2,3
1,4
5,1
8,8
Data Min = -9,7, Max = 8,8, Mean = 0,3

Example: Precipitation plot

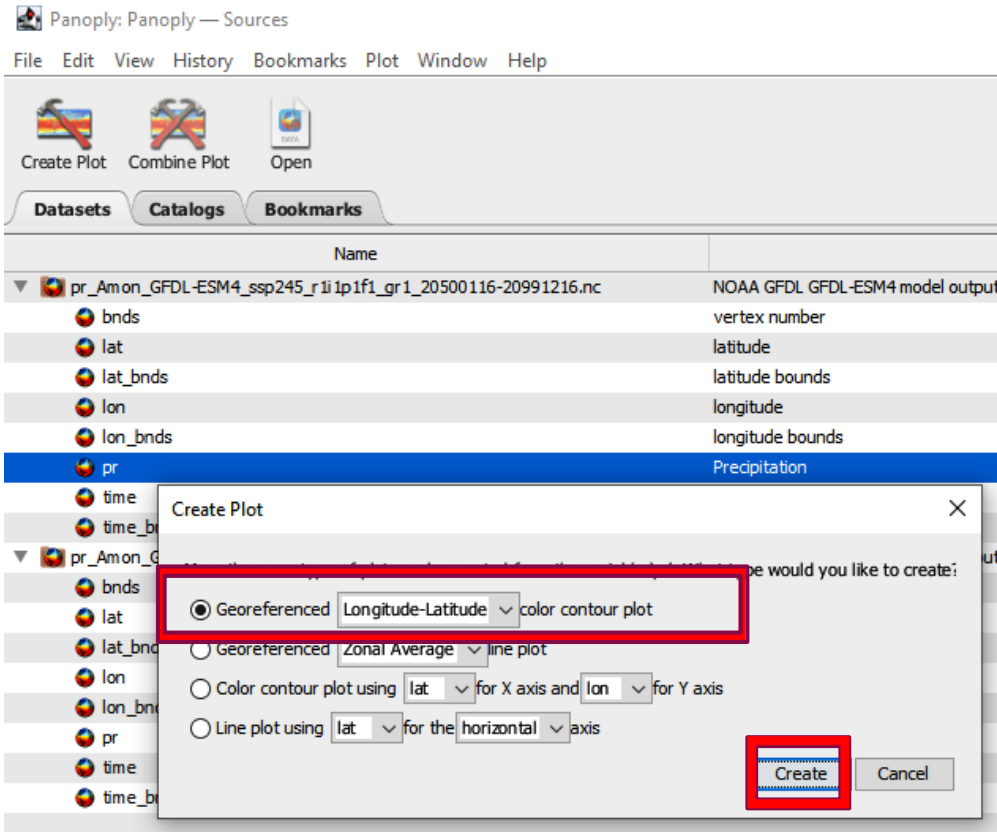
Open files

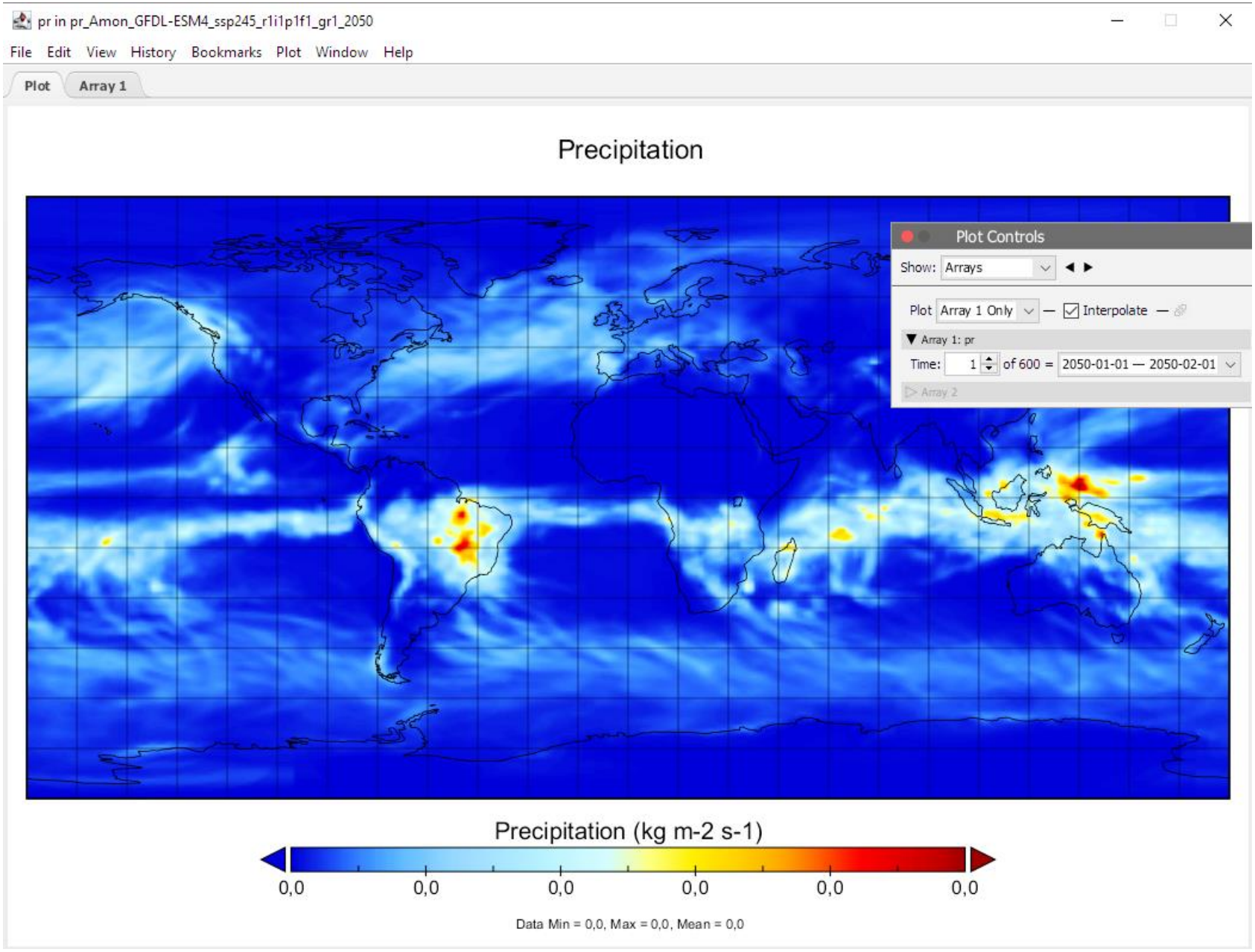
- Click "File" and select "Open"
- Select"pr_Amon_GFDL-ESM4_ssp126_r1i1p1f1_gr1_20500116-20991216.nc" and "pr_Amon_GFDL-ESM4_ssp585_r1i1p1f1_gr1_20500116-20991216.nc" from your download directory. The datasets represent the SSP126 and SSP585 climate change scenarios from the IPCC's Shared Socioeconomic Pathways (SSPs).



Example: Precipitation plot

- As in the previous example, in column "Name" search for “pr - Precipitation“
- Create plot by:
  - Double click on “pr" or
  - On menu bar, click "plot" then select "create plot" or
  - Right click on row “pr" then select "create plot"
  - On pop-up window select "Georeferenced Longitude-Latitude color contour plot" (The 1st row) then "create"

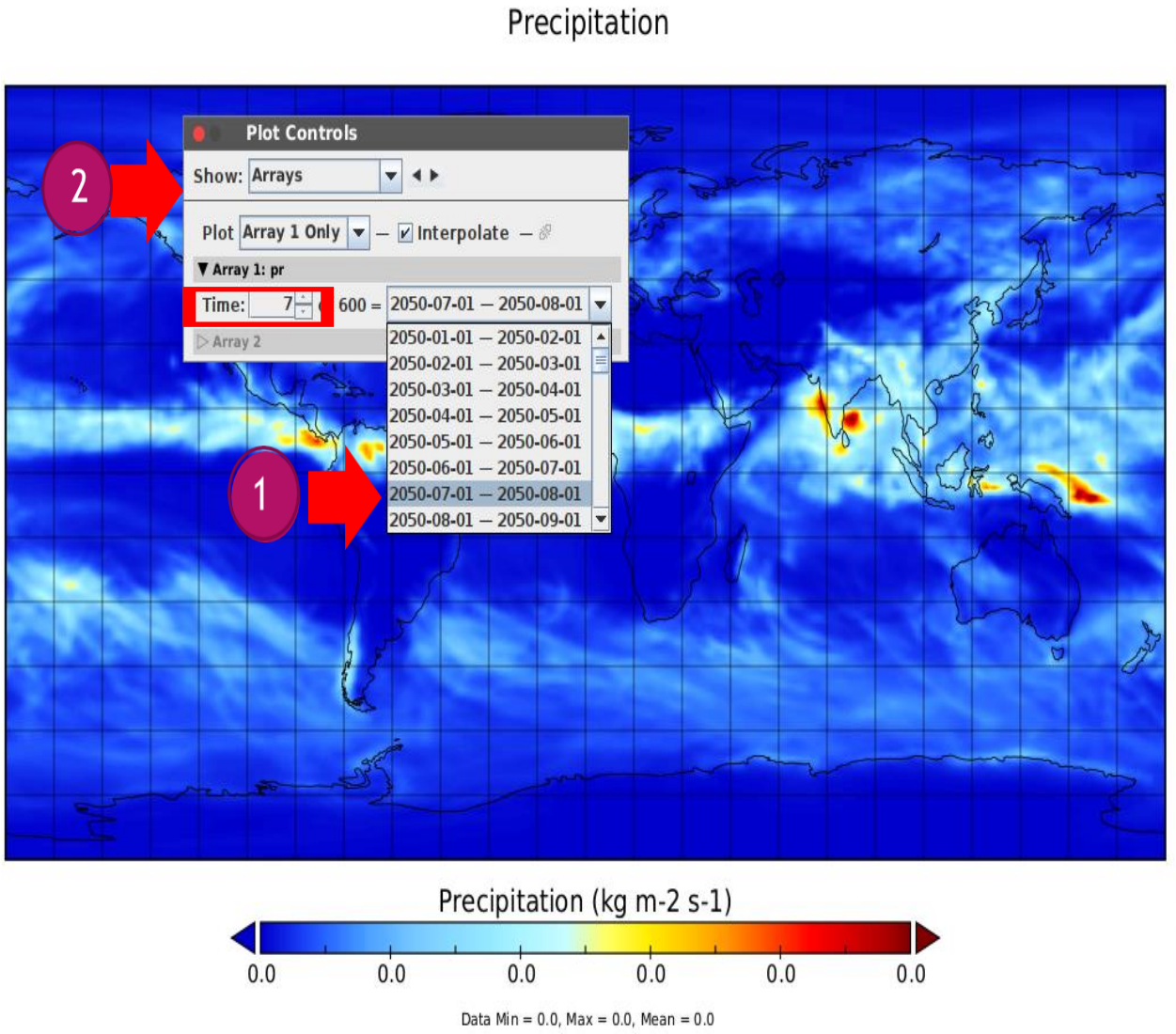



pr in pr_Amon_GFDL-ESM4_ssp245_r1i1p1f1_gr1_2050
File Edit View History Bookmarks Plot Window Help
Plot
Array 1
Precipitation
Plot Controls
Show: Arrays
Plot Array 1 Only — Interpolate —
Array 1: pr
Time: 1 of 600 = 2050-01-01 — 2050-02-01
Array 2
Precipitation (kg m-2 s-1)
0,0 0,0 0,0 0,0 0,0 0,0
Data Min = 0,0, Max = 0,0, Mean = 0,0

Example: Precipitation plot

1. At “Plot Controls", under Array 1: pr you can select the data at specific time bin. For our exercise we select Time 7 (July 2050)

2. Then under the tab “Show” choose the “Scale” panel.



Example: Precipitation plot

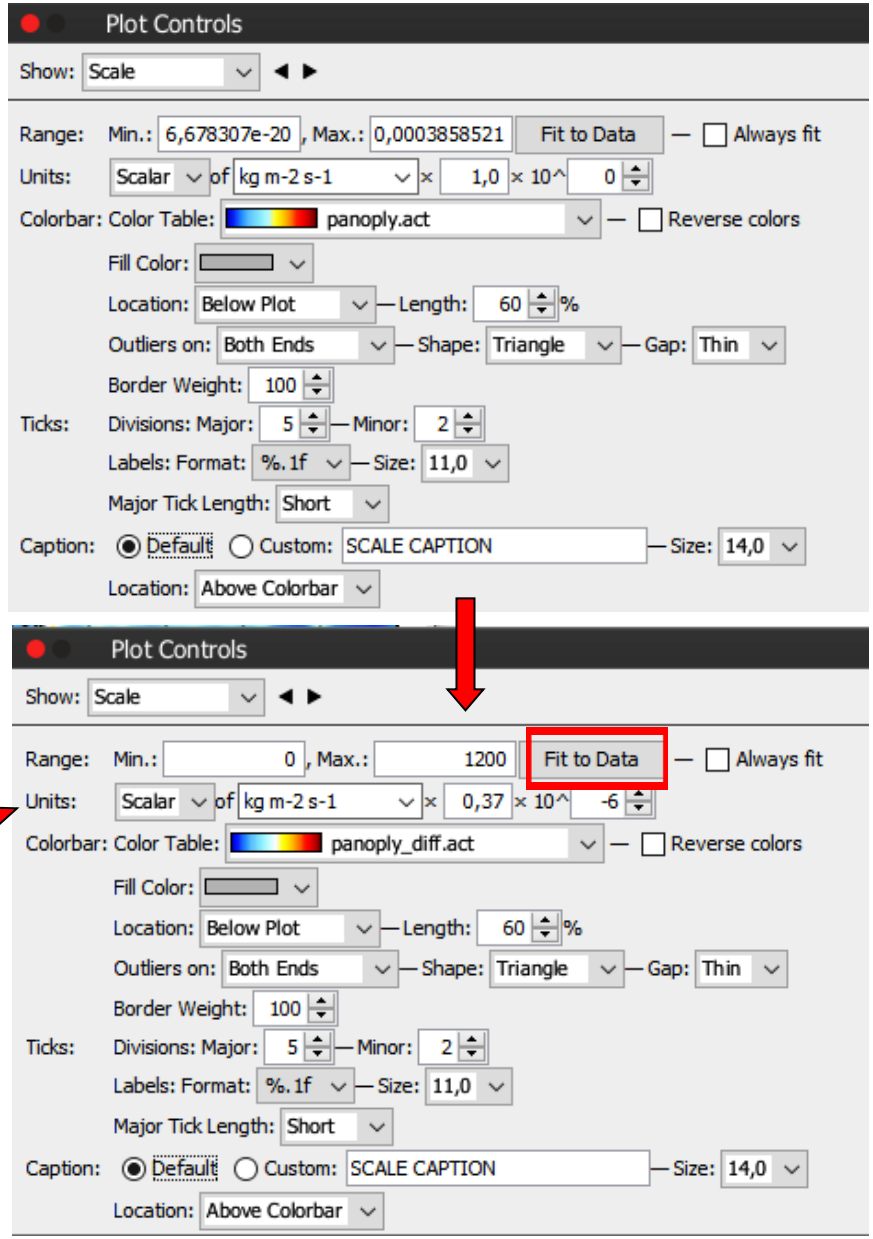
► kg/m2/s are the units used for "precipitation_flux" or "precipitation" data of CMIP5 or CMIP6.

► We know that 1kg = 1Liter = 10e6 mm3 and 1m2 = 10e6 mm2. Therefore 1kg of rain over 1 m2 is equivalent to 1mm.

► So we just need a factor of 86400 (seconds in a day)1 kg/m2/s = 86400 mm/day. Therefore for July we have 31 days x 86400 mm/day =2678400 or 2,68e+06 mm of Total Precipitation.

► In Panoply, at the Scale panel go to the Units tab and you should multiply by $2{,}68 \times 10^{6}$

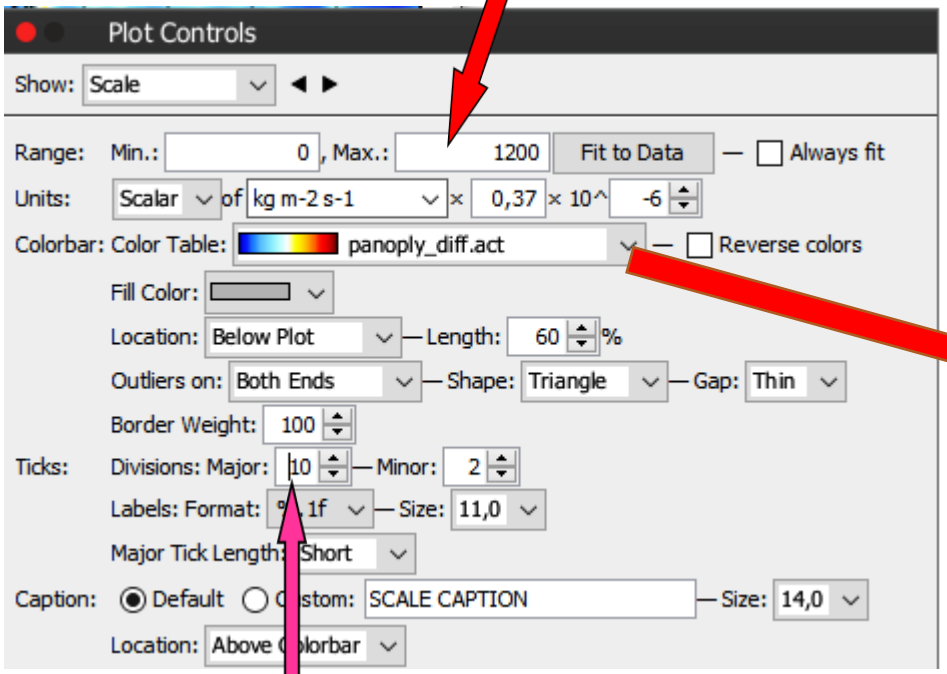
(If you do that you will realize that for an unexplained reason Panoply subtracts rather then multiplies. We could bypass this problem by "multiplying" with $1/(2{,}68 \times 10^{6}) \rightarrow 0{,}37 \times 10^{-6}$). Then click "Fit to Data" .

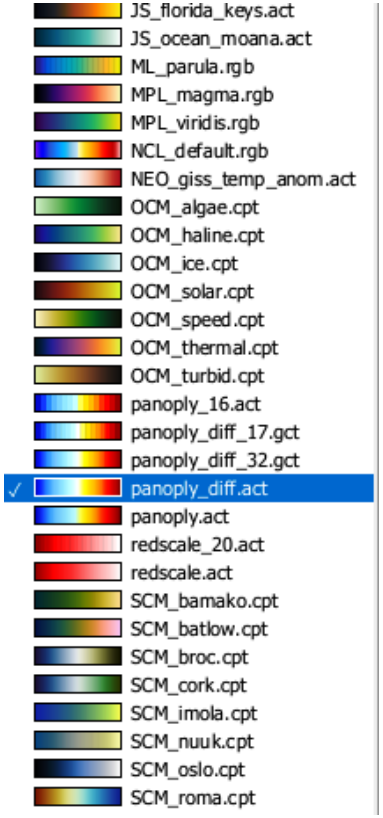


Example: Precipitation plot

On the tab Range we adjust min-max range for better data display.

Change the color table to one that better highlights differences.

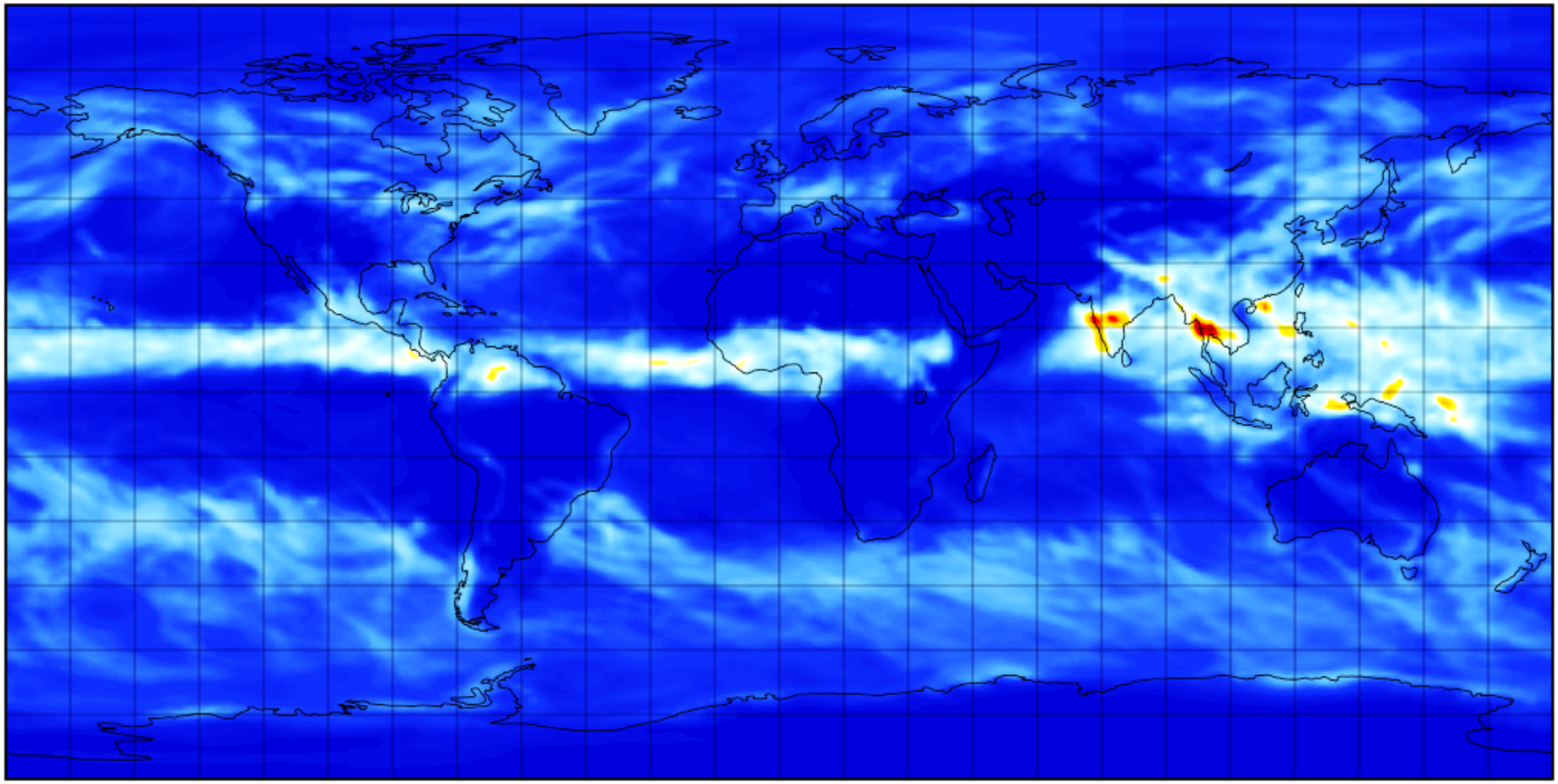




On the tab "Ticks" we change "Divisions : Major" to 10, according to our preferences.

You now can see the according results and save your plot.

Precipitation



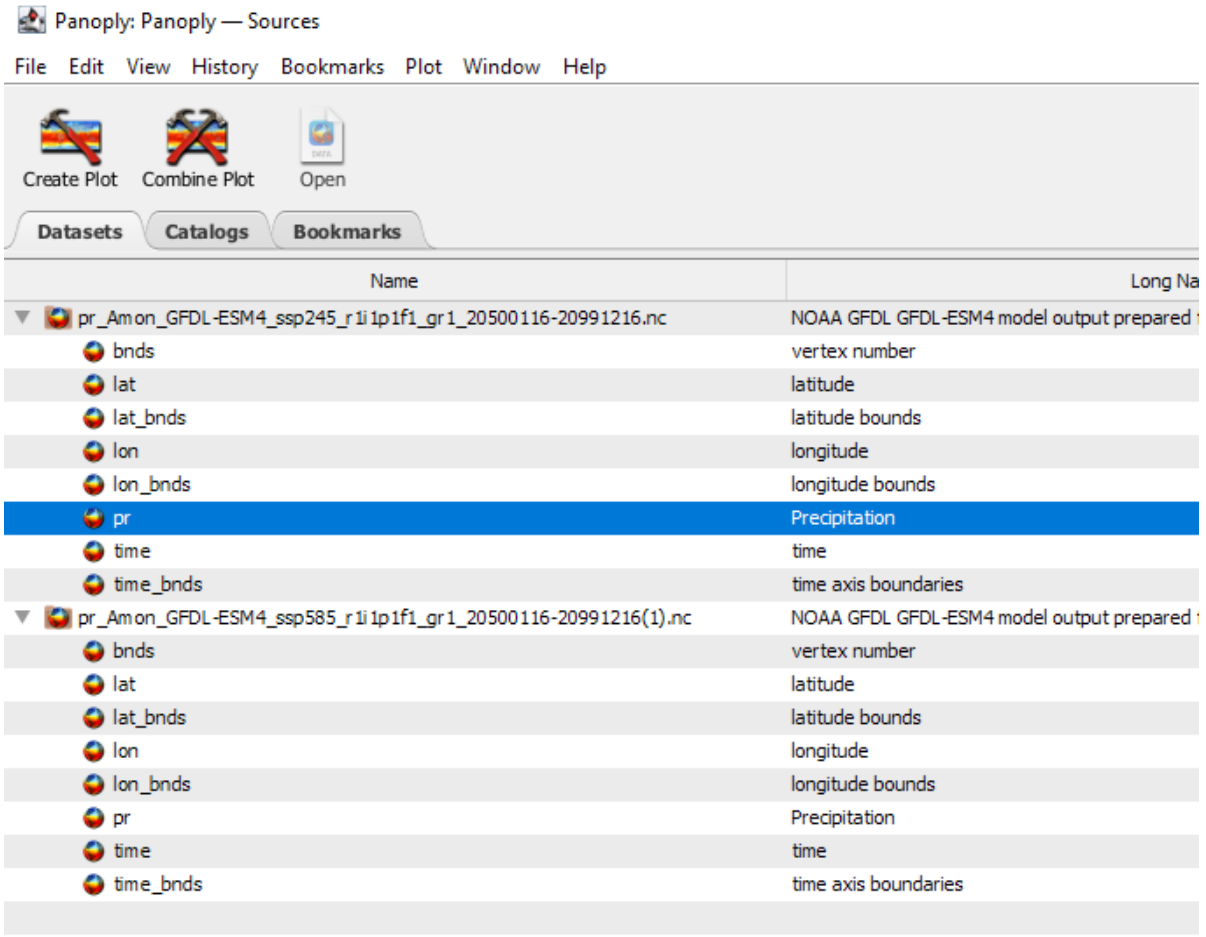
Precipitation (3,7e-07 kg m-2 s-1)

0,0 120,0 240,0 360,0 480,0 600,0 720,0 840,0 960,0 1080,0 1200,0

Data Min = 0,0, Max = 1272,4, Mean = 96,5

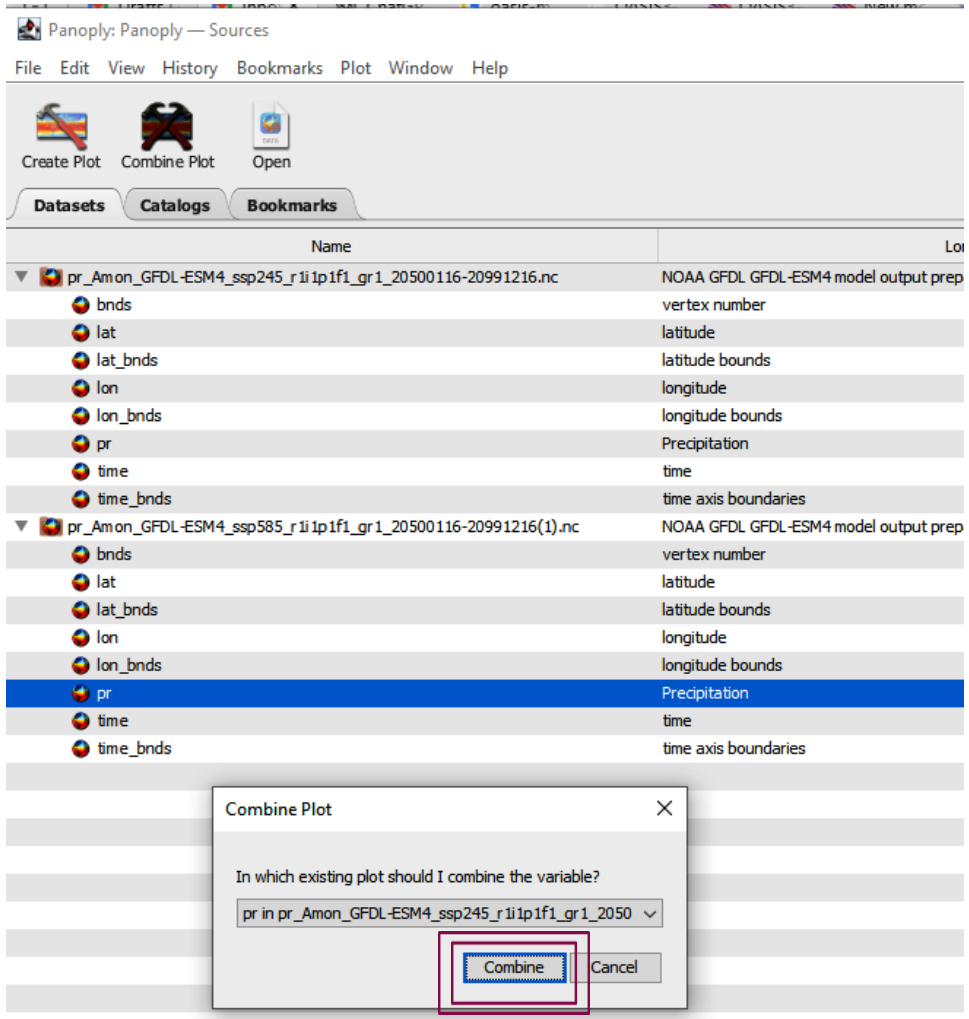
Comparing Precipitation Data Using Combination Plots in Panoply

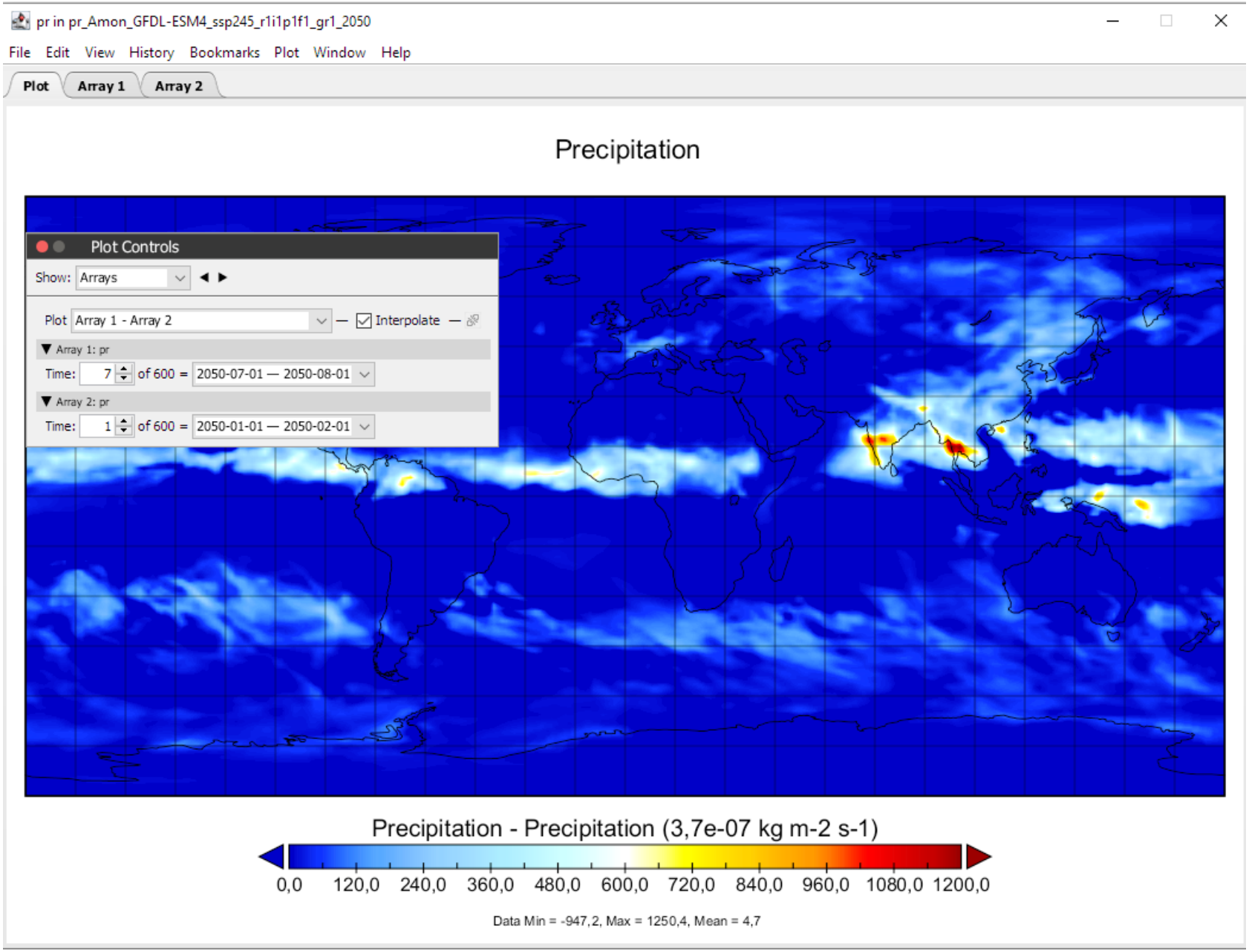
We have already created the plot of our First Dataset and selected the variables that we want to display.



Comparing Precipitation Data Using Combination Plots in Panoply

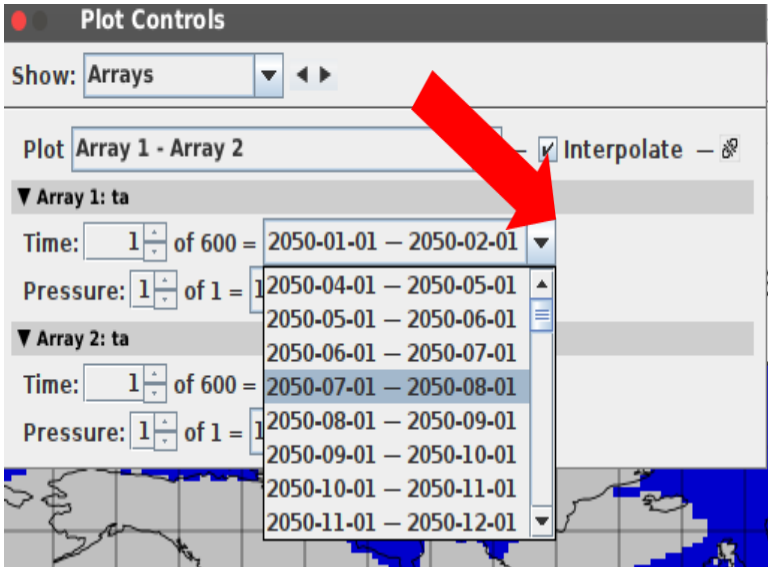
- Open Your Second Dataset or Select the Same Dataset from the Panoply Sources Browser
- Click the data set you wish to Plot (1). *Note: This can be the same dataset or different datasets with the same units (parameters can vary).*
- Click Combine Plot (2). Select the plot with which to combine the variable (i.e., the plot you opened in the first step.)
- Click Combine.



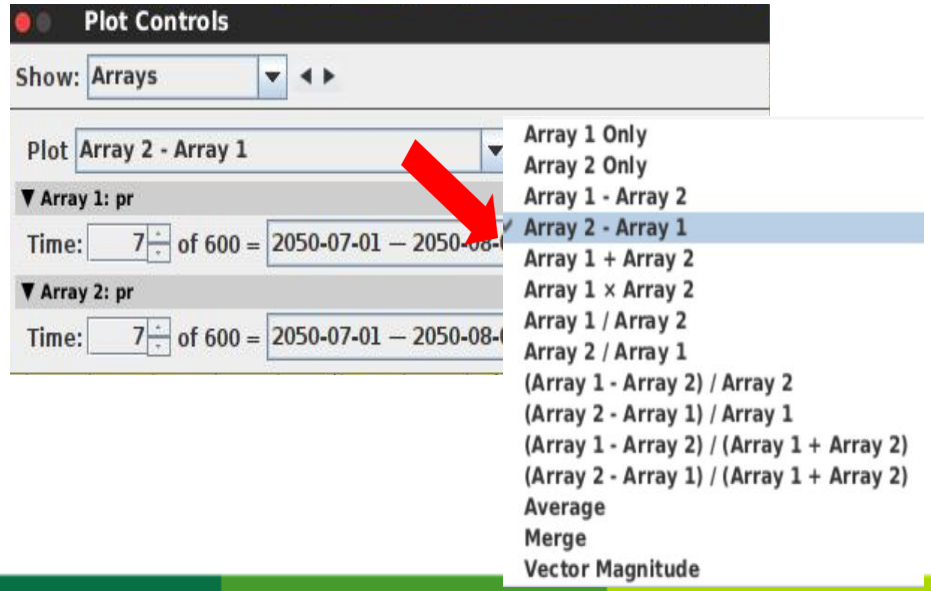

pr in pr_Amon_GFDL-ESM4_ssp245_r1i1p1f1_gr1_2050
File Edit View History Bookmarks Plot Window Help
Plot Array 1 Array 2
Precipitation
Plot Controls
Show: Arrays
Plot Array 1 - Array 2 — Interpolate —
Array 1: pr
Time: 7 of 600 = 2050-07-01 — 2050-08-01
Array 2: pr
Time: 1 of 600 = 2050-01-01 — 2050-02-01
Precipitation - Precipitation (3,7e-07 kg m-2 s-1)
0,0 120,0 240,0 360,0 480,0 600,0 720,0 840,0 960,0 1080,0 1200,0
Data Min = -947,2, Max = 1250,4, Mean = 4,7

Comparing Data Using Combination Plots in Panoply

- On the Array(s) tab, select dates to compare (both for Array 1 and Array 2). Here we choose July 2050.



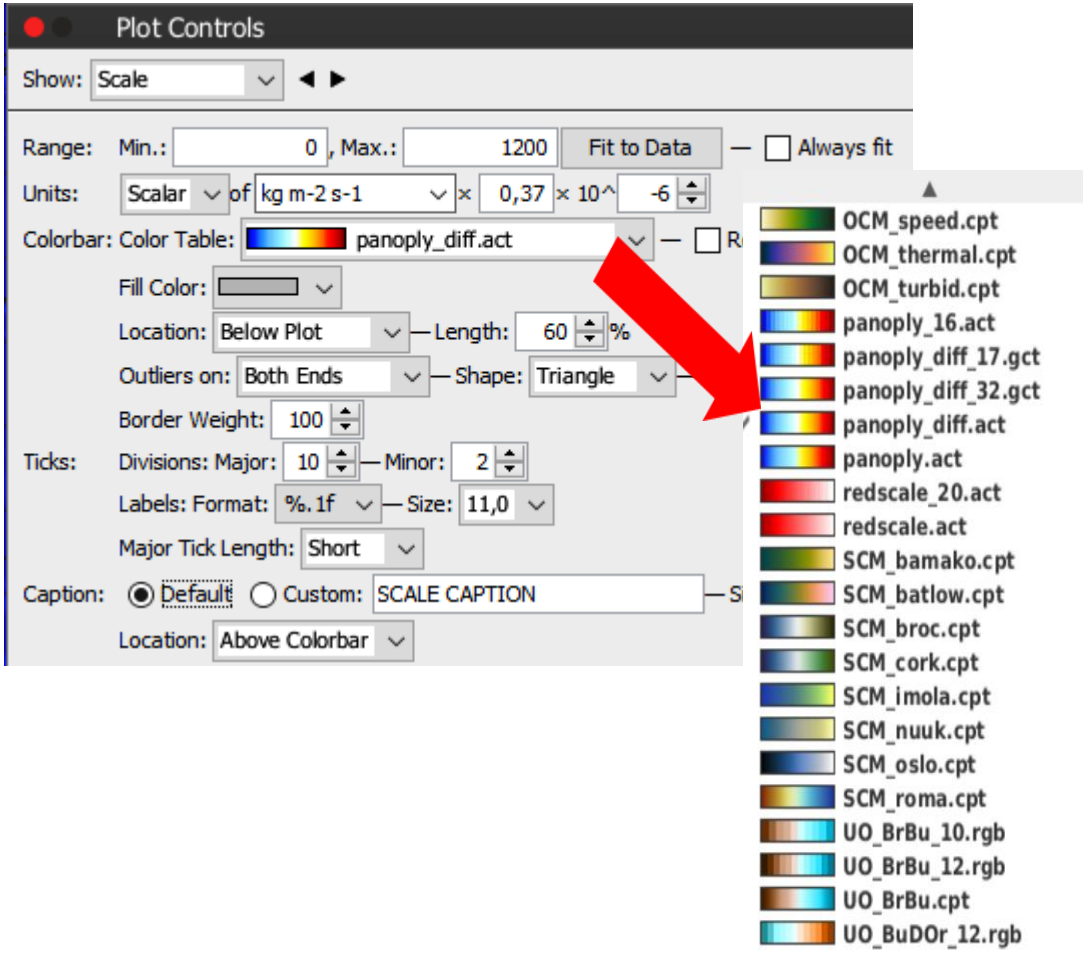
- On the Array(s) tab, select how you want to combine the datasets from the drop down menu.



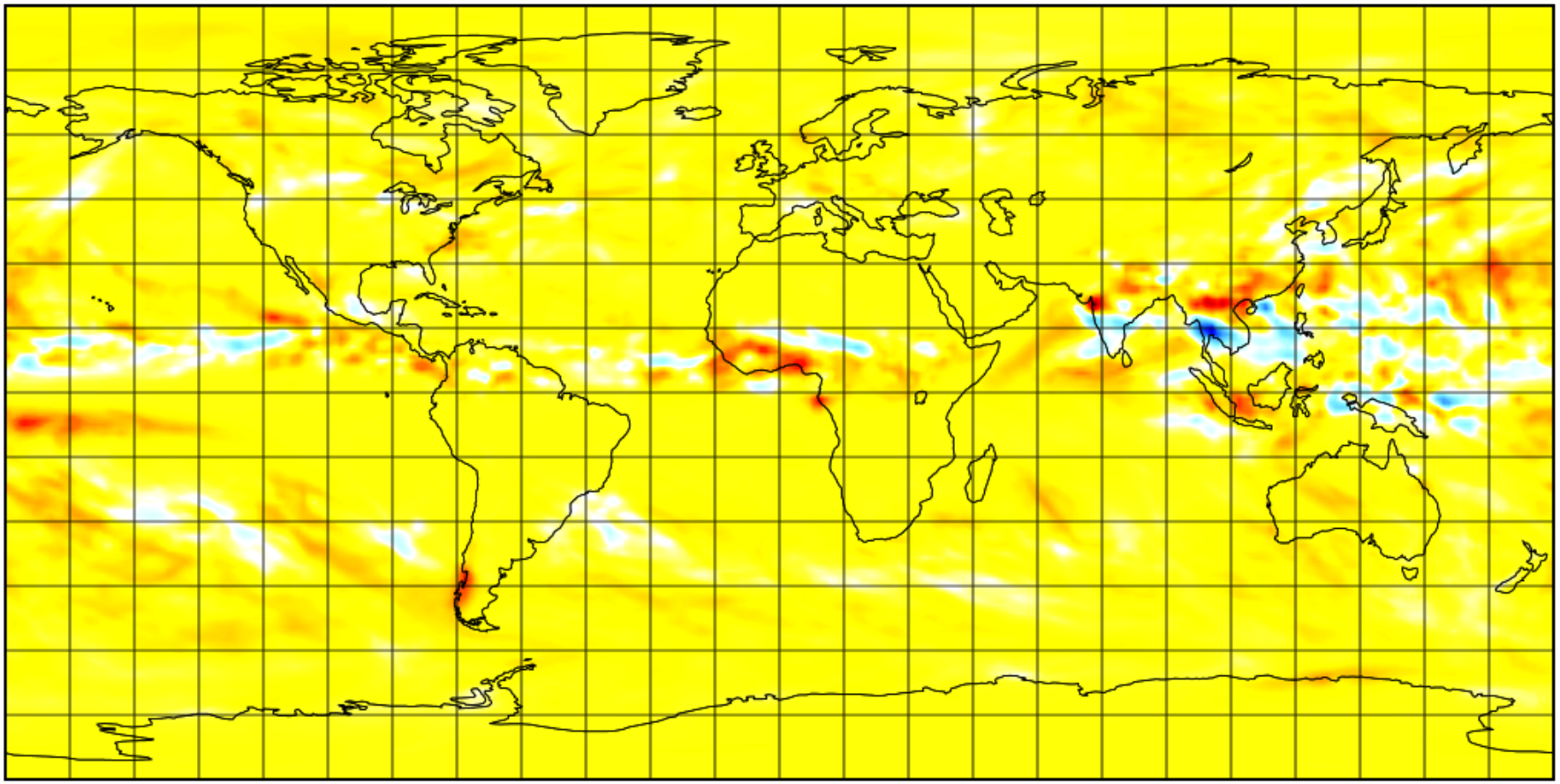
Comparing Data Using Combination Plots in Panoply

- On the Scale tab, adjust min-max range for data display. Tip: It helps to click first “Fit to data” and than re-adjust accordingly.

- Tip: On the Color Table we choose an option with white color representing zero which is more preferable for difference plots. Change the values and see the according results.



Precipitation



Precipitation - Precipitation (3,7e-07 kg m-2 s-1)

-1014,2 -838,9 -663,7 -488,4 -313,2 -138,0 37,3 212,5 387,8 563,0 738,3

Data Min = -1014,2, Max = 738,3, Mean = -1,4