Xraster PLUGIN FOR QGIS

Multidimensional Raster GIS

Tutorial
(oceanography)

Jun 2025

Course Data:

The course can be completed using your own data or using the data provided for specific tasks. The data file **Xraster_course_data1.zip (1.6 GB)** can be downloaded using the link below.

Dane: https://drive.google.com/file/d/1qyy7My0WNv4hIlStU-H9DUJ4xS5oP94y/view?usp=sharing

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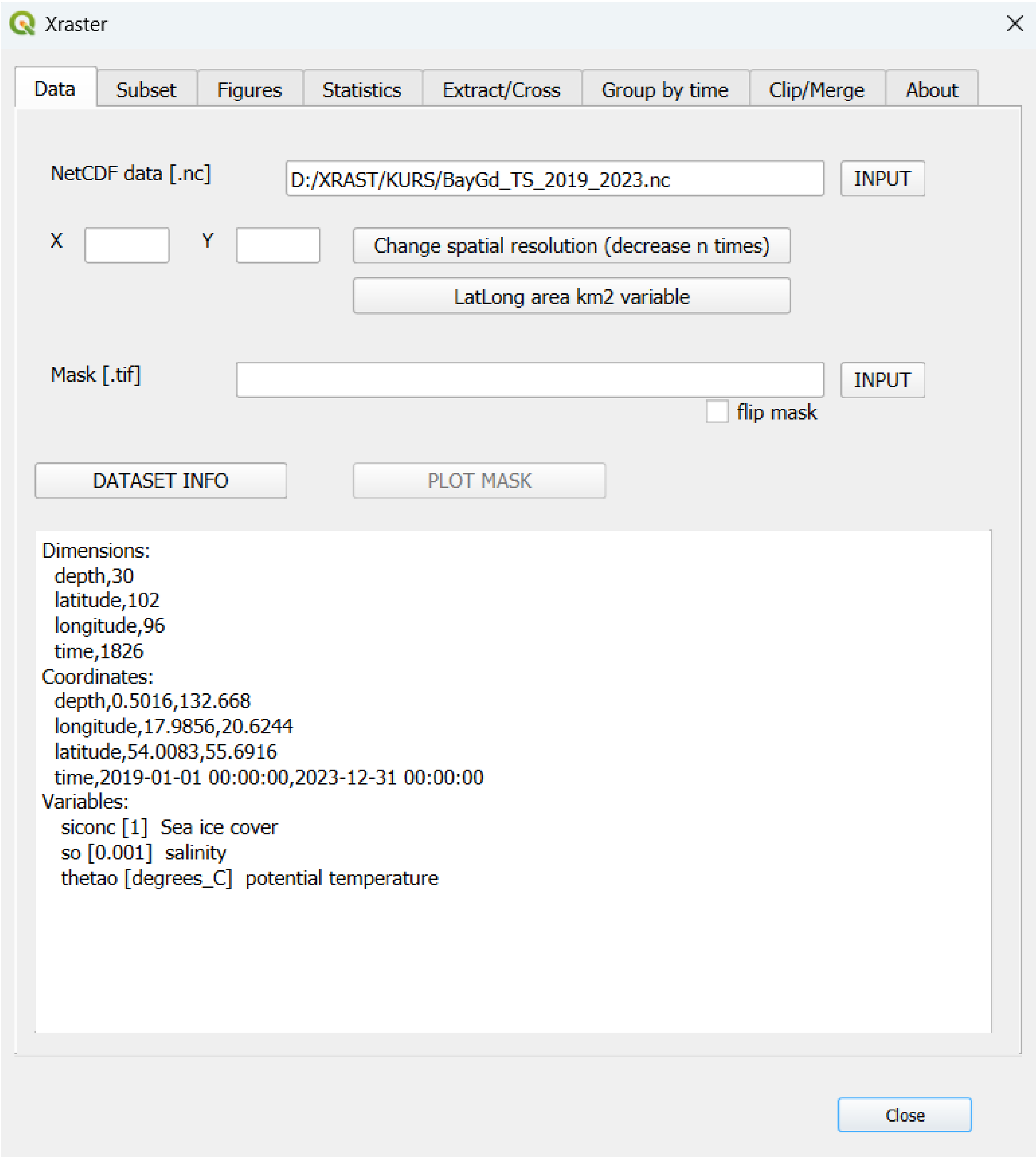
1. Introduction and initial data exploration

1.1 Launch the Xraster plugin and load the NetCDF data file **BayGd_TS_2019_2023.nc** using the **INPUT** button (for NetCDF data). Information about the data will be displayed on the panel.

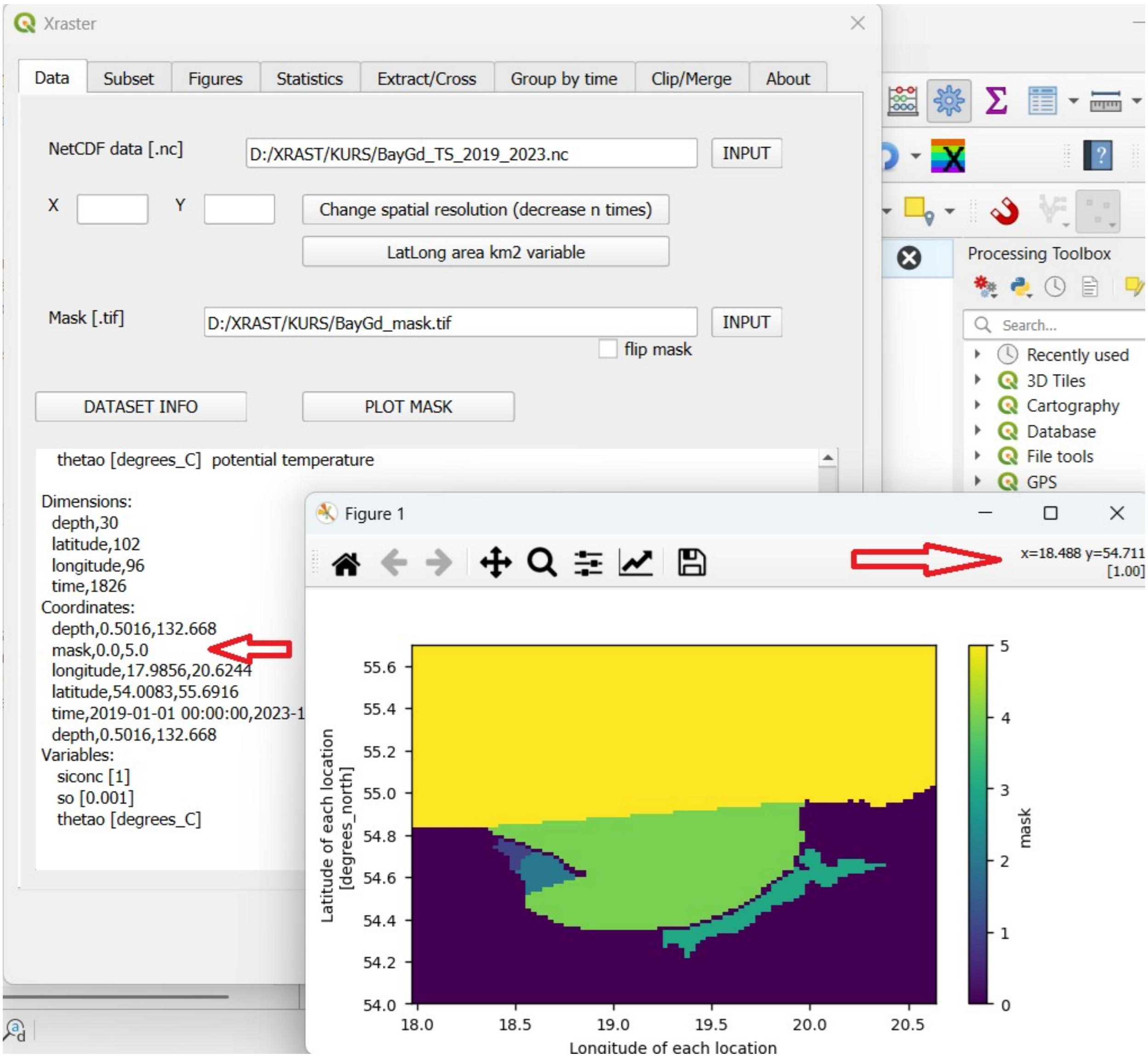


The data has four dimensions: two-dimensional rasters (with geographic coordinates) consisting of 102 rows and 96 columns. For each point in time (the **time** dimension), there are 30 such rasters corresponding to different depths (the **depth** dimension).

Next, there is information about the coordinate ranges. The final section provides details about the variables and their units. Our variables are:

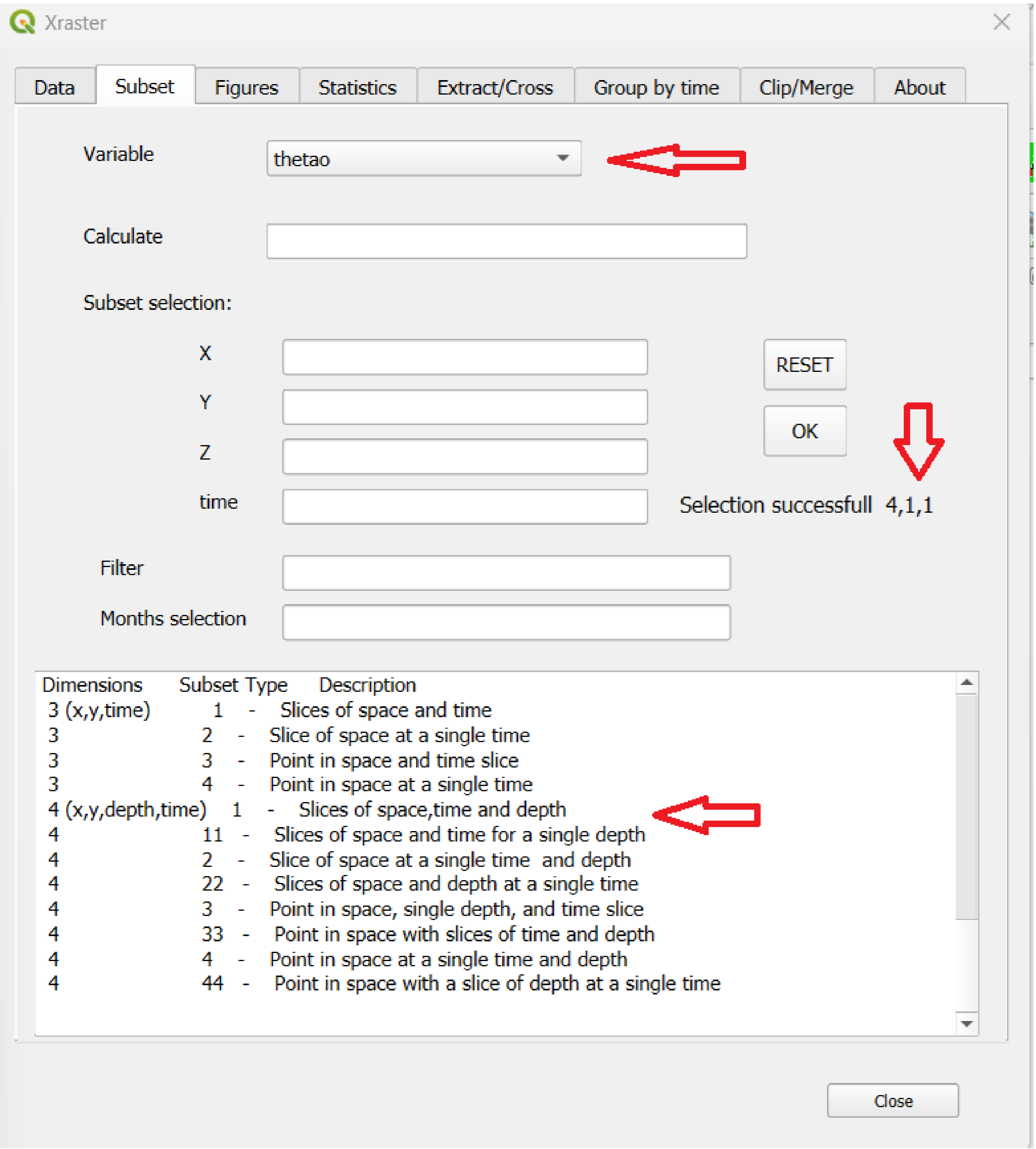
- **siconc** – sea ice cover (relevant only at the surface), with values ranging from 0 to 1. A value of 0 indicates no ice in the pixel, and 1 indicates full ice coverage.
- **so** – salinity (in ‰), and
- **thetao** – temperature, both of which have values for each depth level.

1.2 Next, we'll load a mask using the **INPUT** button (for Mask). Load the file **BayGD_mask.tif**. If no message appears after loading, it means the mask is valid (it has the same dimensions as our two-dimensional rasters with geographic coordinates). Click on **DATASET INFO** – information about the data will appear on the panel, and under **Coordinates**, details about the mask will be shown (it contains values from 0 to 5). By clicking on **PLOT MASK**, you can display the mask.



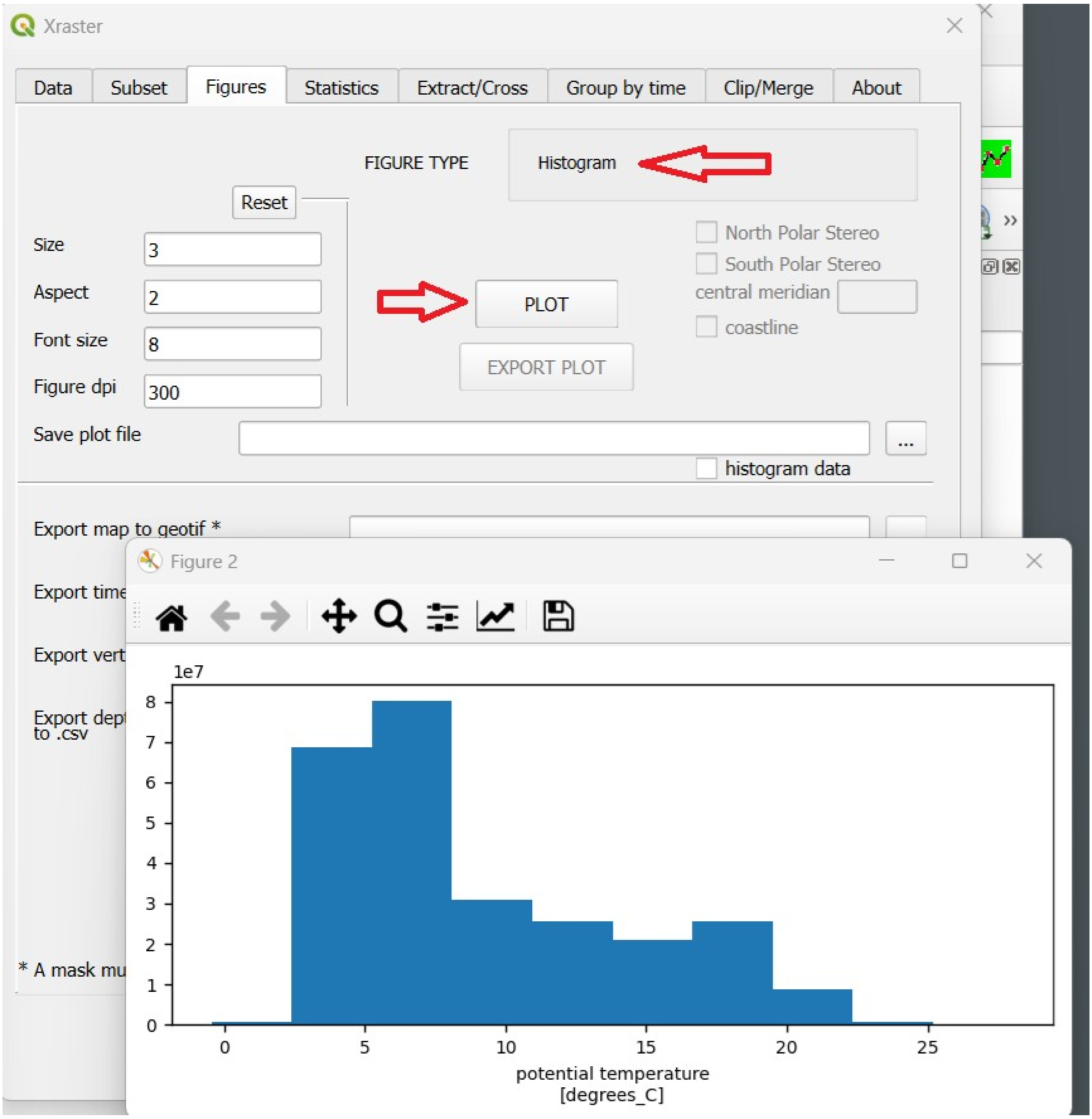
The mask is a raster that defines analysis zones (in its absence, the entire area is analyzed) using integer identifiers. By hovering the cursor over a specific area, you can see which number represents it.

1.3 The exploratory data analysis involves selecting a variable and a data subset, followed by visualization. Go to the **SUBSET** tab, select the variable thetao (temperature), and click **OK**. Wait (approximately 40 seconds) until the message **Selection successful 4,1,1** appears under the button. The time required to prepare the subset depends on its size. On the information panel, you can read that the subset described as **4,1,1** has 4 dimensions, is of type **1 – Slice of space, time, and depth**, and includes a mask (**1**). Our subset contains all data for the variable **thetao**.



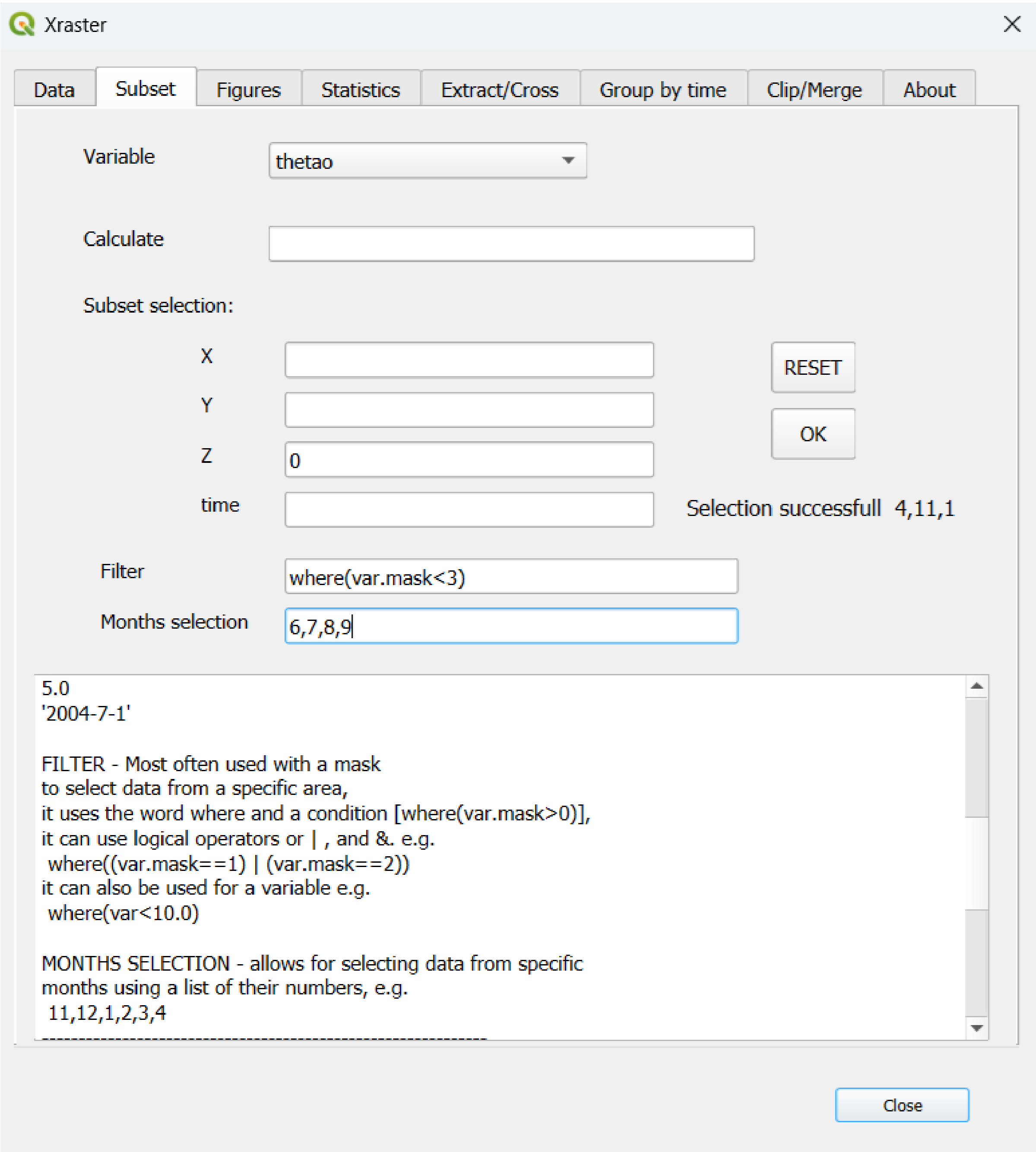
1.4 Go to the **FIGURES** tab. The current subset type allows for visualization using a histogram. Click **PLOT** to generate the histogram.

The histogram shows, among other things, the data range within the subset (min: -0.2, max: 25). This allows you to check whether there are any outliers in the data.

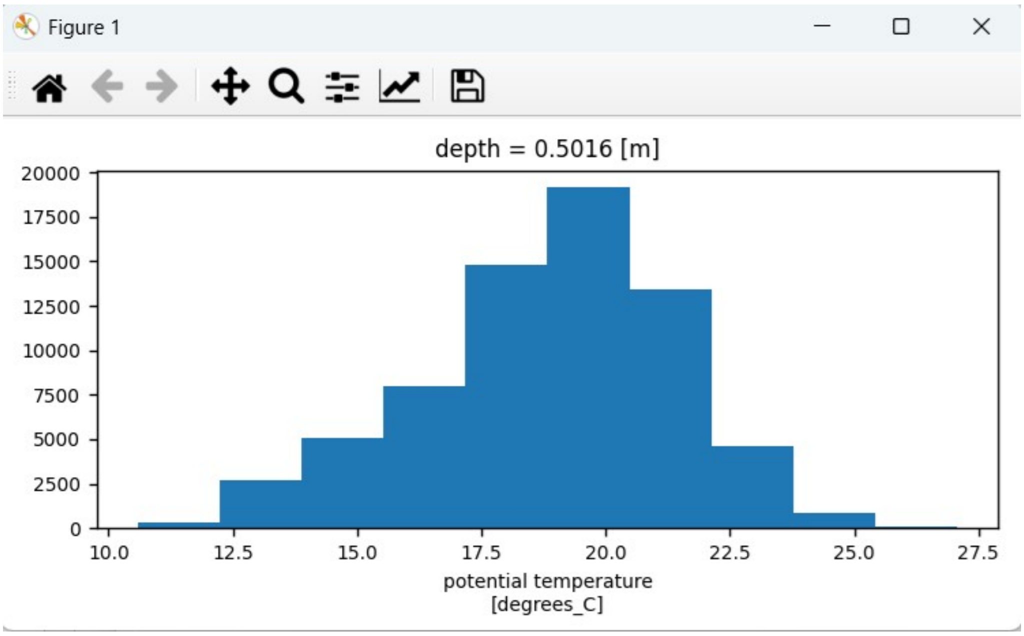


x

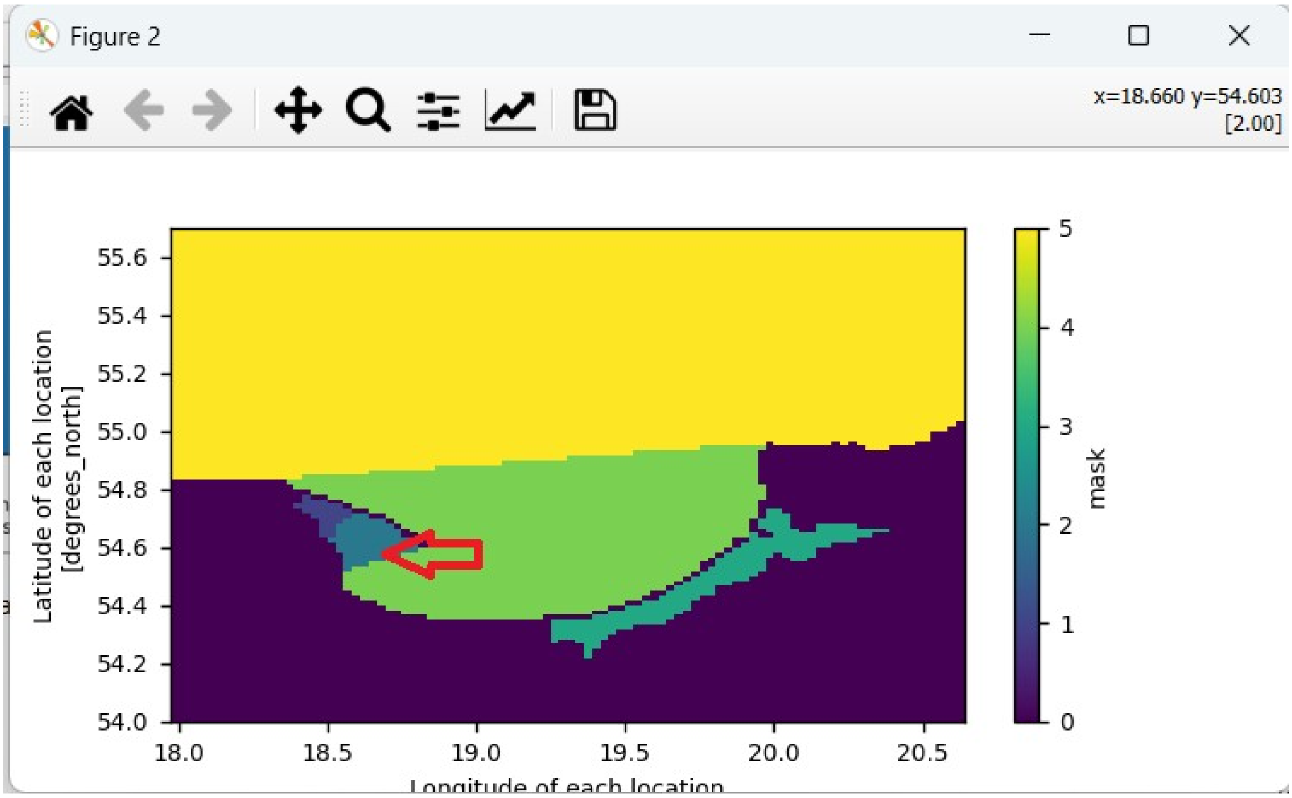
1.5 Now we will check the water temperature values in areas with IDs **1** and **2** (PUCK BAY), at the **surface level** (depth = 0) during the months of **June to September**. Go back to the **SUBSET** tab.
Enter **Z = 0** (to select surface level). Specify the filter – the syntax can be found on the panel – to limit the data to months **6, 7, 8, 9**, then click **OK**. The subset will be created much faster. Its type **11** indicates: *Slice of space and time for a single depth*.



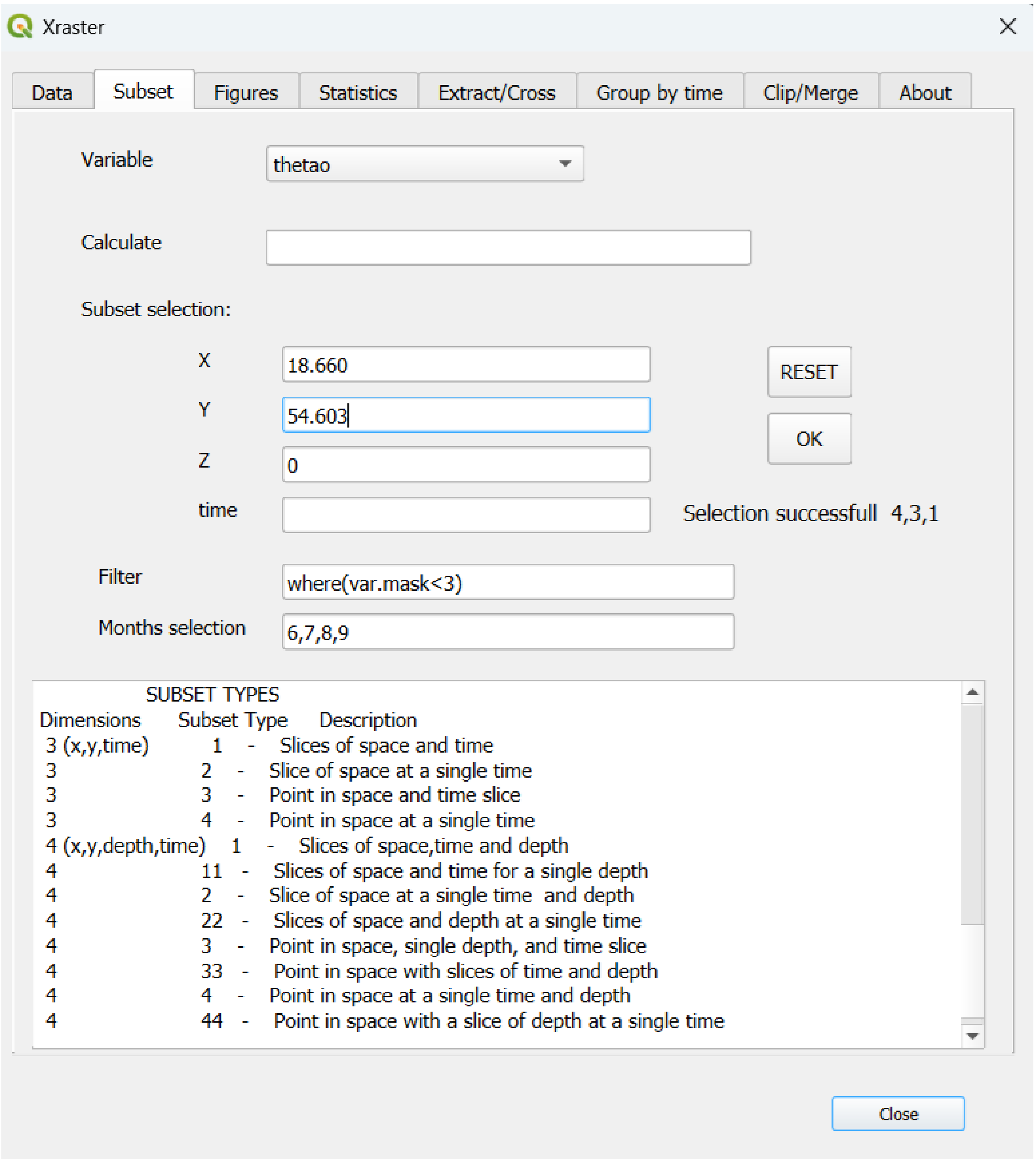
You can now go back to the **FIGURES** tab and create a histogram for the new subset.



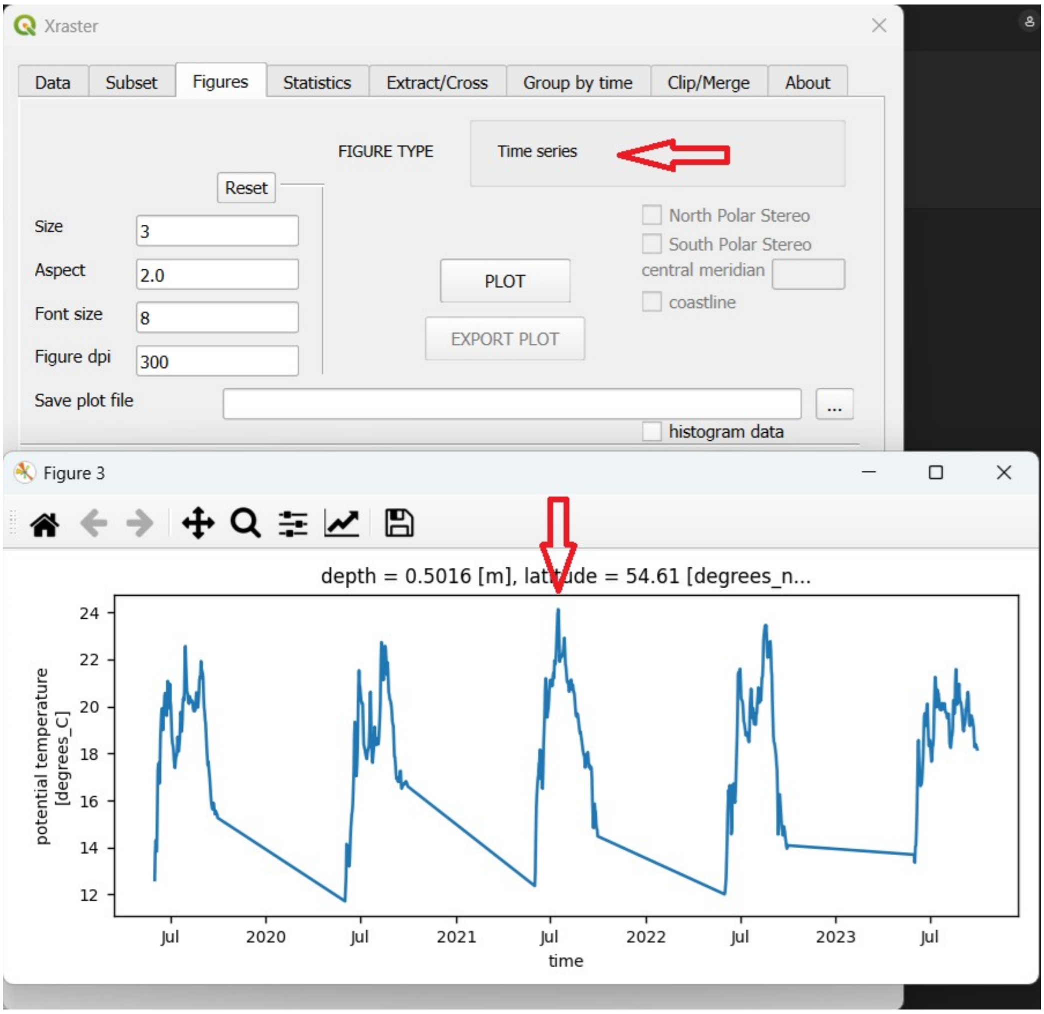
1.6 Now we will check how the temperature changed over time at a selected point in the analyzed area. Select a point on the mask and note its coordinates: **x = 18.660, y = 54.603**.



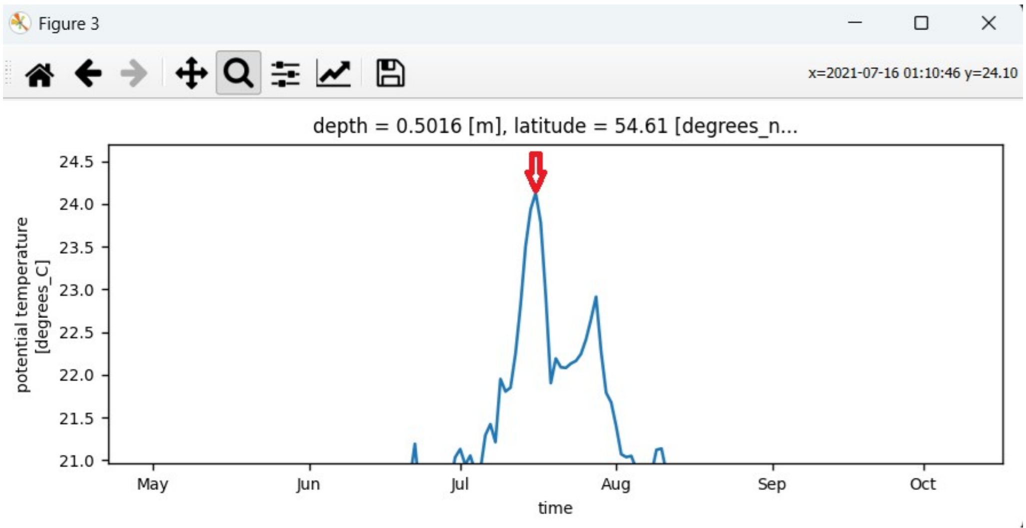
1.7 Go to the **SUBSET** tab, enter the coordinates, and create the subset. Type **3** indicates: *Point in space, single depth, and time slice*.



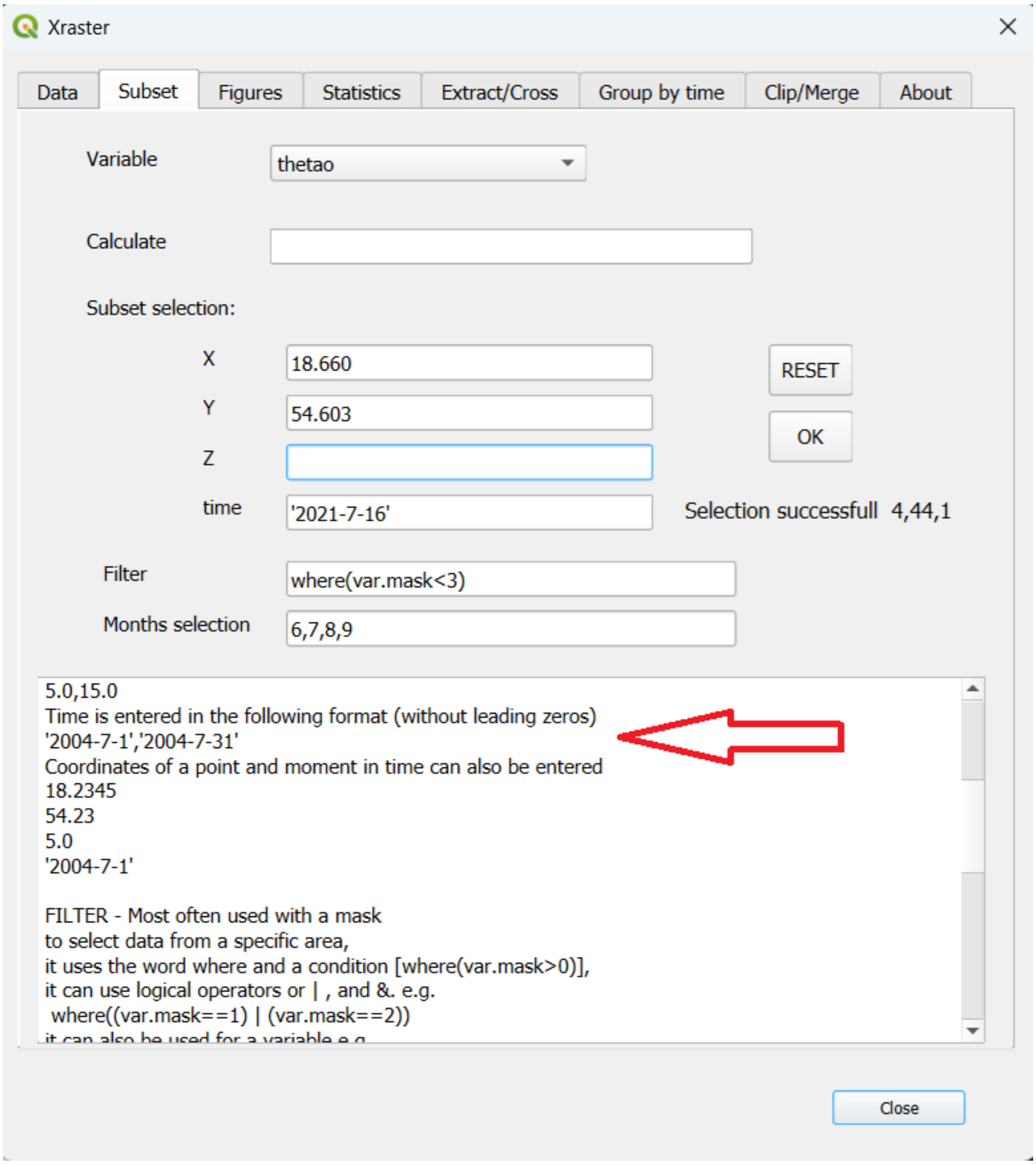
1.8 Go to the **FIGURES** tab. The created subset can be visualized as a **Time series**. Click **PLOT** to generate the chart.



You can zoom in on the chart using the magnifying glass tool, hover the cursor over the maximum temperature value, and read its date (2021-07-16).

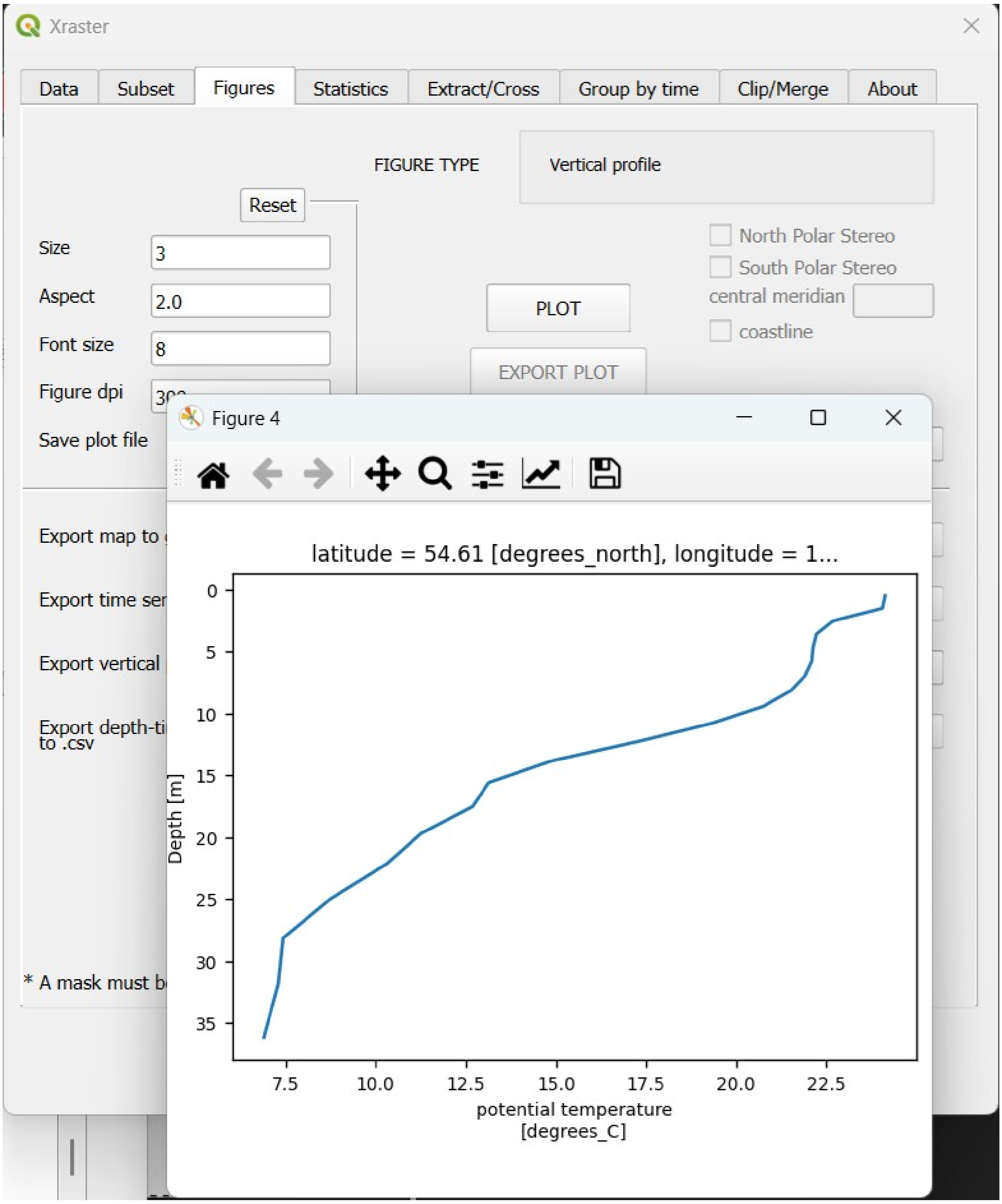


1.9 For this date, we will check the temperature profile at the point. Go to the **SUBSET** tab and enter the time — the format for entering it can be found on the panel.



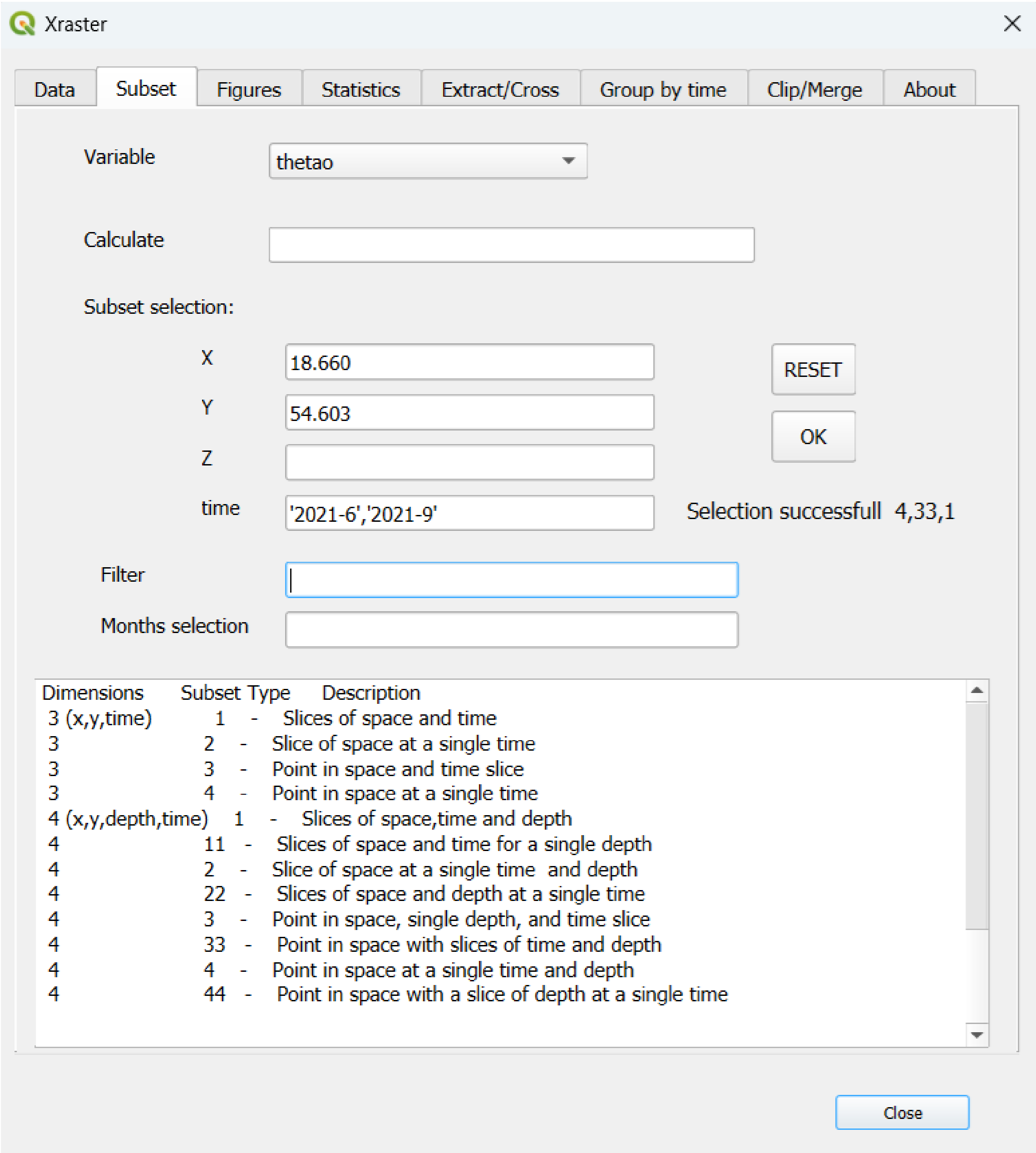
Type **44** means: *Point in space with a slice of depth at a single time*.

1.10 Go to the **FIGURES** tab. This data type allows visualization as a **Vertical profile**. You will get the vertical temperature distribution at the selected point on the specified day.

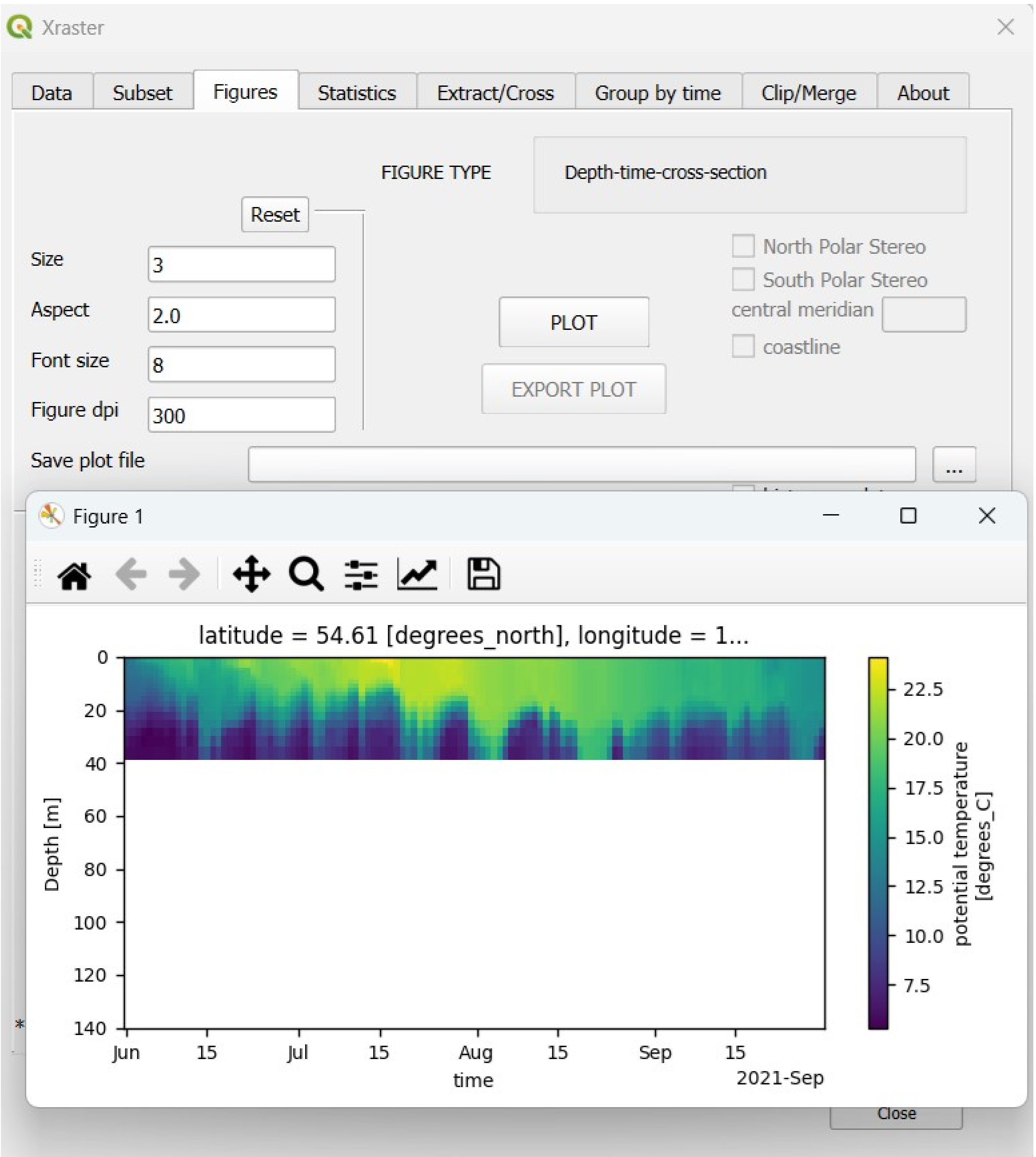


1.11 We will examine how temperature changes with depth at the selected point from June to September 2021. Go to the **SUBSET** tab and enter the time period (you can use only years and months). The filter and months can be kept or removed, as they do not affect the subset definition in this case.

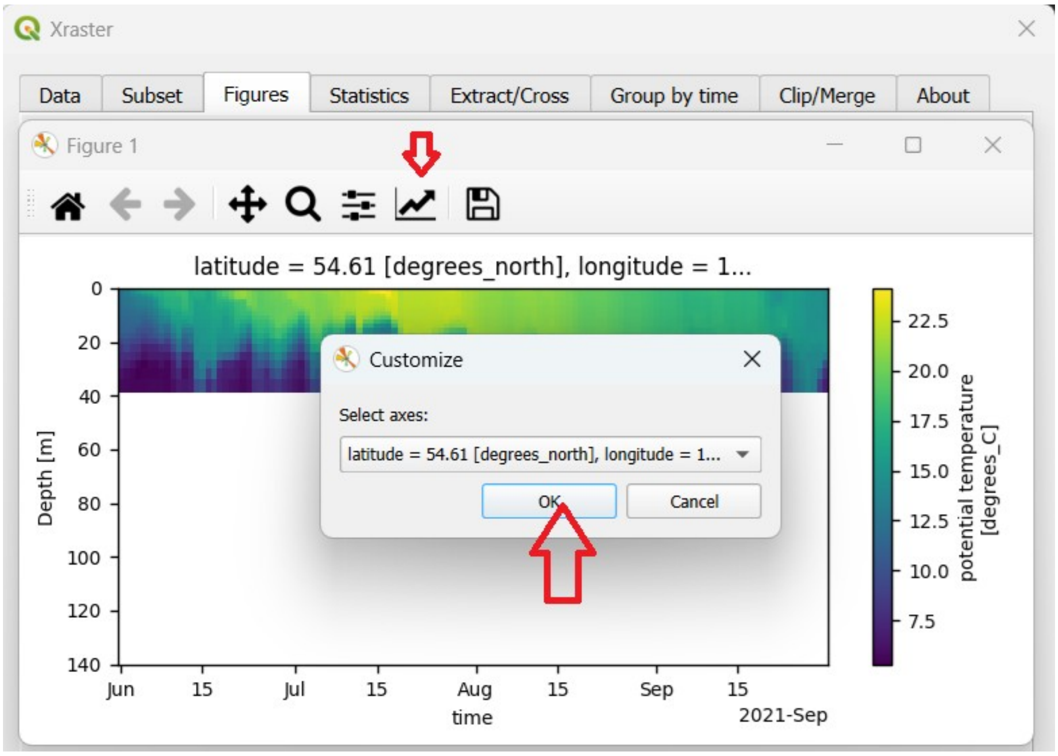
The resulting subset type will be **4,33,1**, which means: *Point in space with slices of time and depth*.



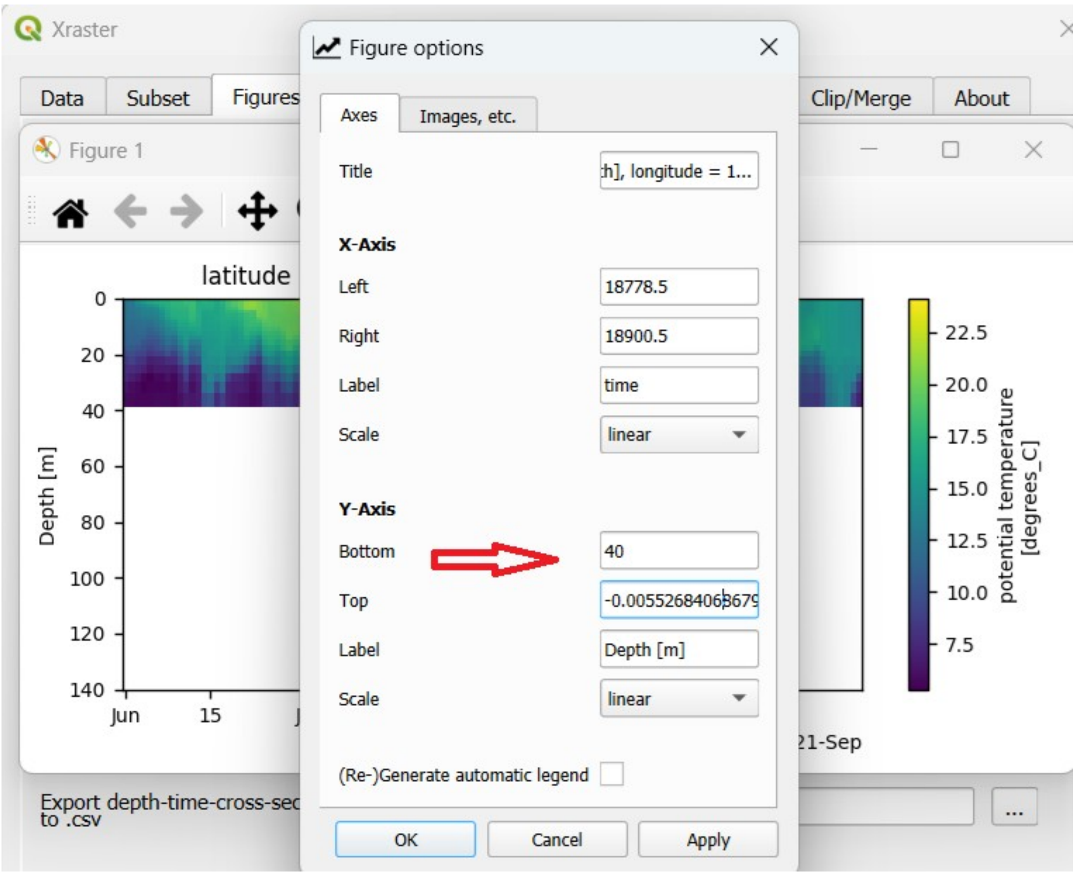
1.12 Go to the **FIGURES** tab. This subset type corresponds to a **Depth-time cross-section**. Click **PLOT**.



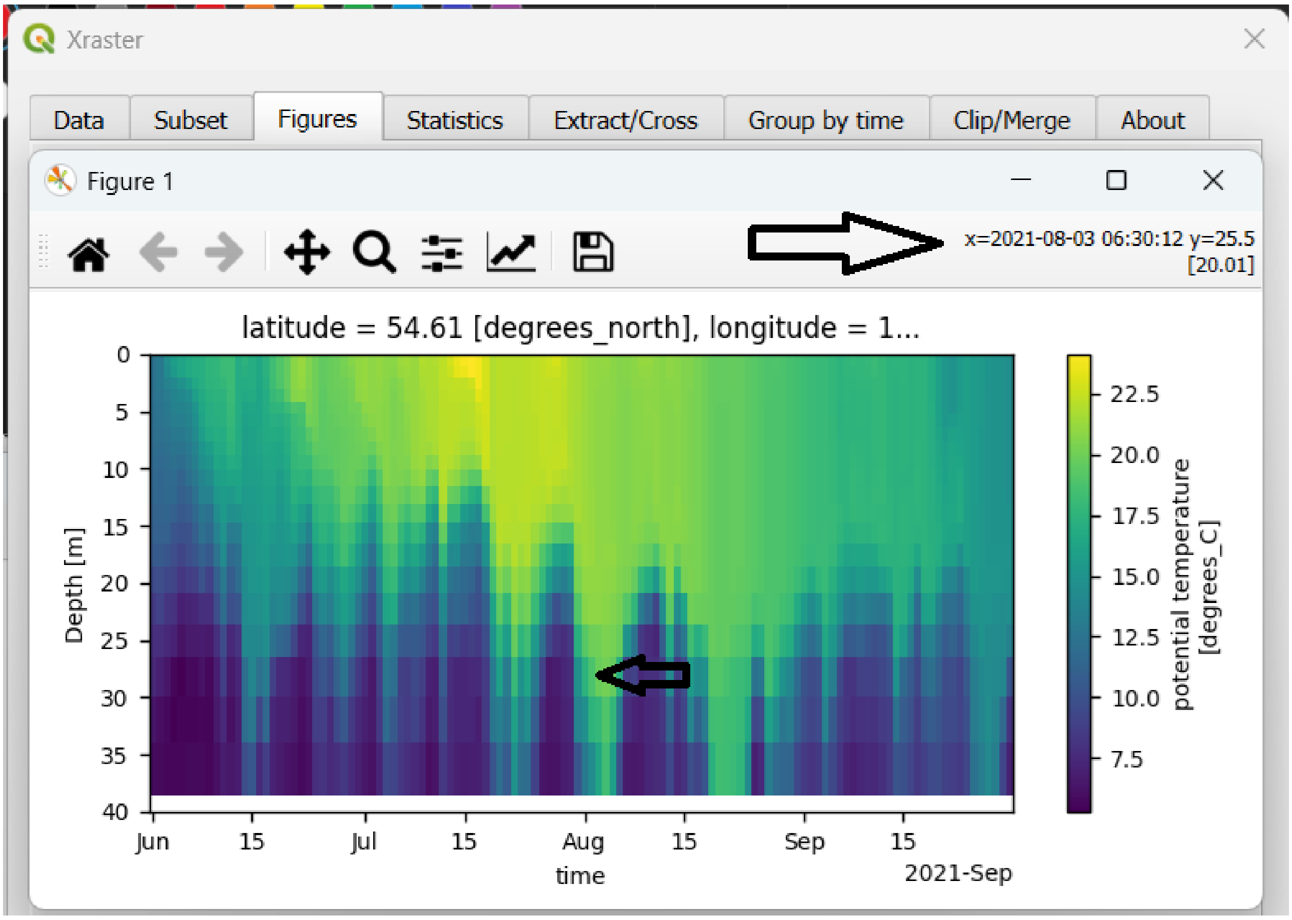
You can change the scale on the vertical axis by clicking the second-to-last icon on the chart. Then select the first option and click **OK**.



Change the maximum depth to 40 and click **OK**.



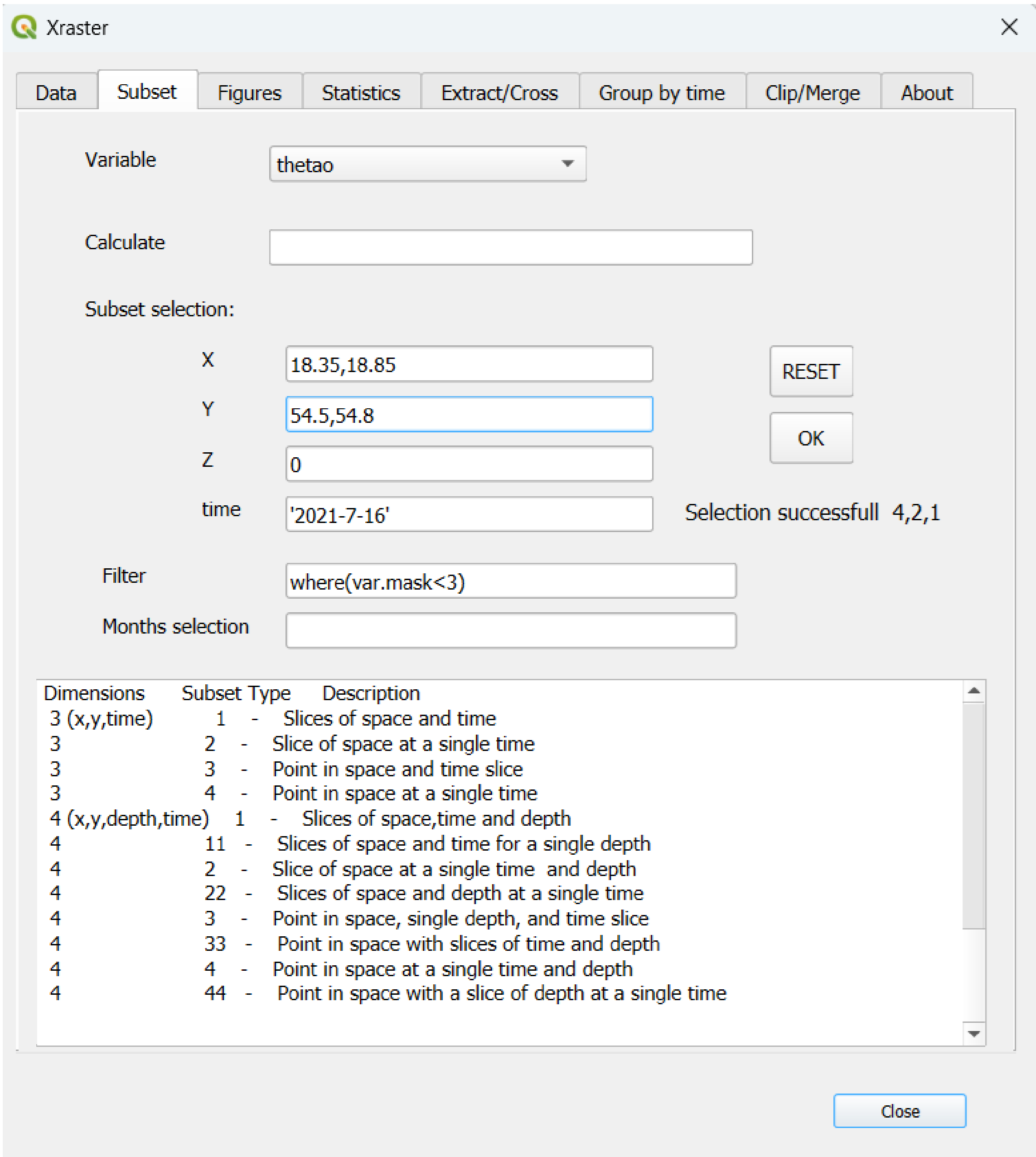
We get a chart where we can explore values by pointing to any spot with the cursor. The displayed information includes the date, depth, and variable value.



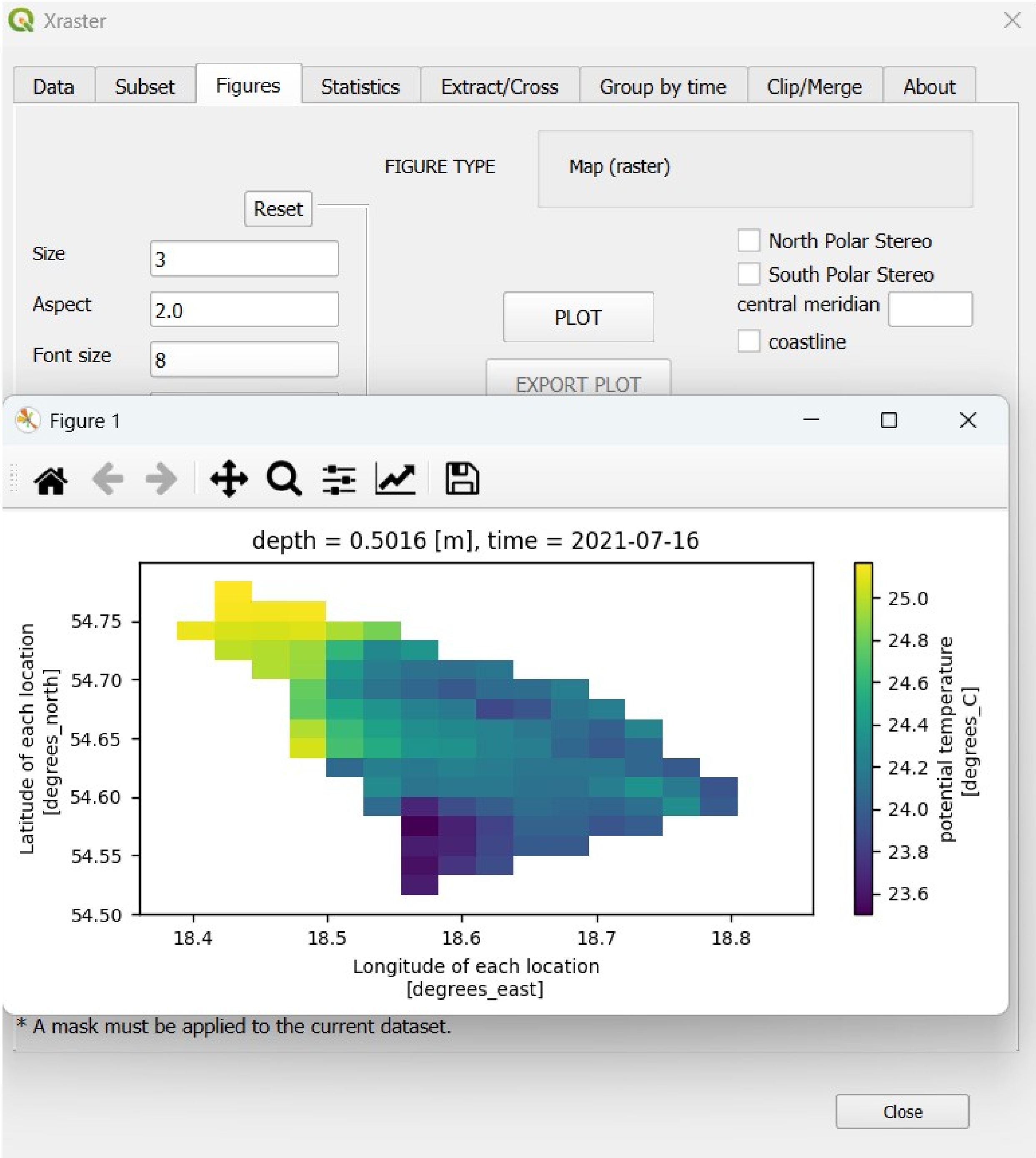
x

1.13 We will create a surface temperature distribution map for July 16, 2021. Go to the **SUBSET** tab and enter the date, depth zero, and coordinate ranges for the map (these can be noted by analyzing the mask). Click **OK**.

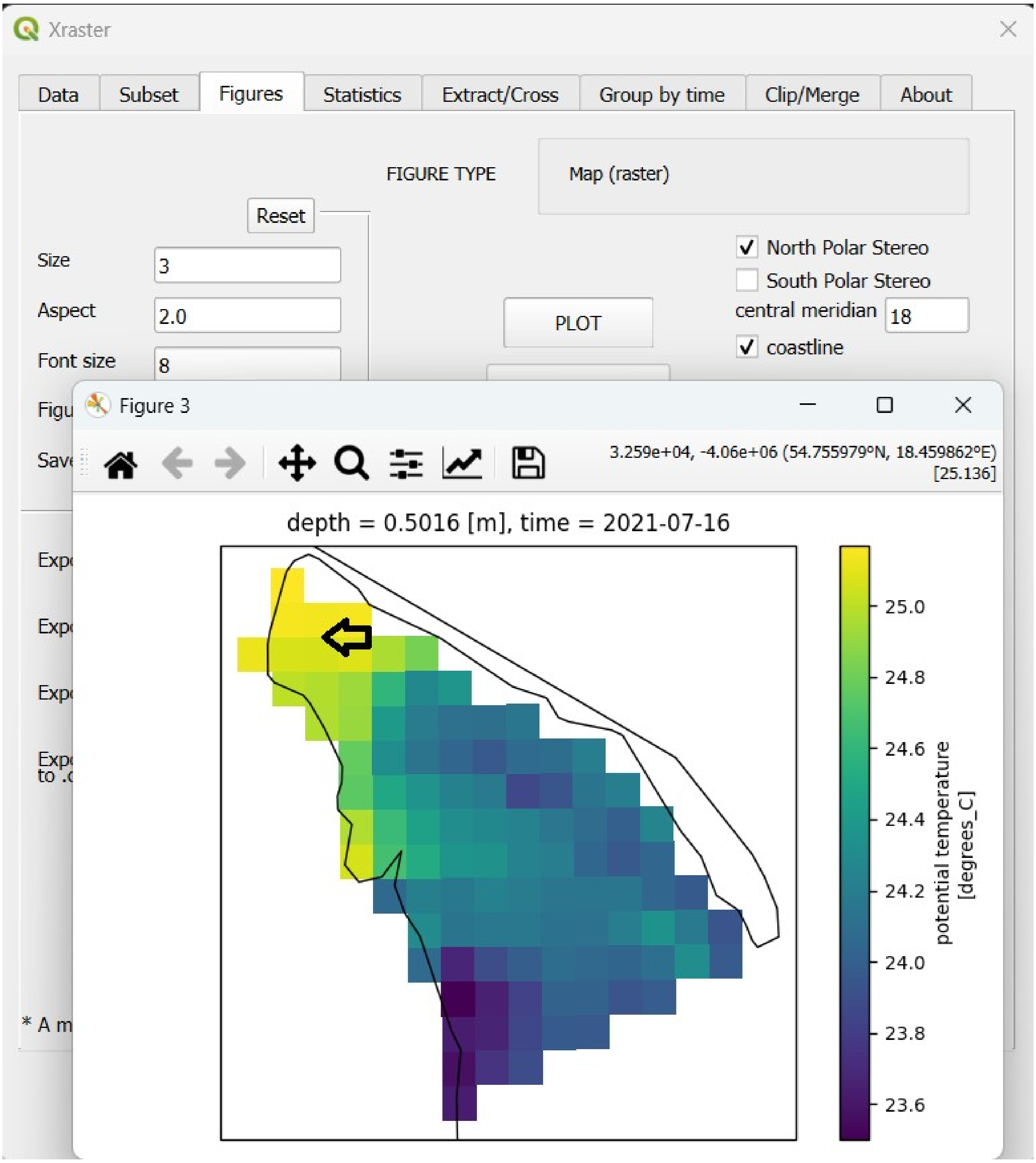
Type **2** means: *Slice of space at a single time and depth*.



1.14 Go to the **FIGURES** tab. This data type corresponds to a **map**. Click **PLOT**.



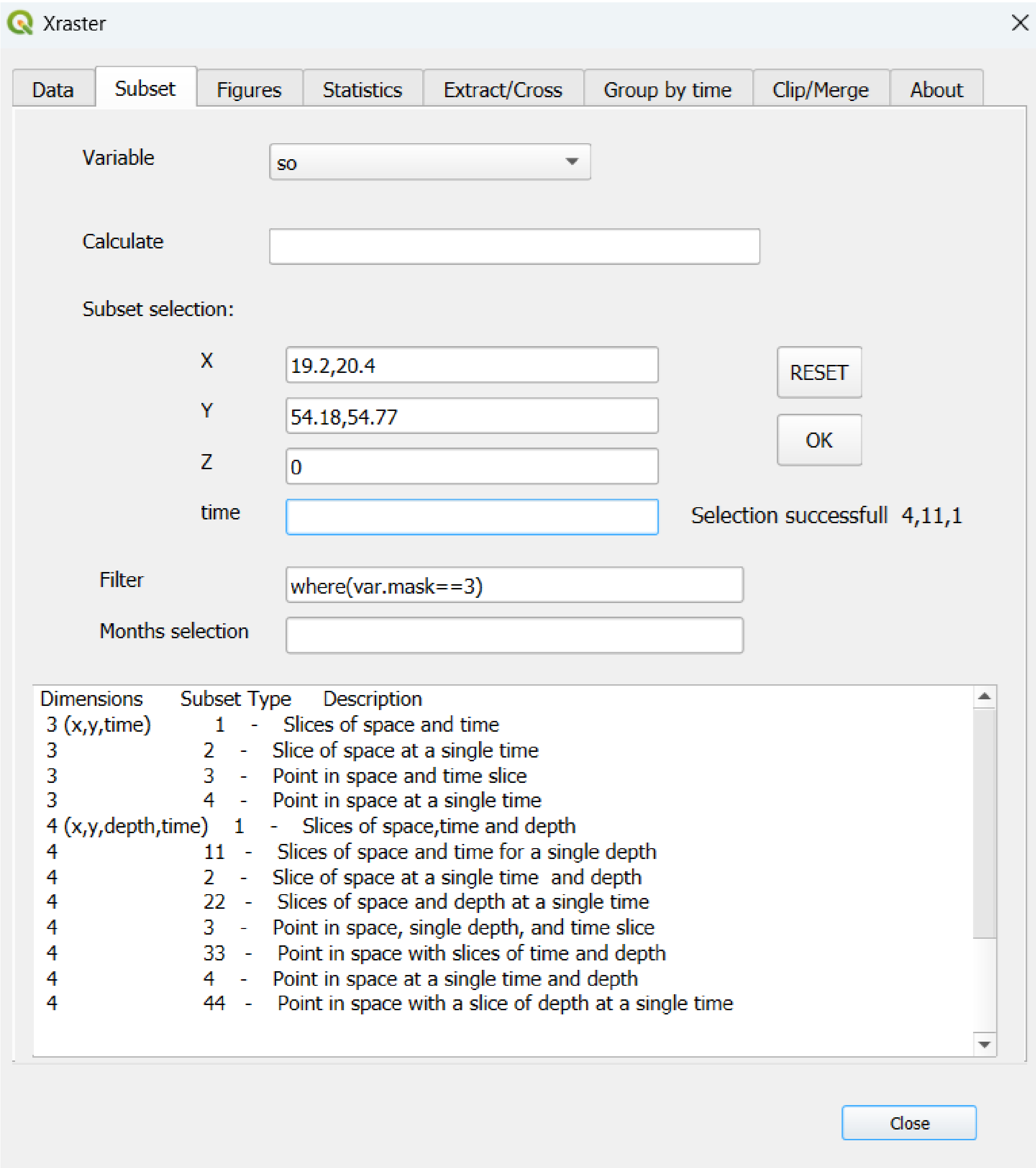
1.15 You can create the map by selecting the **North Polar Stereo** projection, checking the **coastline** option, and setting the central meridian to 18 degrees. As before, by hovering the cursor over a point on the map, you can read the coordinates and variable value.



2. Statistical analysis of the data

Statistical analysis can be conducted for areas (statistics for a given zone varying over time) and over time (statistics for each pixel over time). In GIS (ESRI) terminology, the first type corresponds to the Zonal Statistics operation (calculated for each point in time), and the second to Cell Statistics.

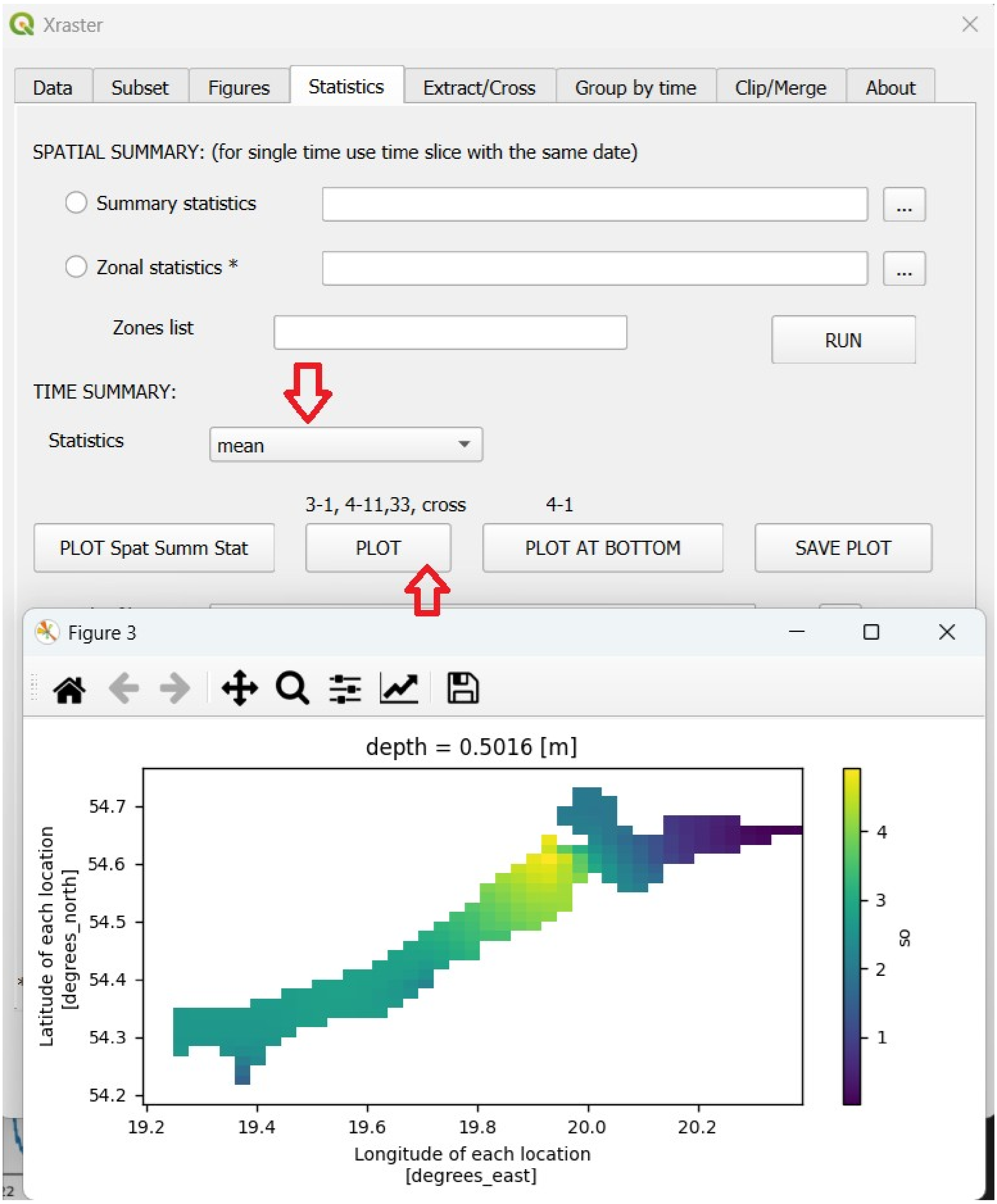
2.1 We'll calculate the mean salinity for the area marked with the mask identifier 3.
Go to **SUBSET** and define a data subset. To change the map extent that will be created in the next step, enter the bounding geographic coordinates for the chosen area.



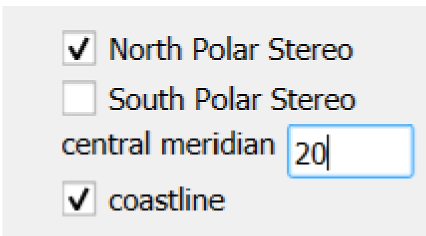
2.2 Next, open the **STATISTICS** tab, set **Statistics** to **Mean**, and click the **PLOT SPAT SUMM STAT** button (Spatial Summary Statistics).

The chart shows the changes in mean surface salinity calculated for the entire zone (ID = 3) day by day.

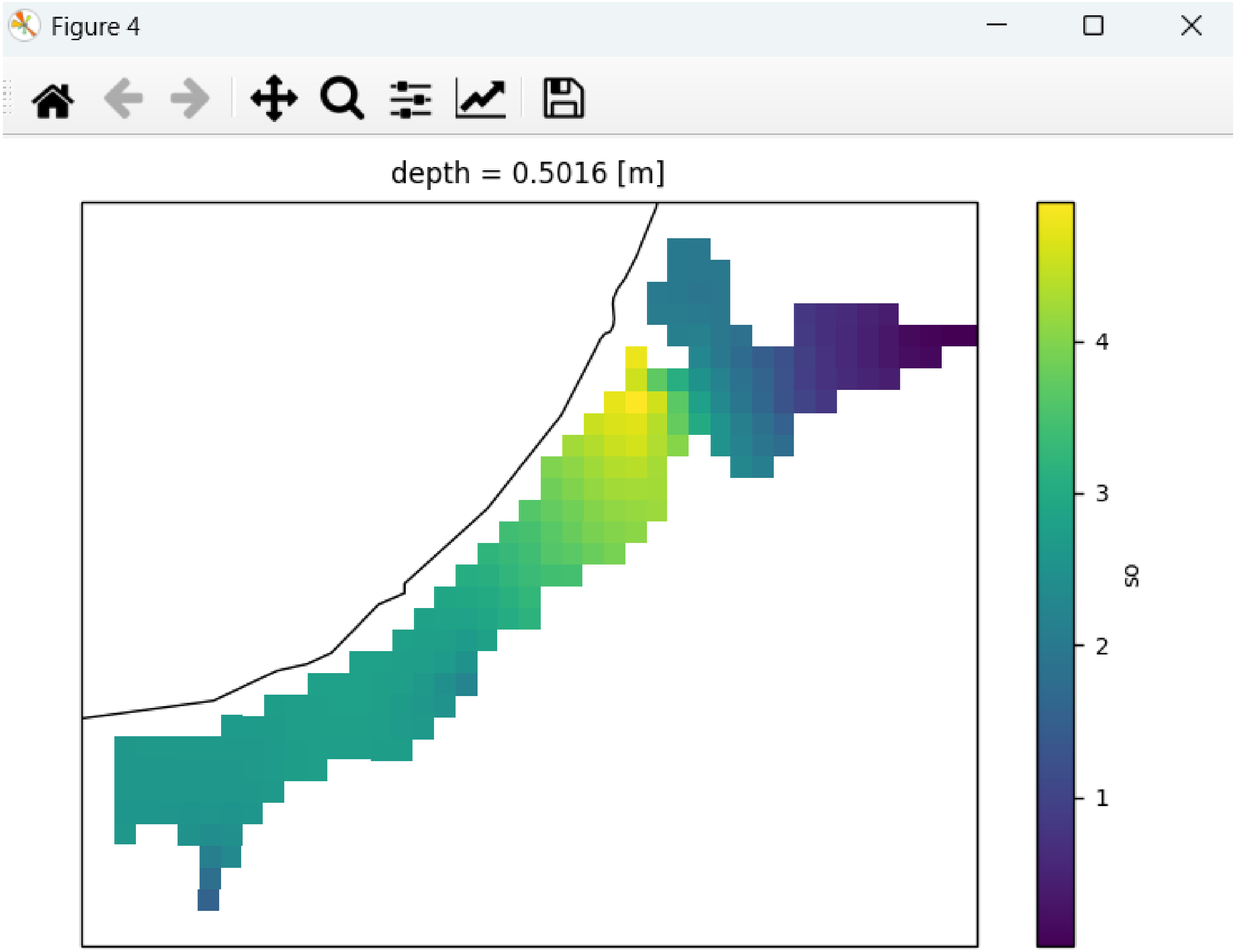
2.3 To create a map of mean salinity for the entire period (i.e., the average value at each pixel), simply click **PLOT**.



Analogously to the previous step, we can set the following in the **FIGURES** tab:

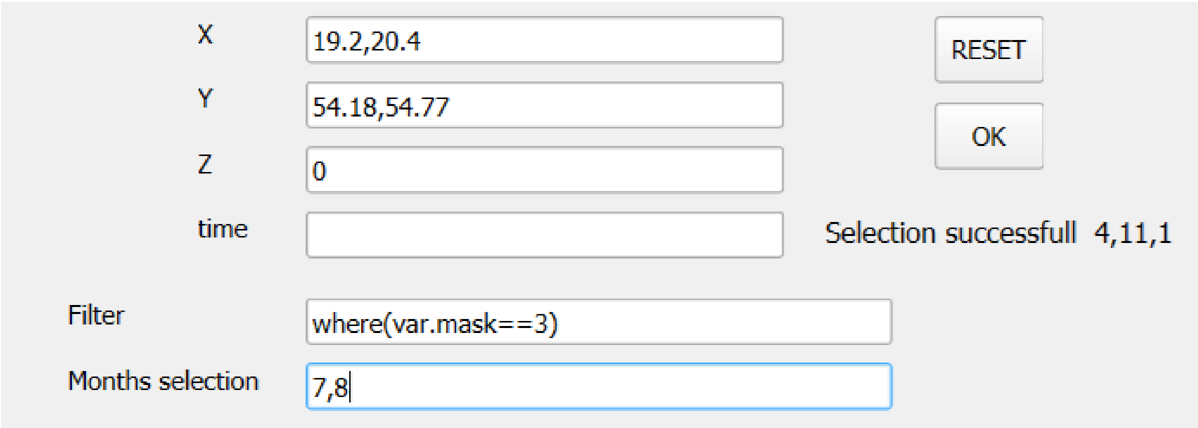


We will obtain a map in the form of:

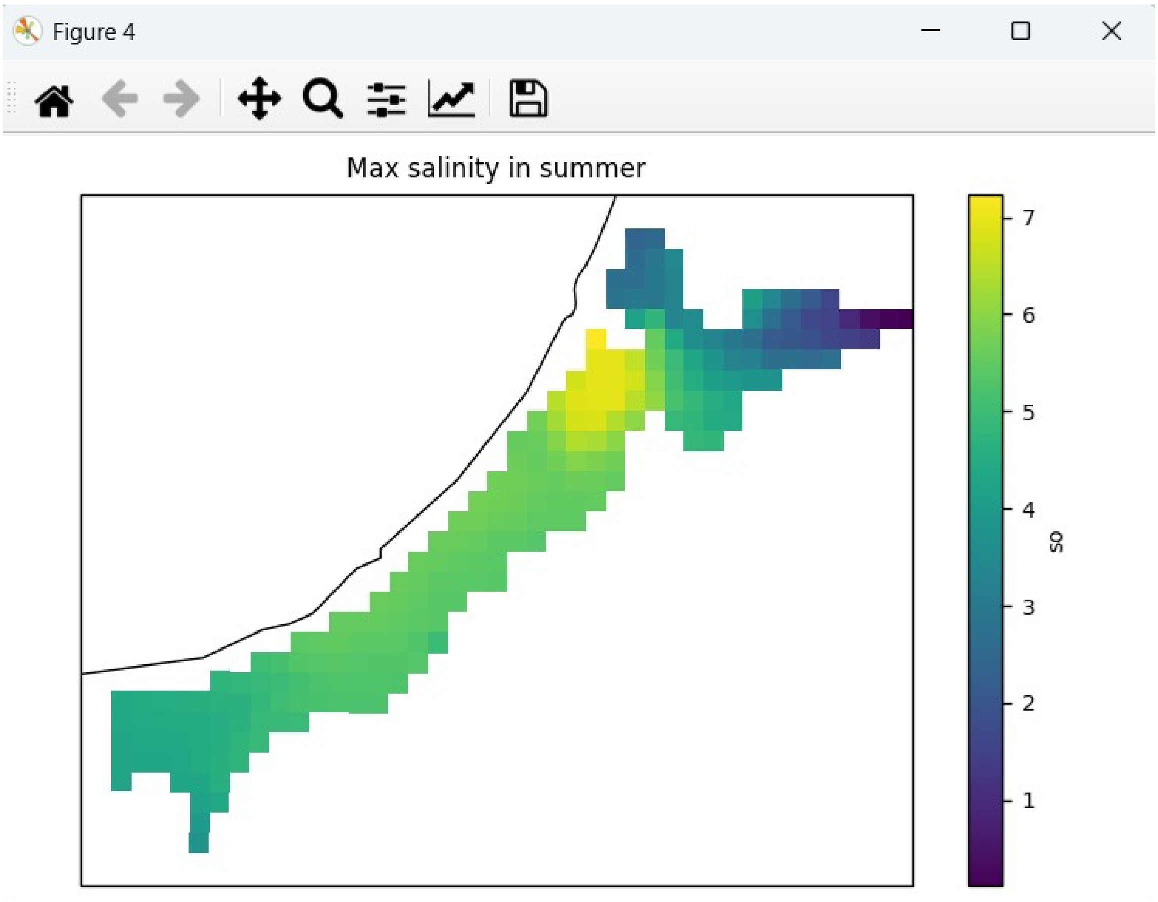


This is a map of mean salinity over the entire period.

2.4 To generate a map of maximum salinity in July and August over the entire study period, we modify the data subset in **SUBSET**.

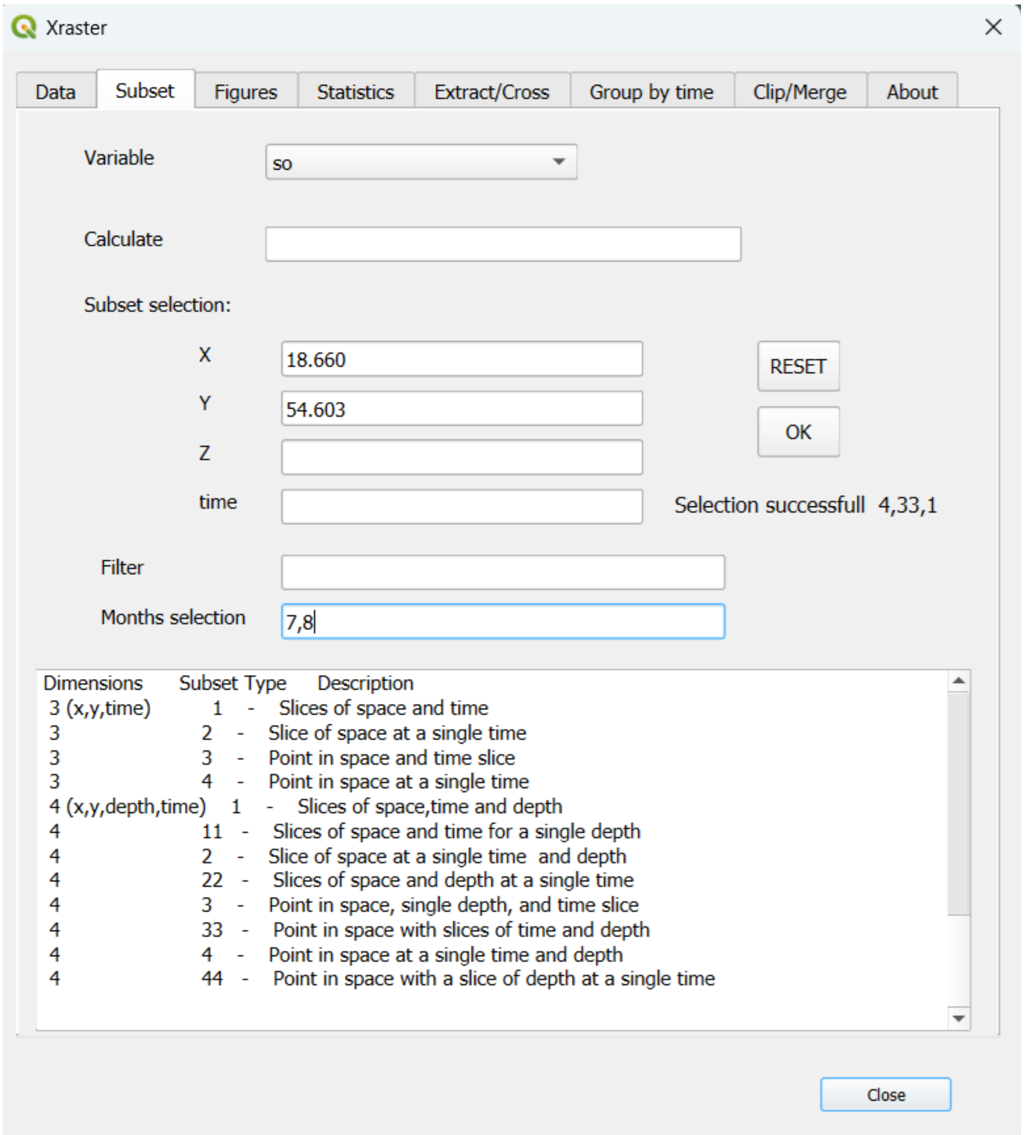


Then create the map the same way as before, but this time set the statistic to **Max** instead of **Mean**.

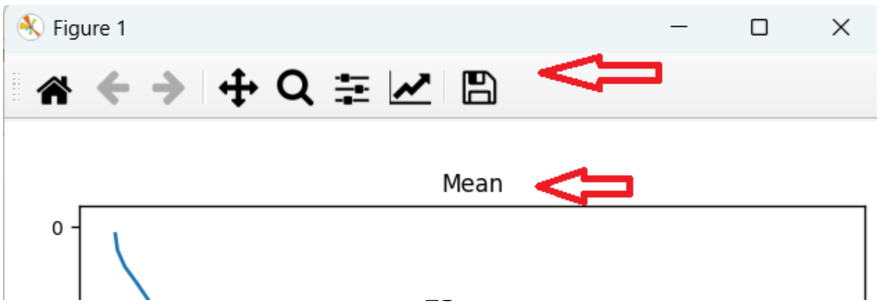


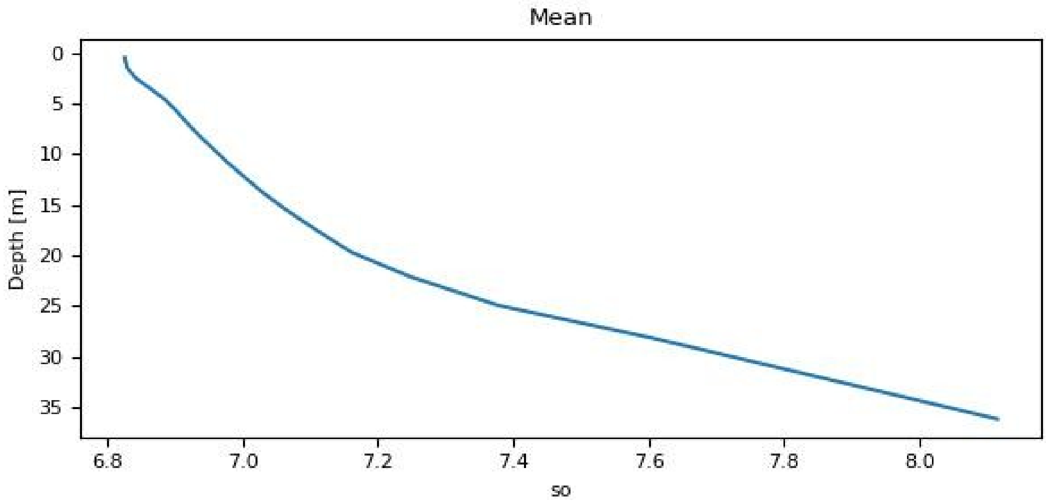
The title has been changed following the method shown in section 1.12.

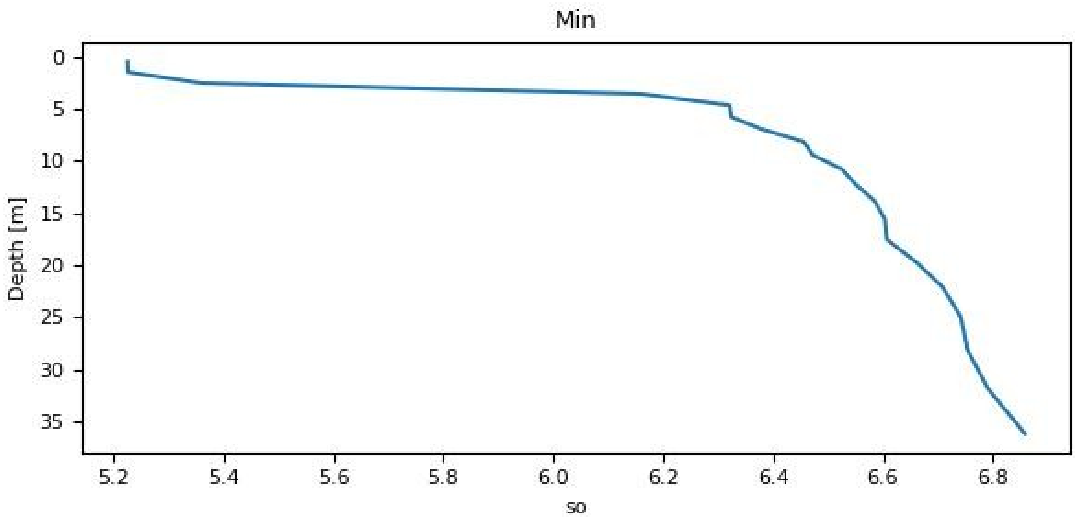
2.5 We can also determine the average (as well as minimum and maximum) vertical distribution of salinity at a previously defined point. We will limit the data subset to the summer months (July and August).
Create the subset in **SUBSET**. Type 33 refers to a *Point in space with slices of time and depth*. Statistics will be calculated separately for each depth level.



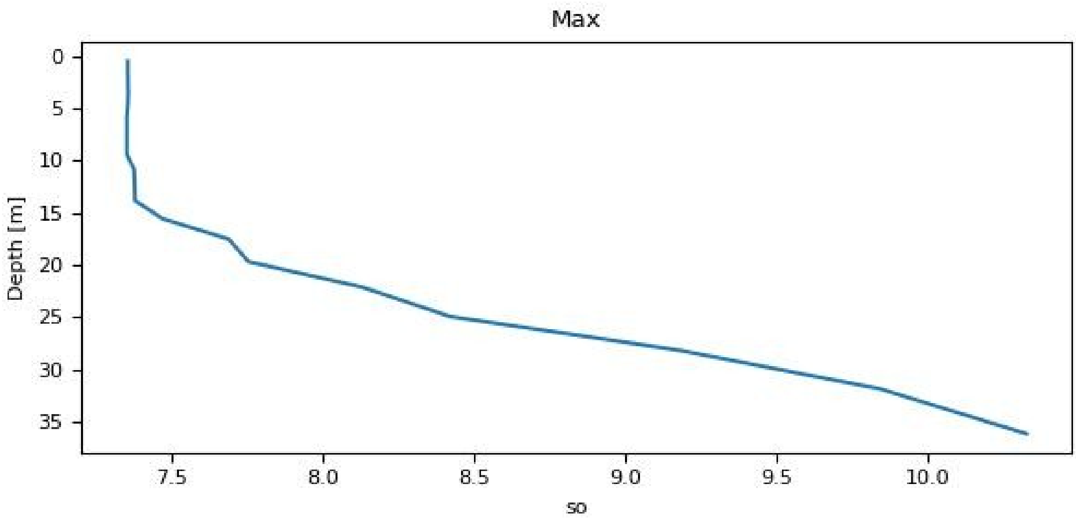
Go to **STATISTICS** and click **PLOT** for the three different statistics (mean, max, and min).
This time, the plots were saved as .jpg files by clicking the floppy disk icon. The titles of the figures were also changed.




Mean
Depth [m]
so
0
5
10
15
20
25
30
35
6.8
7.0
7.2
7.4
7.6
7.8
8.0


Min
Depth [m]
so
0
5
10
15
20
25
30
35
5.2
5.4
5.6
5.8
6.0
6.2
6.4
6.6
6.8

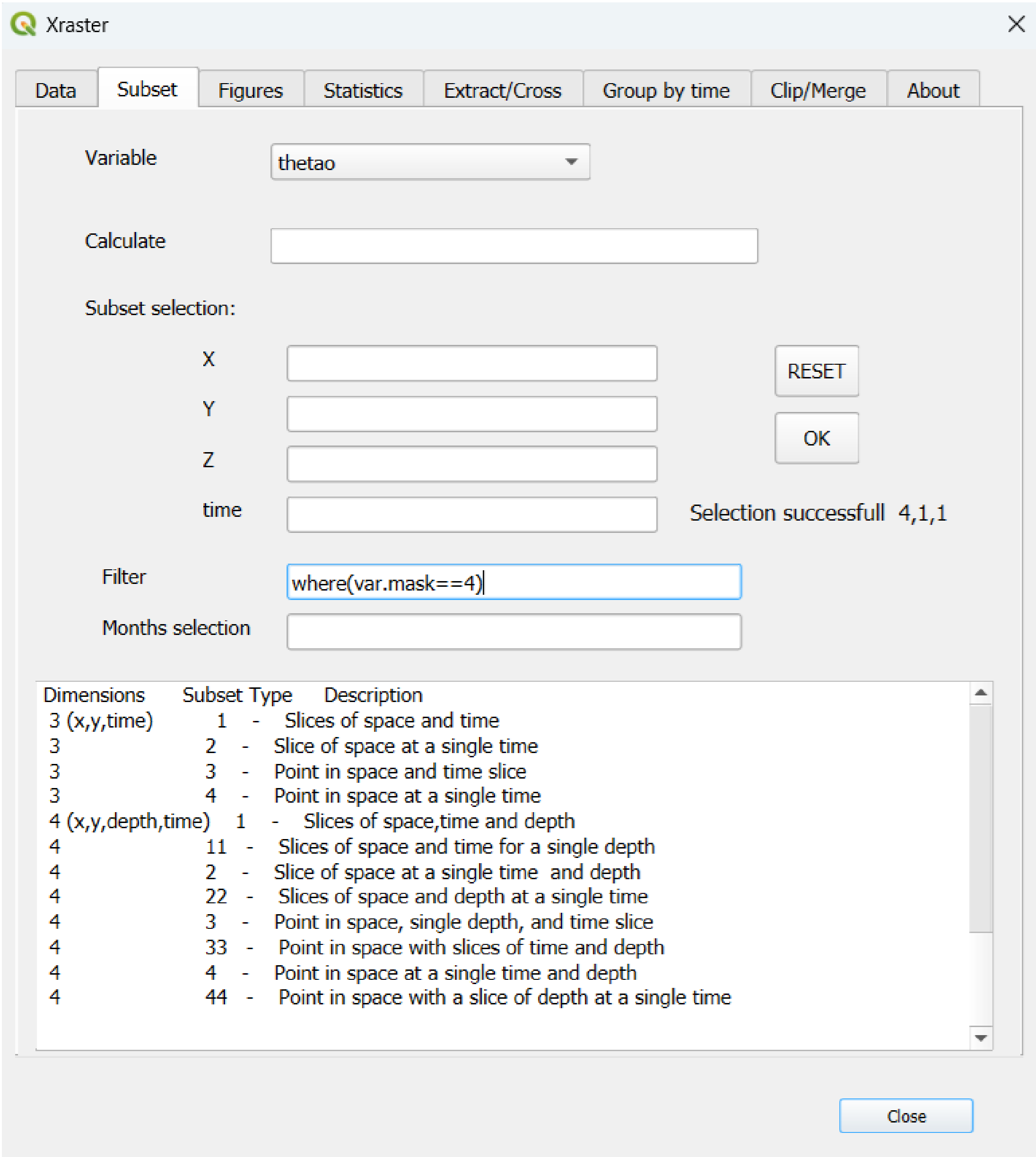
x


Max
Depth [m]
so
0
5
10
15
20
25
30
35
7.5
8.0
8.5
9.0
9.5
10.0

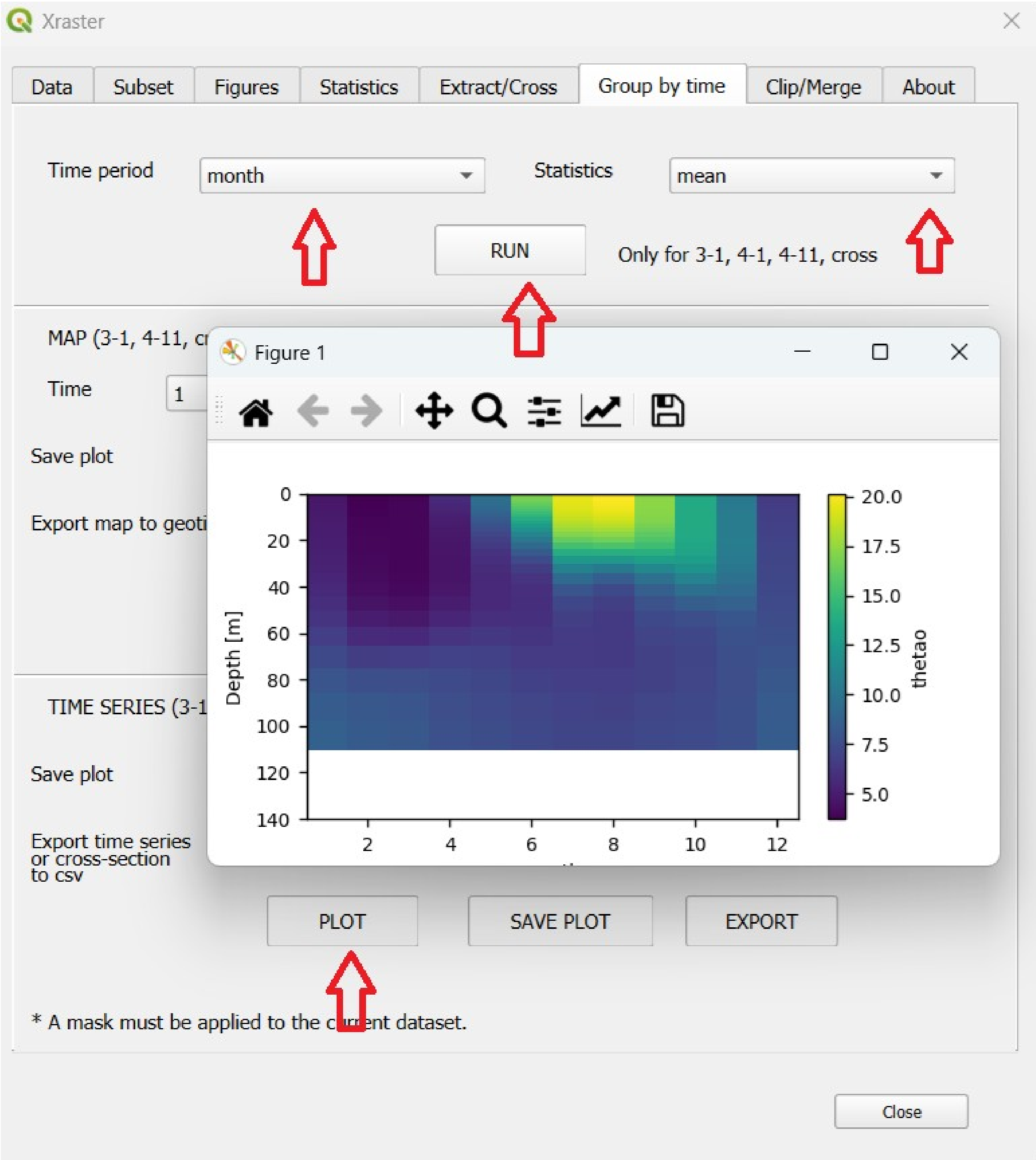
3. Data analysis using grouping

Grouping divides the data into groups defined by a **Time period** (e.g., by months), and then calculates statistics separately for each group. These statistics are then combined and visualized as a **time series** or a **depth-time cross-section**. The statistics calculated for individual groups can also be analyzed (this can be done using **STATISTICS**, but each time a separate data subset needs to be created).

3.1 We will determine the average temperature distribution for individual months at various depths. This distribution is created for the complete dataset, limited to the zone with identifier 4 in **SUBSET**.

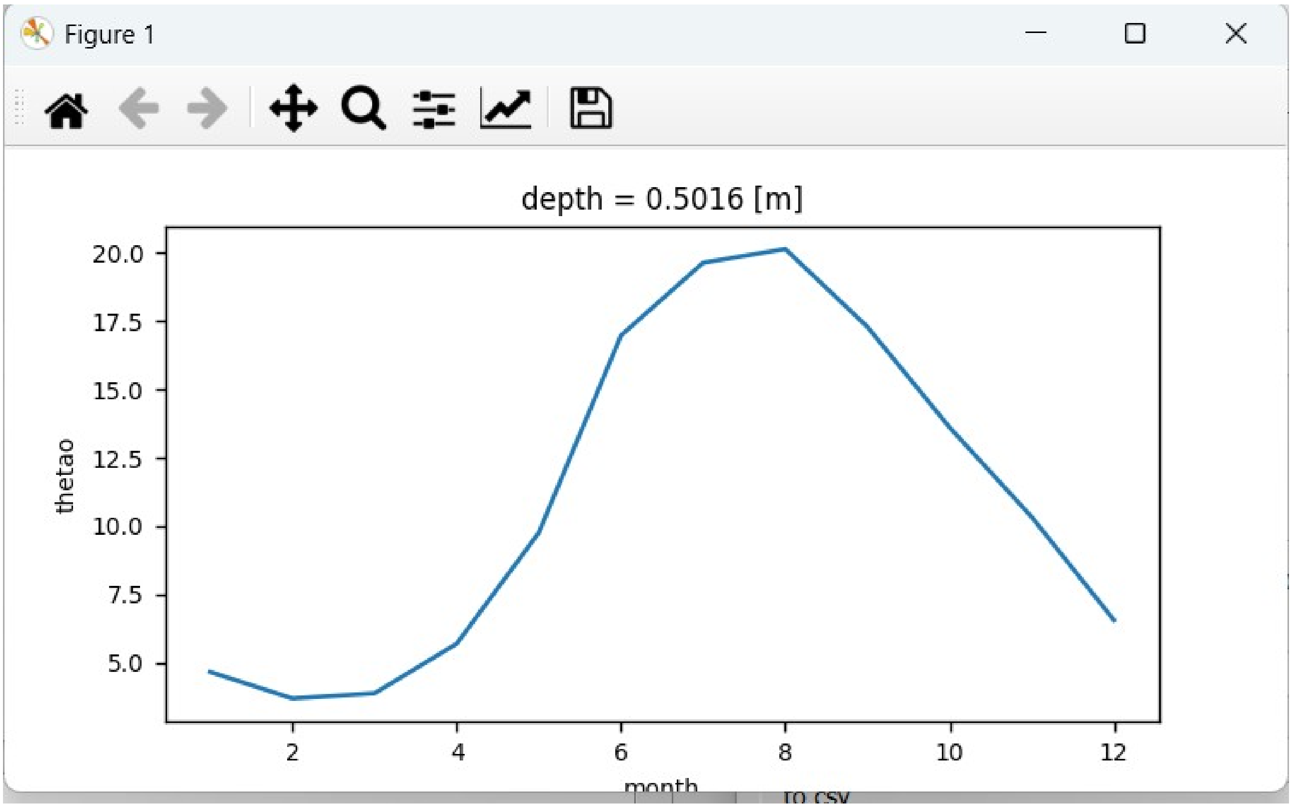


3.2 Go to the **Group by time** tab, set **Time period** to *month* and **Statistics** to *mean*. Click **RUN**, then click **PLOT**. A **depth-time cross-section** plot is generated, showing the statistics calculated for each month and each depth.



We will now modify the data subset by limiting it to a depth of zero (the water surface).

3.3 We perform the same steps in the **Group by time** tab and obtain the average temperature values for each month in the form of a **time series**.



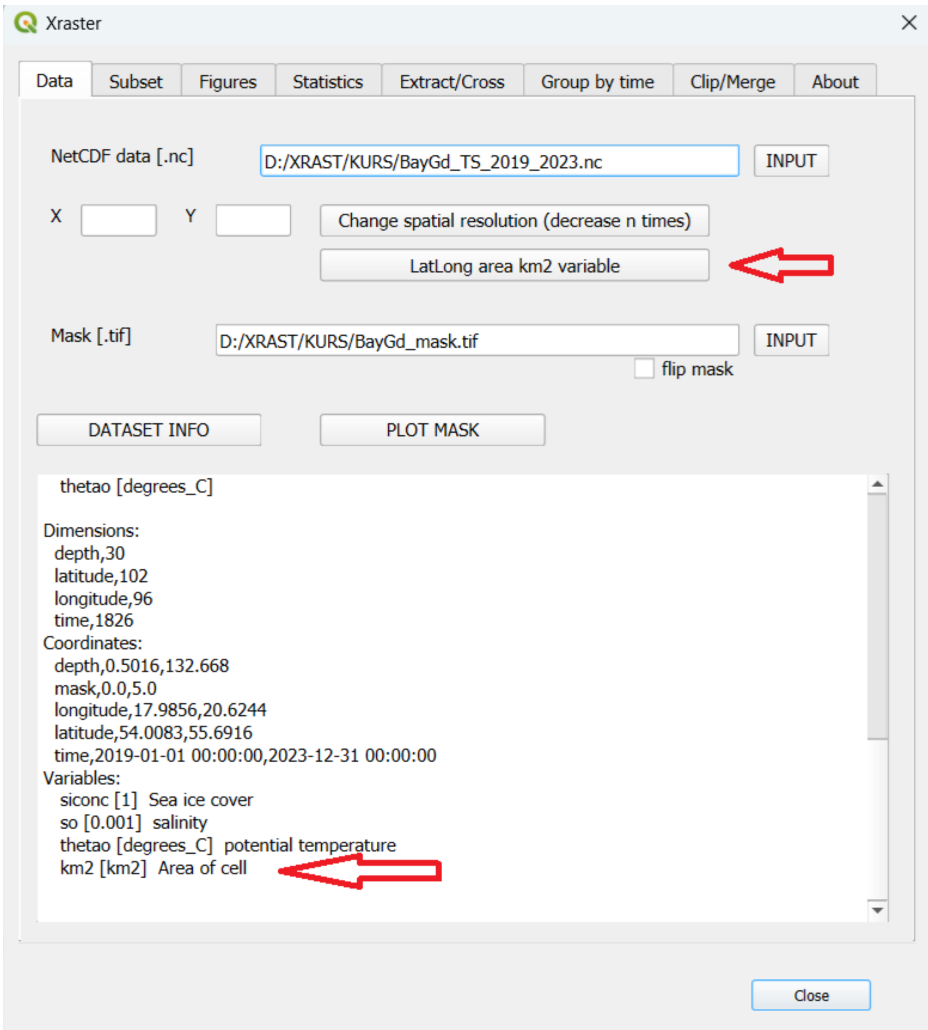
4. Calculation of ice cover area.

The sea ice fraction of a given raster cell is defined by values ranging from 0 (no ice) to 1 (complete ice cover). Therefore, the ice-covered area of a cell can be calculated as the product of the **sea ice fraction** and the **cell area**. To determine the total ice-covered area of a waterbody, the ice-covered areas of all cells need to be summed.

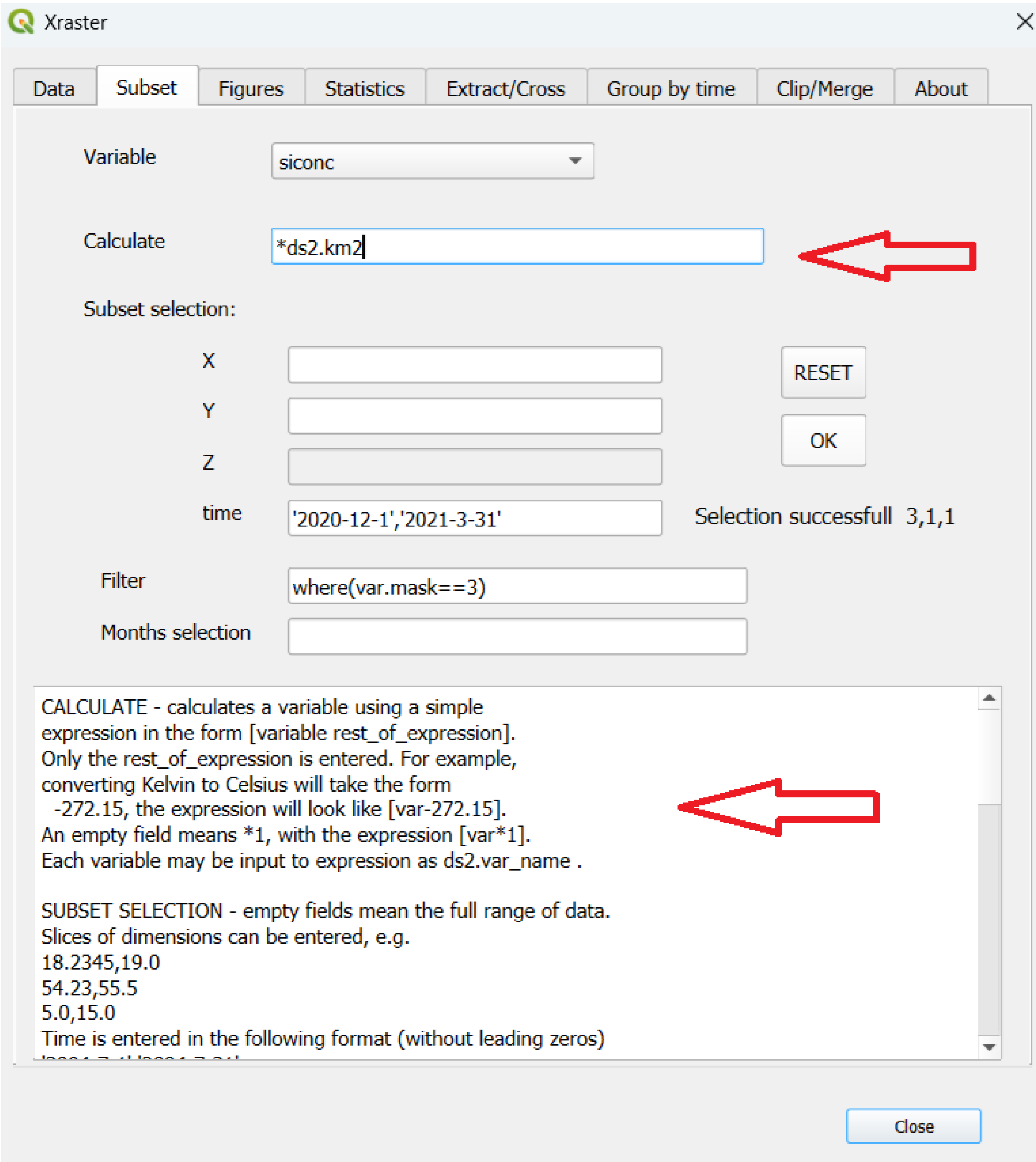
The task will be to calculate how the ice-covered area changed during the **winter of 2020/2021**. For this purpose, we will need a variable representing the surface area of each cell in the two-dimensional raster of the study area.

- In the case of data in **geographic coordinates**, a special variable that represents the cell area in km² can be used.
- In the case of **projected (rectangular) coordinates**, the cell area is constant or can be assumed to be constant.

4.1 Go to the **Data** tab and click the **LatLong area km² variable** button. If you then click on **DATASET INFO**, you will see that an additional variable named **km2** has been created, described as *Area of cell*, with the unit **km²**.



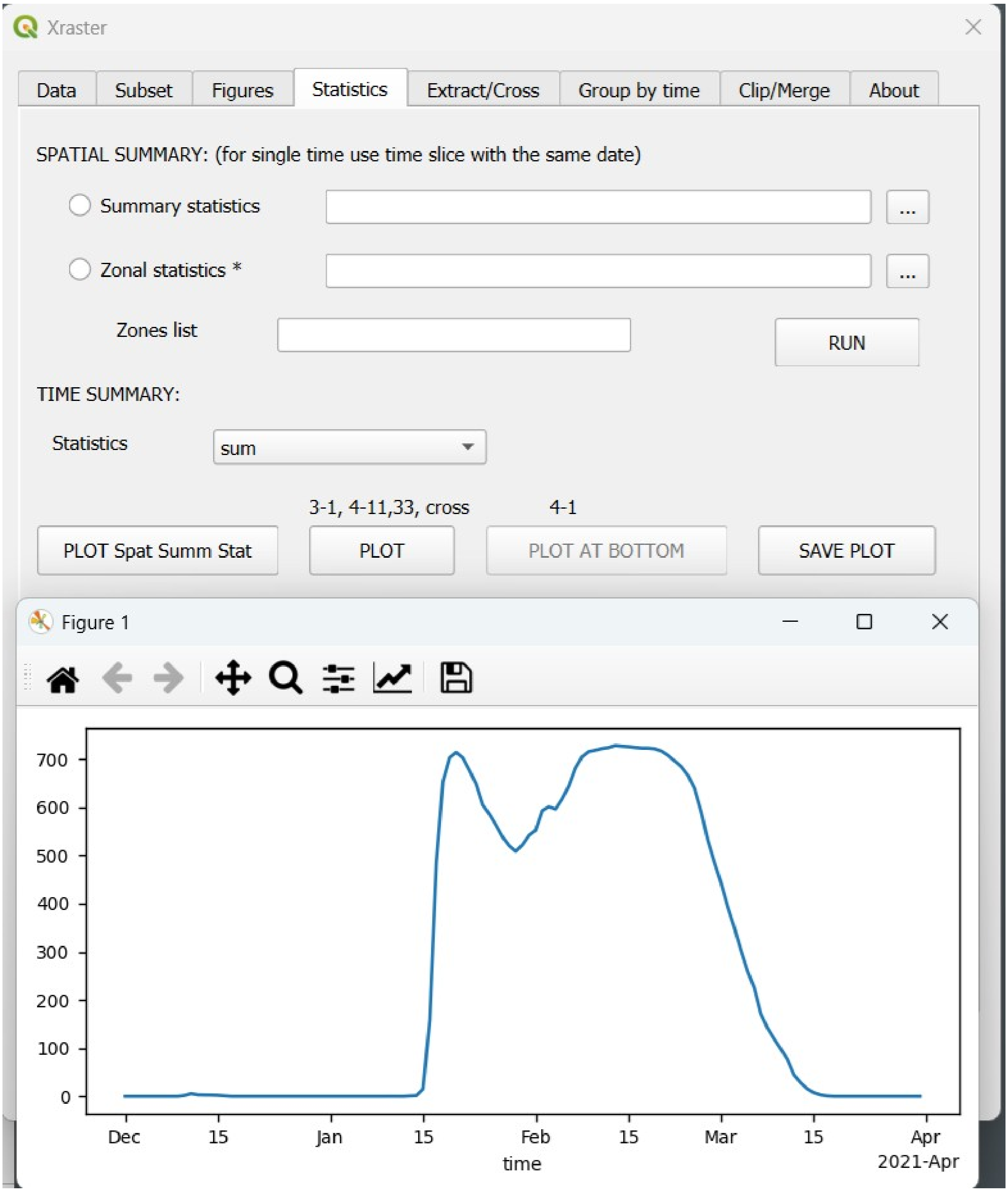
4.2 Go to the SUBSET tab and select the variable siconc (the km2 variable is not visible, but it can be accessed using the expression `ds2.km2` in the Calculate field).
Enter the expression `var * ds2.km2` as instructed in the panel (with **`*ds2.km2`** indicating multiplication by the cell area).



The filter limits the data to **zone 3**, and the **time range** is restricted to the period from **December 2020 to March 2021**. The type **3,1,1** indicates **three-dimensional data** – a *slice of space and time*. The final **1** indicates the presence of a **mask**.

We will now perform a **summation over all cells** in **zone 3** for **each time point**. This will give us the total **ice-covered area** in zone 3 over time during the winter of 2020/2021.

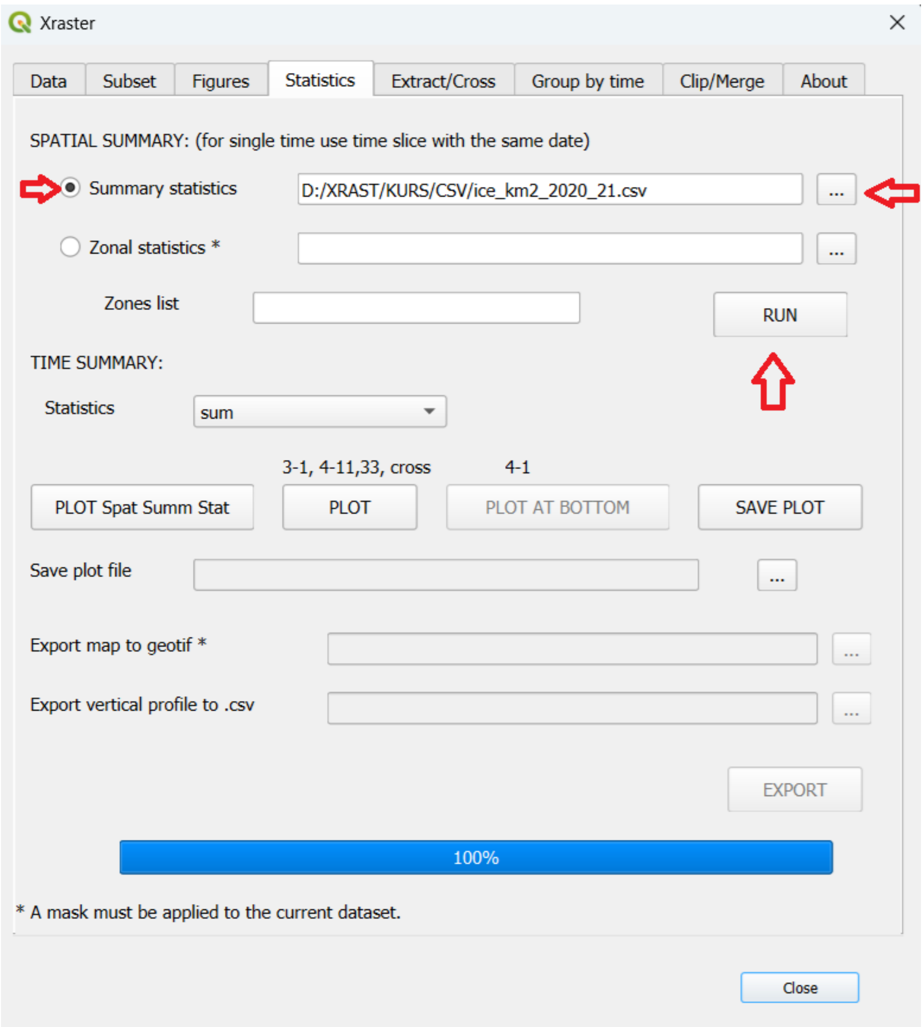
4.3 Go to the STATISTICS tab (TIME SUMMARY), set Statistics to *sum*, and click PLOT Spat Summ Stat. This will generate a plot showing the total ice-covered area over time, summed across all cells in zone 3.



We obtain a plot of ice cover for the selected area in square kilometers. It is easy to see that the maximum ice coverage occurred around February 12, reaching approximately 730 km².

The data from the plot can be saved as a text file using the SPATIAL SUMMARY option (Summary statistics).

4.4 We save the data from the plot as a text file using Summary statistics from the same tab. Check the Summary Statistics option, enter the desired file name, and click RUN.



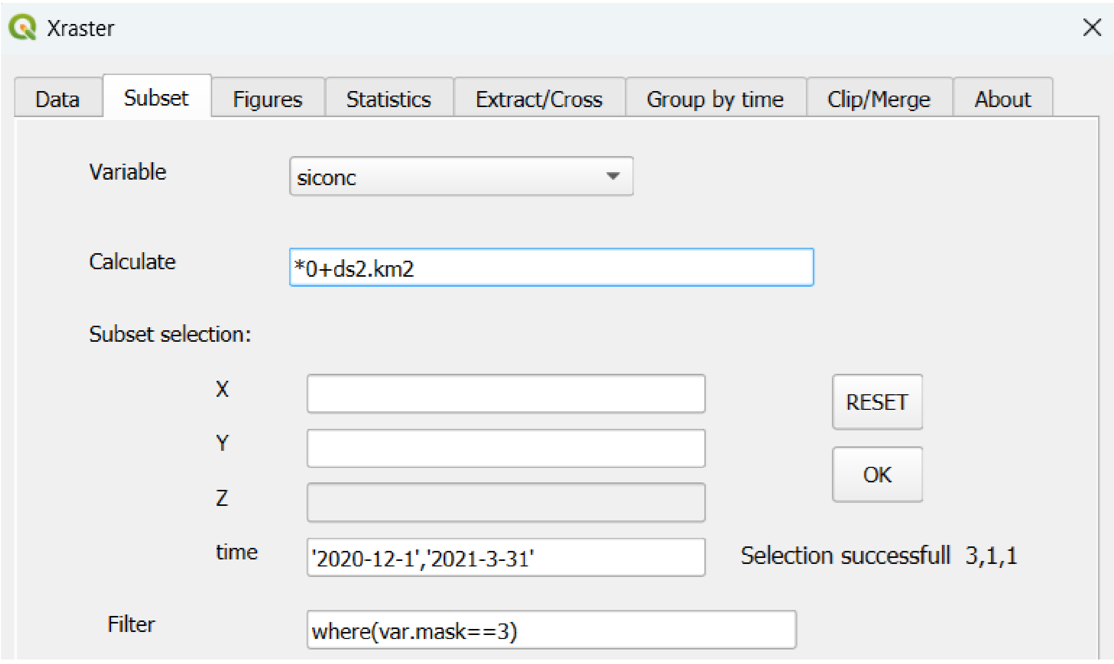
The resulting text file contains the SUM statistic and allows you to precisely identify when the maximum value occurred (a snippet of the resulting file is shown).

time,mean,min,max,median,std,sum
....
2021-02-10 00:00:00,3.1932,0.0,3.3319,3.2882,0.3672, 718.47
2021-02-11 00:00:00,3.2089,0.0,3.3315,3.2942,0.3728, 722.01
2021-02-12 00:00:00,3.2175,0.0,3.3348,3.2966,0.3798, 723.95
2021-02-13 00:00:00,3.2372,0.0,3.3339,3.3097,0.382, 728.36
2021-02-14 00:00:00,3.2313,0.0,3.3299,3.3097,0.4151, 727.05
2021-02-15 00:00:00,3.2264,0.0,3.319,3.3062,0.4202, 725.93
2021-02-16 00:00:00,3.2191,0.0,3.3159,3.3033,0.424, 724.31
2021-02-17 00:00:00,3.2133,0.0,3.3138,3.2997,0.4321, 723.0
....

It is clear that the maximum value occurred on February 13 and amounted to 728.36 square kilometers.

If we want to obtain ice coverage values in percent, we need the total surface area of zone 3.
We modify the expression so that the data represents the area of each cell.
To do this, we set the initial variable to 0 and add the cell area value to it.

4.5 In the SUBSET tab, enter the expression **`var*0+ ds2.km2`** according to the instructions on the panel as **`*0+ds2.km2`**, and click OK.

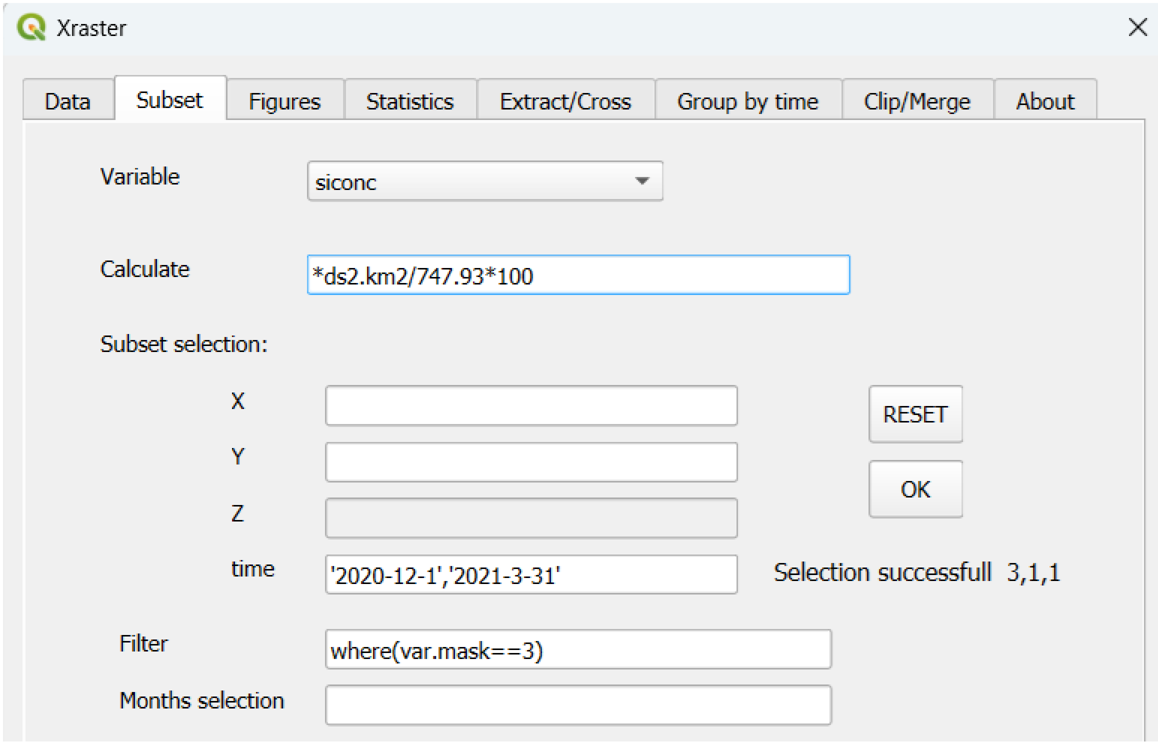


Next, perform the operation as before, changing the file name, all dates, of course, give the same result.

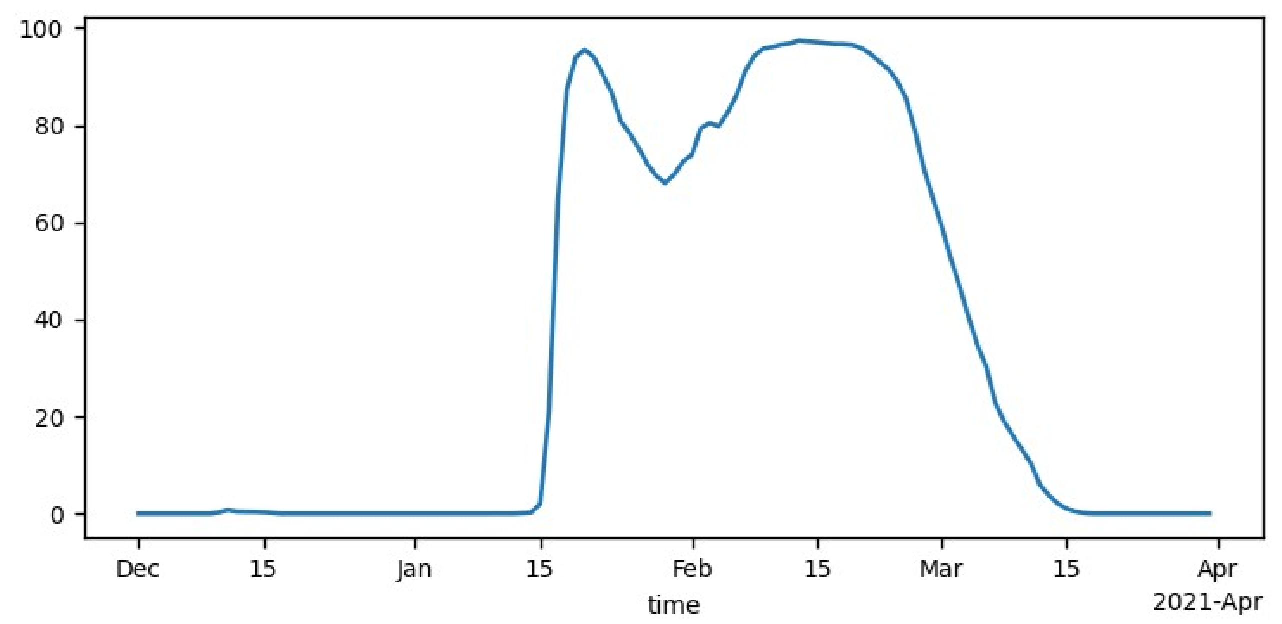
time,mean,min,max,median,std,sum
2020-12-01 00:00:00,3.3241,3.3052,3.3451,3.3228,0.0109, 747.93
2020-12-02 00:00:00,3.3241,3.3052,3.3451,3.3228,0.0109, 747.93
2020-12-03 00:00:00,3.3241,3.3052,3.3451,3.3228,0.0109, 747.93
2020-12-04 00:00:00,3.3241,3.3052,3.3451,3.3228,0.0109, 747.93
2020-12-05 00:00:00,3.3241,3.3052,3.3451,3.3228,0.0109, 747.93
2020-12-06 00:00:00,3.3241,3.3052,3.3451,3.3228,0.0109, 747.93

The area of zone 3 on our map is 747.93 km^2.

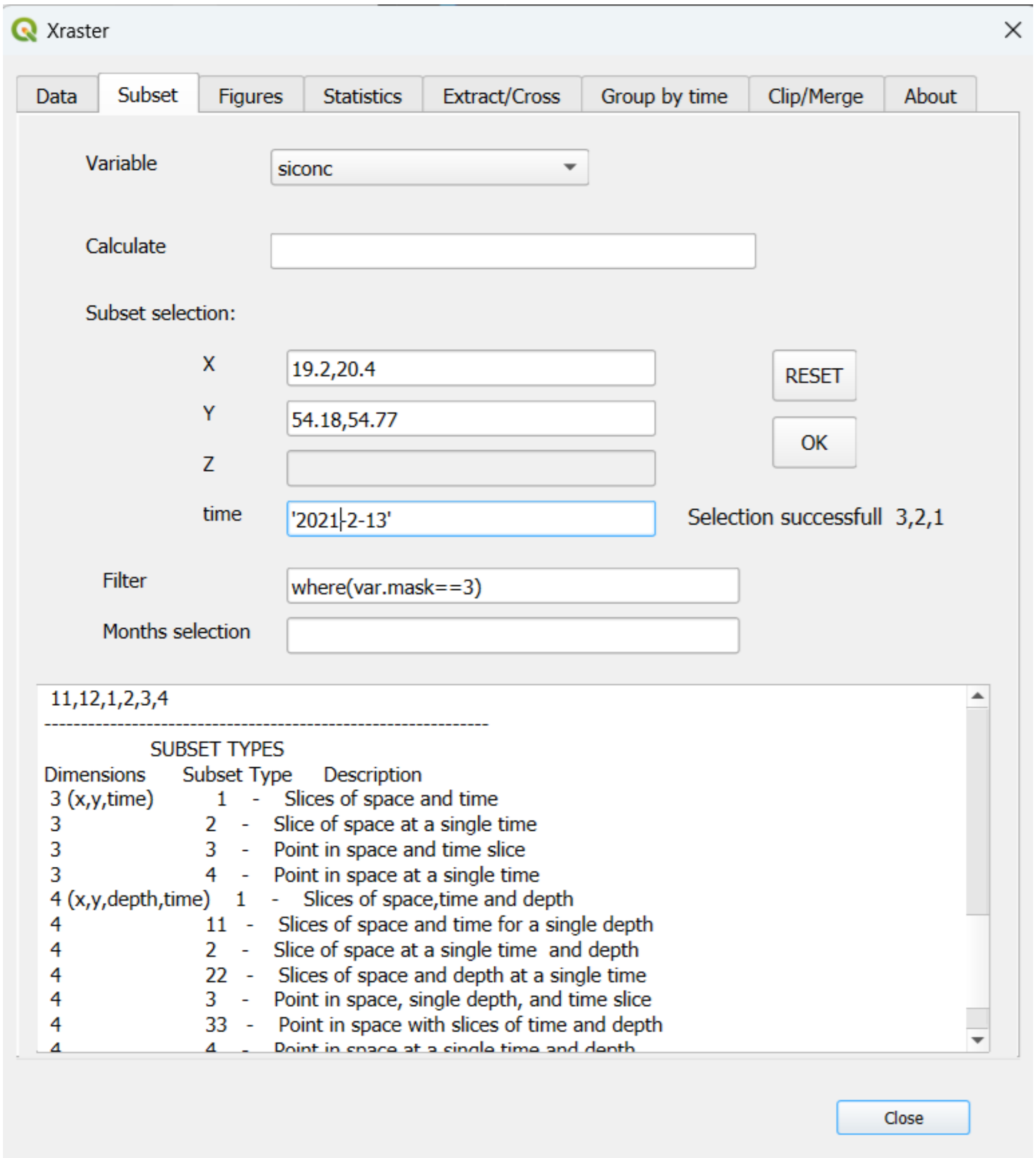
4.6 We change the expression in the SUBSET tab to the form:



and using an operation analogous to that in section 4.3, we will obtain a coverage map in percentages.

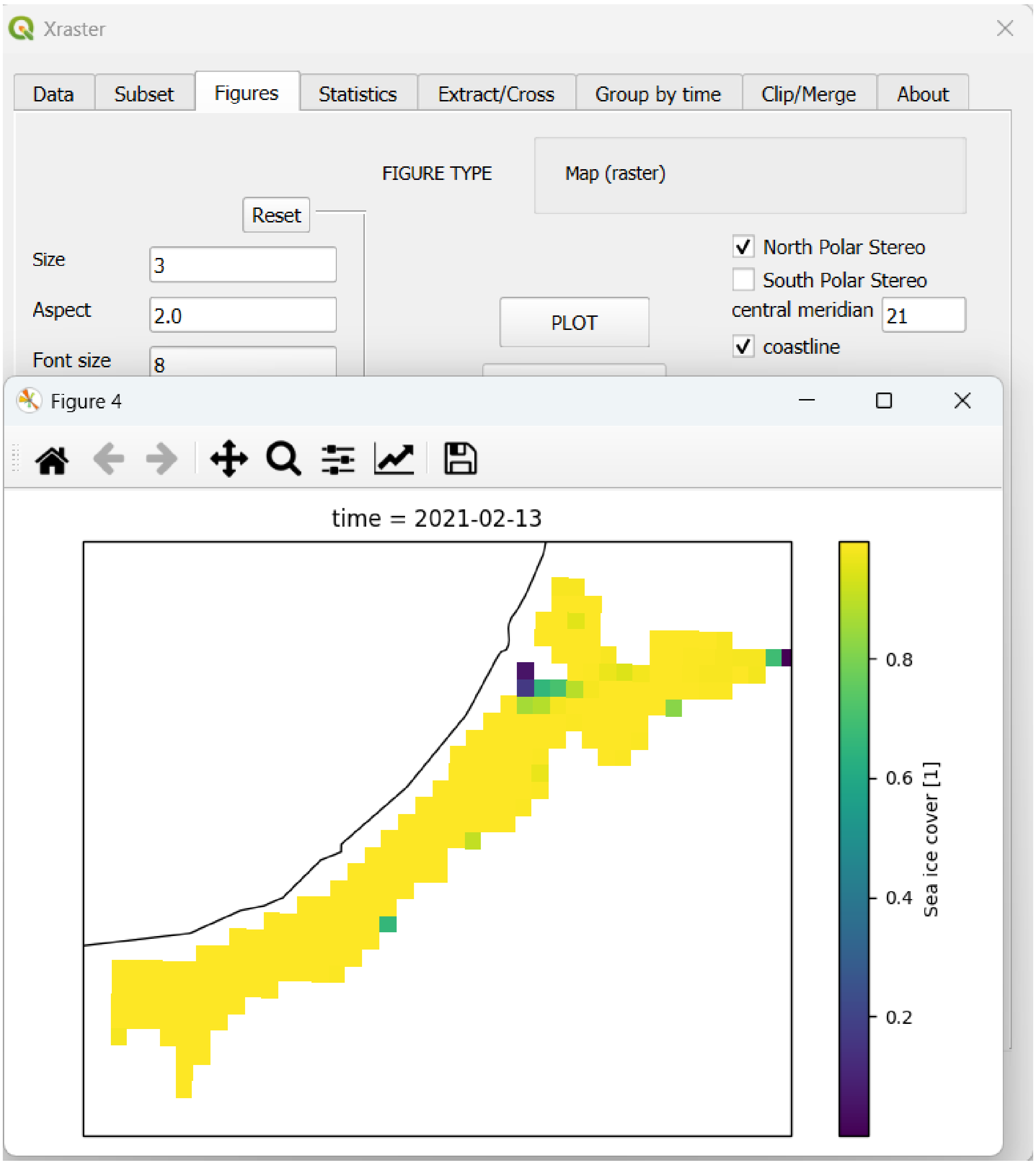


4.7 We can obtain an ice coverage map for February 13, 2021, by changing the subset in the SUBSET tab.



The data type now indicates **"Slice of space at a single time."**

4.8 We create the map in **FIGURES**, just as we did before.

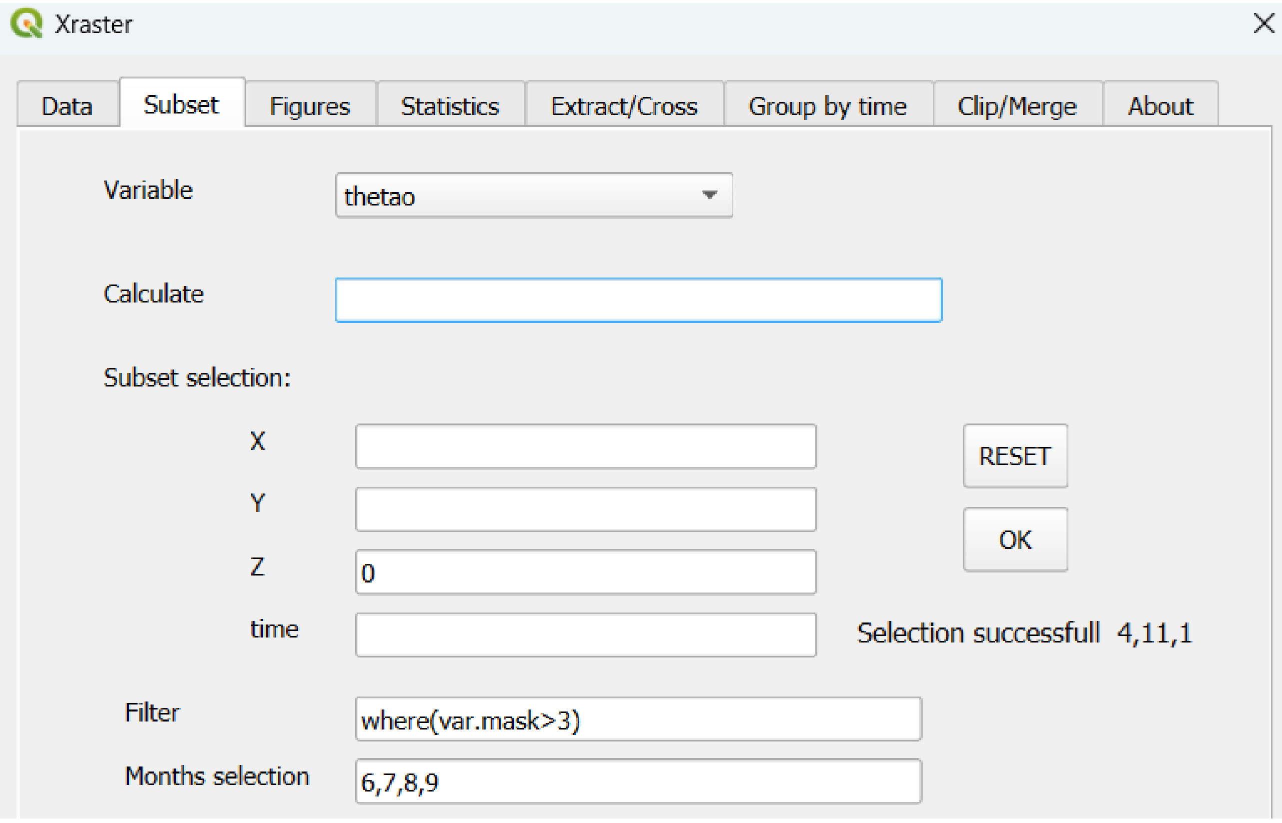


We can see that almost the entire area is covered with ice.

5. Changes in average water temperature during the summer period

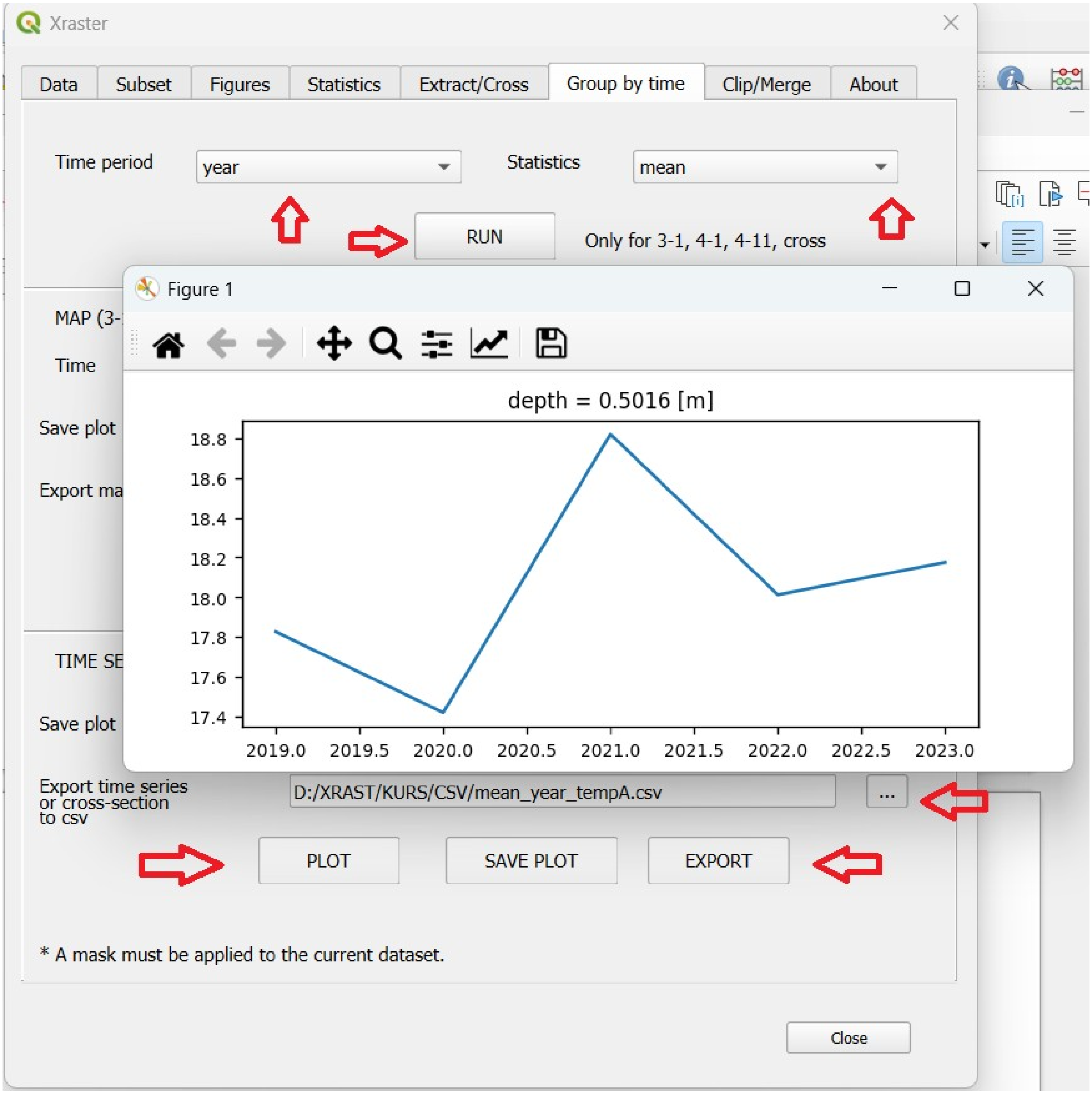
Changes in average temperature over a specific area and during a specific season are an important indicator of climate change. This task can be carried out relatively easily under the assumption that raster cells have a constant area. However, this is not true for data with geographic coordinates. While this may be negligible for small areas, for larger regions a weighted average should be used, with weights corresponding to the surface area of the cells.

5.1 For our data, we will calculate the area-weighted average temperatures for open waters with IDs 4 and 5 (on the data mask) during the summer period (June – September) for each year. We will start with the assumption that the cell areas are equal. Let's define the data subset.



The subset contains water temperature data for zones with identifiers 4 and 5, for the months from June to September.

5.2 We go to the Group by time tab and set the following: Time period to *year;* Statistics to *mean;* Then click RUN.
Next, create the plot by clicking PLOT (in *Time Series…*), enter the name of the text file for the data from the graph, and click EXPORT.



The created file **mean_year_tempA.csv** contains the calculated average temperatures:

year,thetao
2019,17.8223
2020,17.4149
2021,18.819
2022,18.0111
2023,18.1713

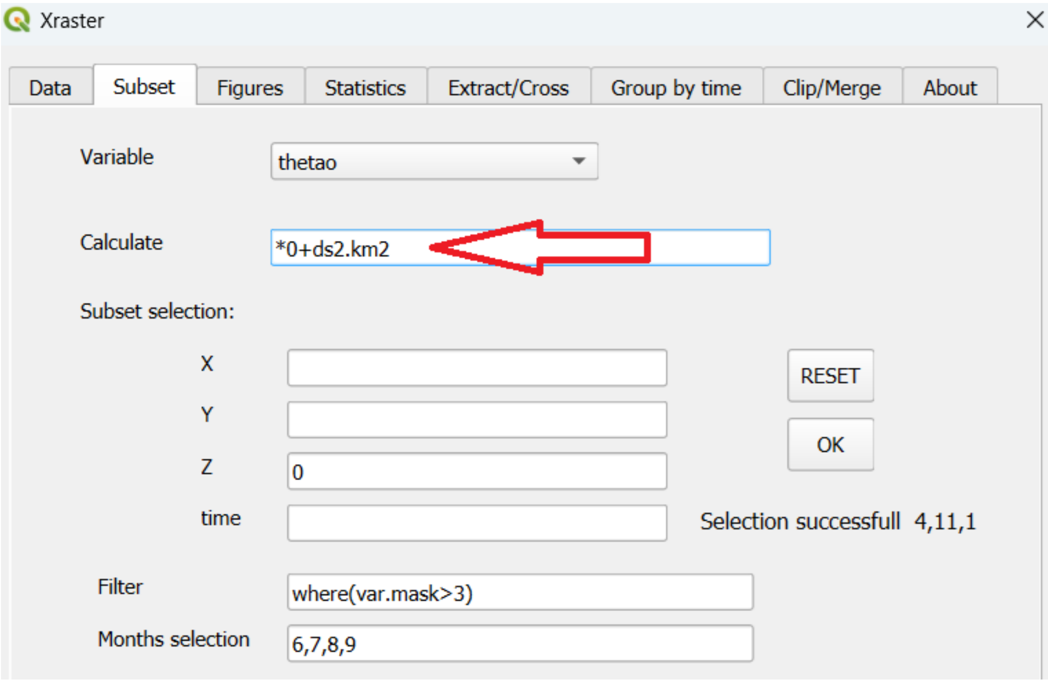
5.3 The weighted average (W), taking into account the weights corresponding to the surface area of individual cells, will be calculated using the formula:

$$W = \frac{\sum_{i=1}^{n} w_i X_i}{\sum_{i=1}^{n} w_i}$$

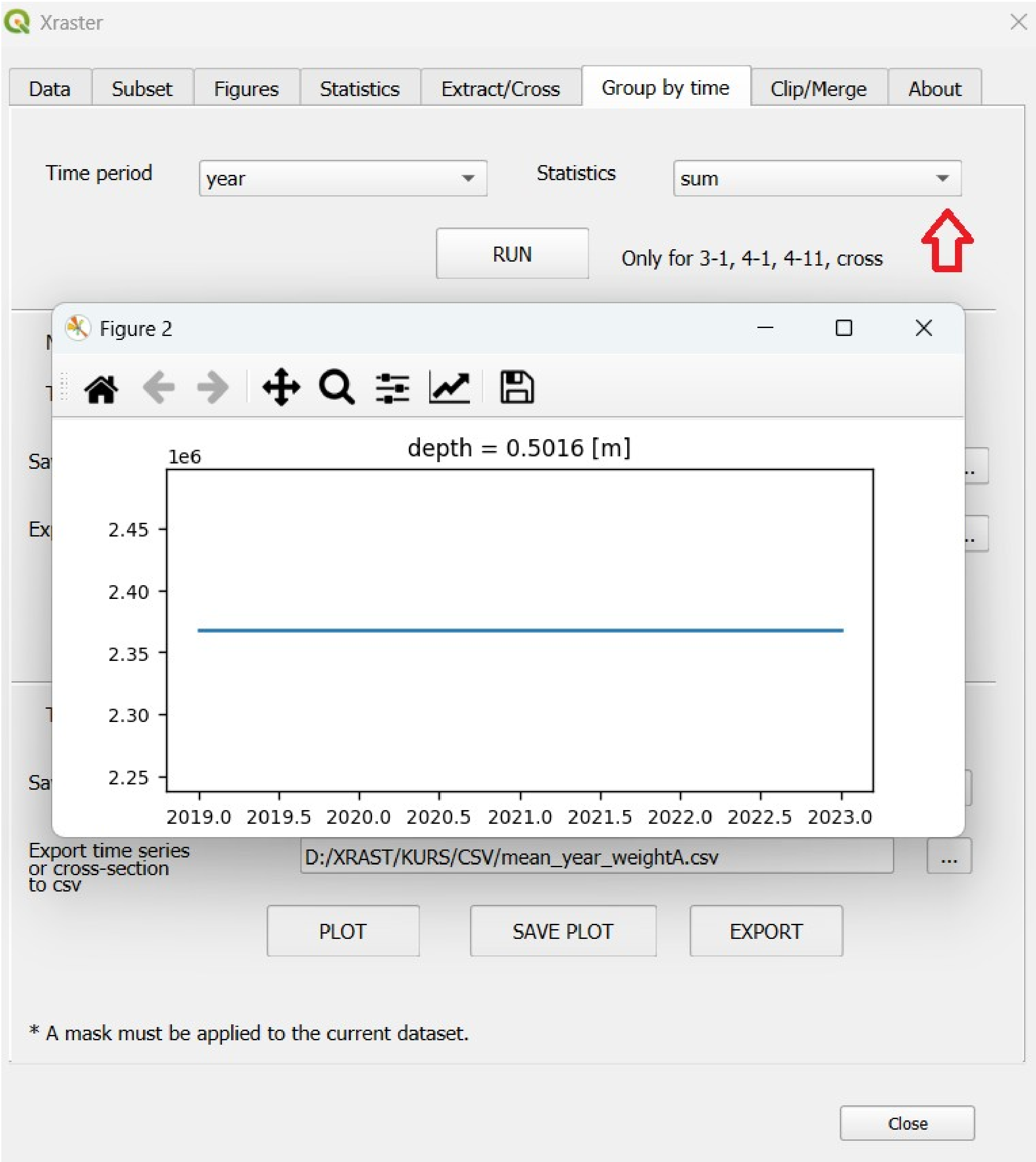
The weight (w) will be the surface area of individual cells. In practice, the operation will consist of summing the products of the variable and the weight, divided by the sum of the weights

W = $\Sigma((w*X)/\Sigma(w))$.

The first step will involve determining the sum of the weights. To do this, we enter an expression that assigns each cell only the weight value (the variable is multiplied by 0, and the weight value is added).



5.4 We go to the Group by time tab and proceed as before, but this time set Statistics to *sum*.

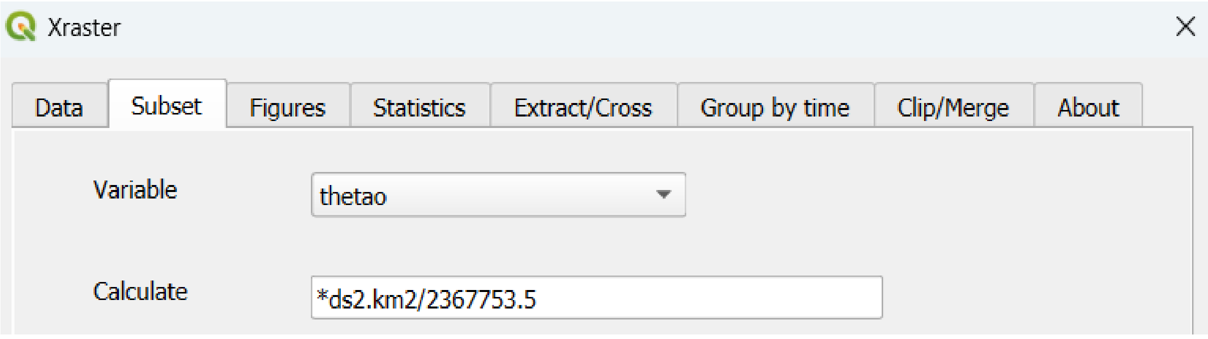


The generated file contains the sums of weights (surface area in km² * number of days), which are identical for each year.

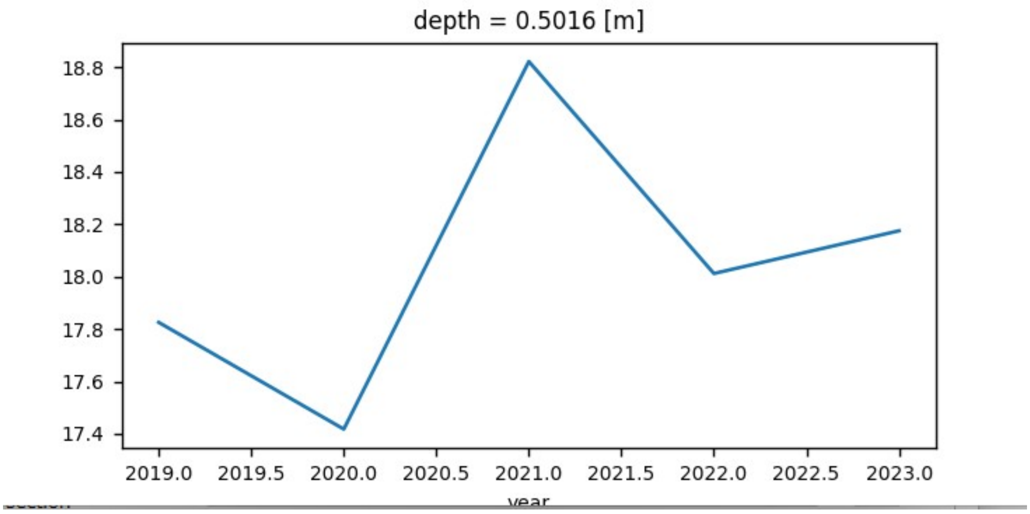
year,thetao
2019,**2367753.5**
2020,2367753.5
2021,2367753.5
2022,2367753.5
2023,2367753.5

We copy the value of the sum of weights in order to insert it into the expression.

5.5 We create a new subset using an expression that is the product of temperature and weight divided by the sum of the weights.



We repeat the previously performed operation in the Group by time tab (section 5.4). This gives us the resulting plot.



Similarly, we create a text file with temperature values for each year, representing the **weighted average.**

year,thetao
2019,17.8255
2020,17.4179
2021,18.8217
2022,18.0121
2023,18.1753

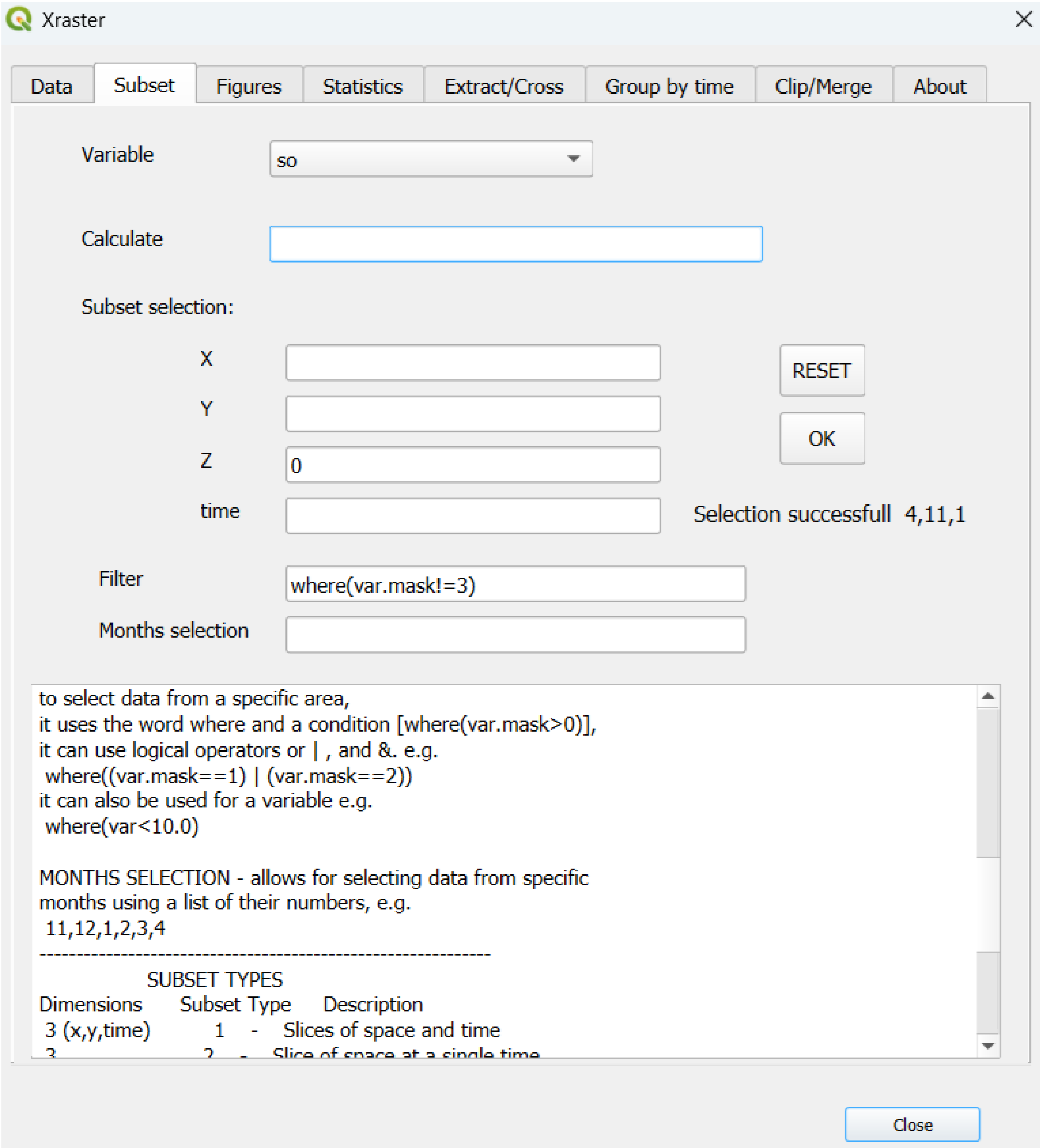
For comparison, the averages without weighting were as follows:

year,thetao
2019,17.8223
2020,17.4149
2021,18.819
2022,18.0111
2023,18.1713

The differences are minor, but for larger areas, especially at high latitudes, they can be significant.

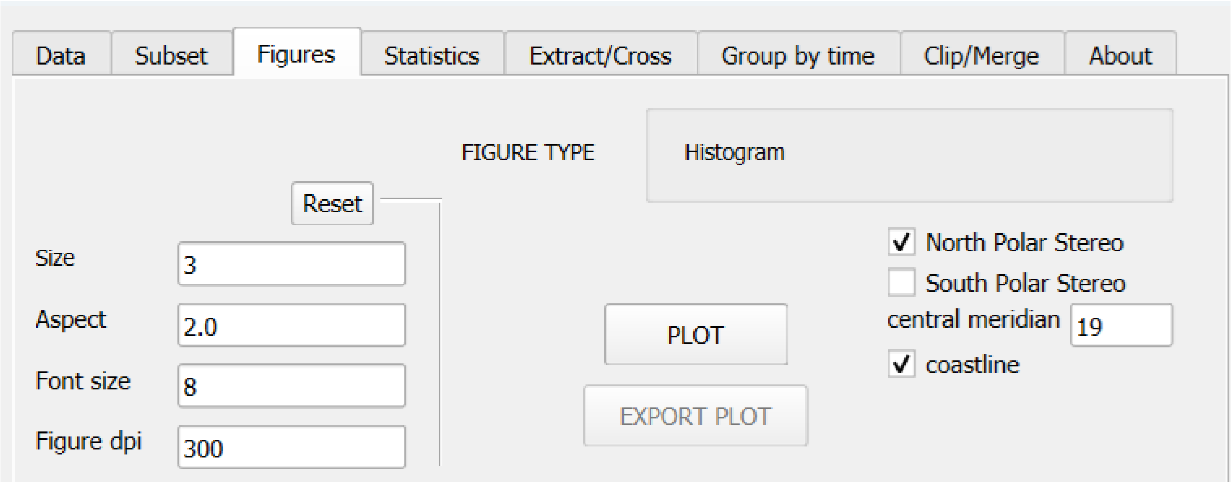
6. River water outflow analysis (classification).

6.1 Determine the map of minimum surface salinity values (excluding zone 3). To do this, create a subset for surface data, excluding the area with identifier 3 on the mask.

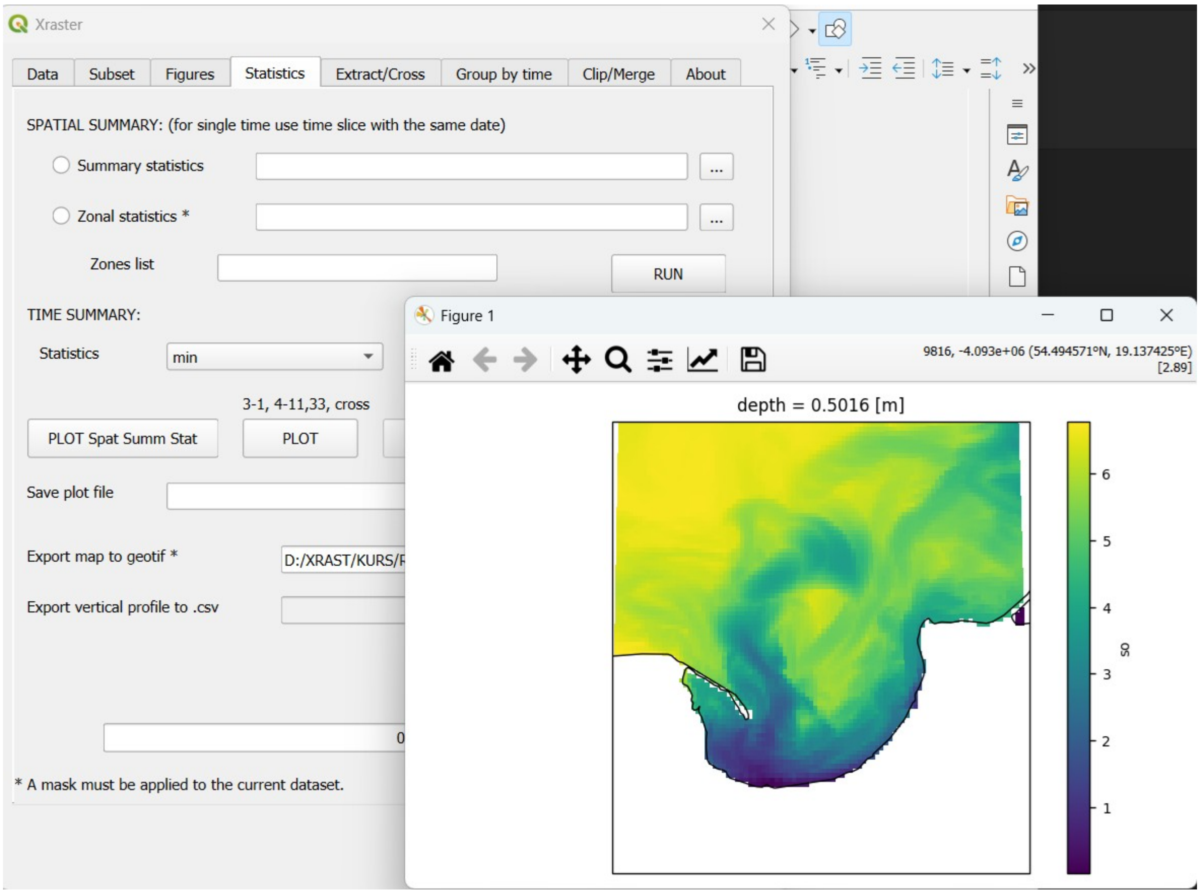


The data type 4,11,1 means *Slice of space and time for a single depth*, where the final value 1 indicates the presence of a mask.

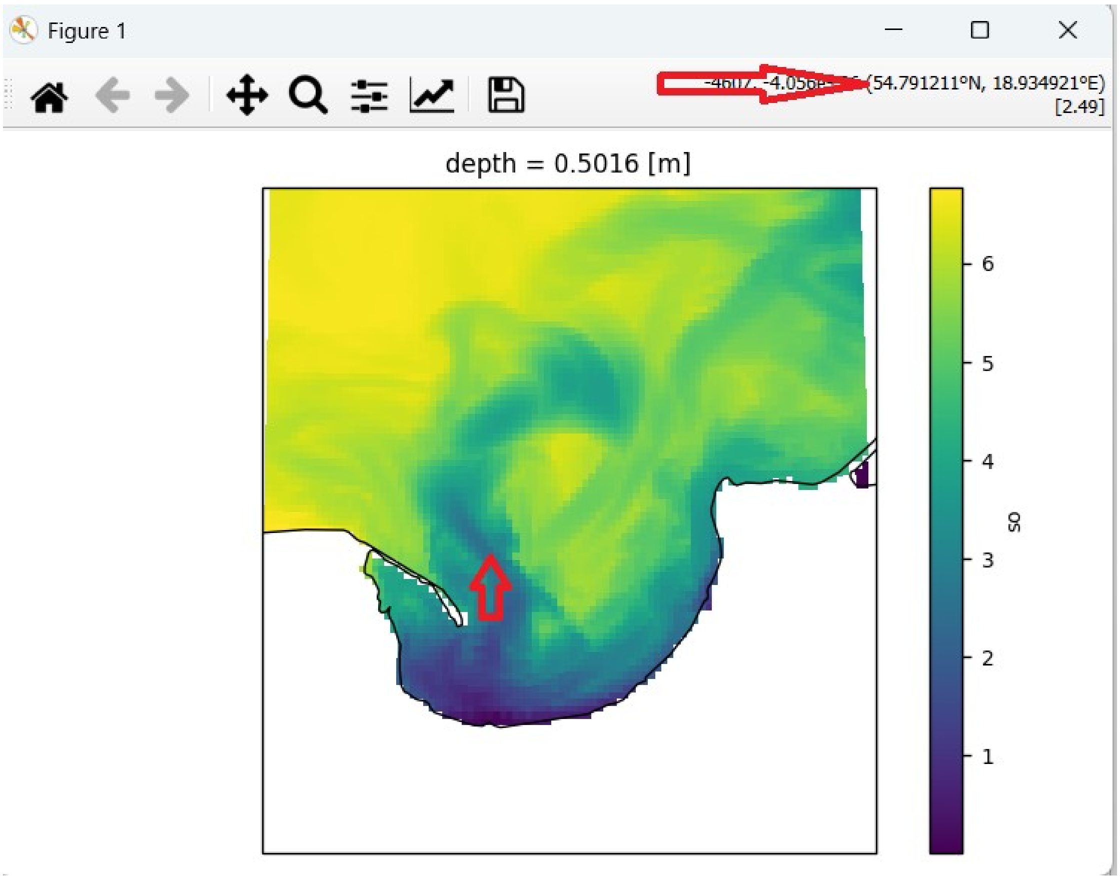
6.2 We set the projection, central meridian, and coastline in the FIGURES tab.



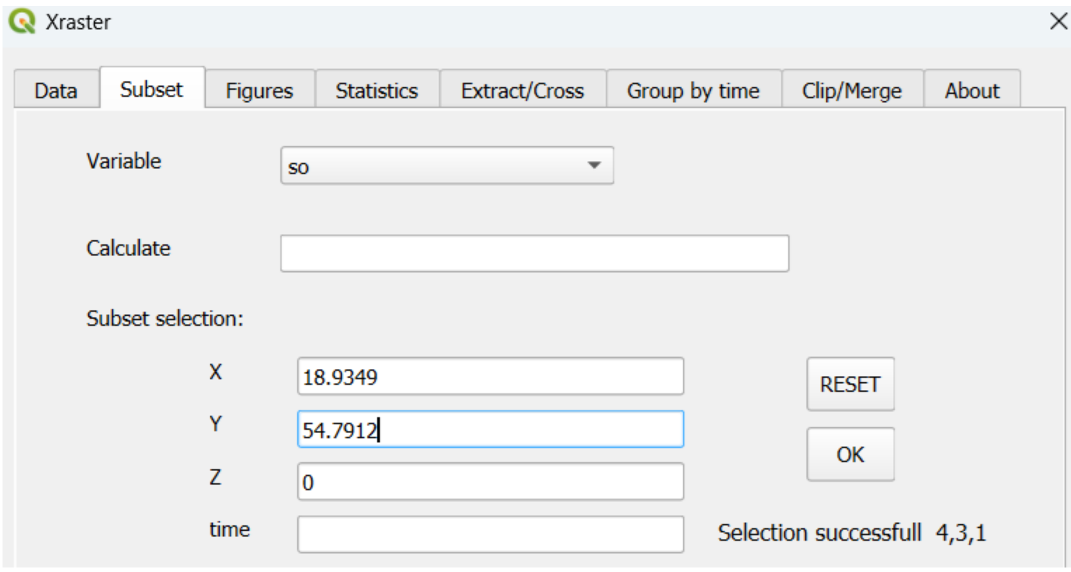
6.3 We go to the STATISTICS tab, select *min*, and click PLOT.



6.4 We will create a map of the surface salinity distribution for one of the extreme situations. To find the date when it occurred, we read the coordinates of the point where the values were extreme: **54.7912° N, 18.9349° E**.

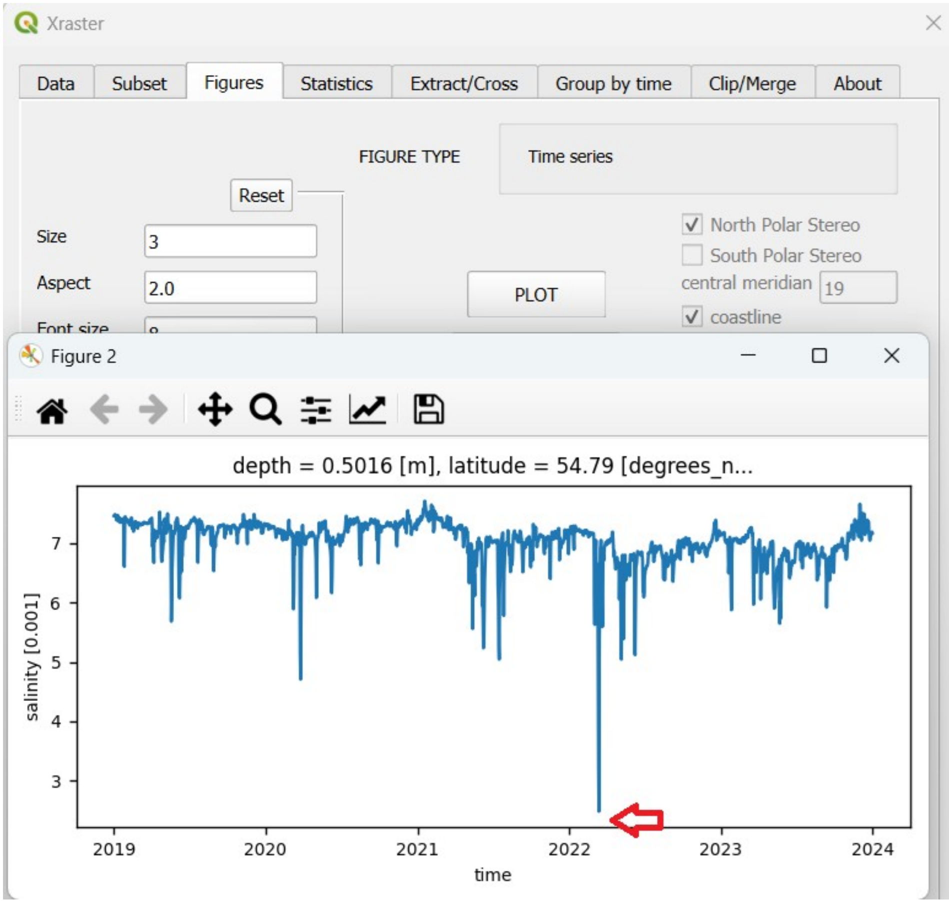


6.5 We create a data subset for this point.

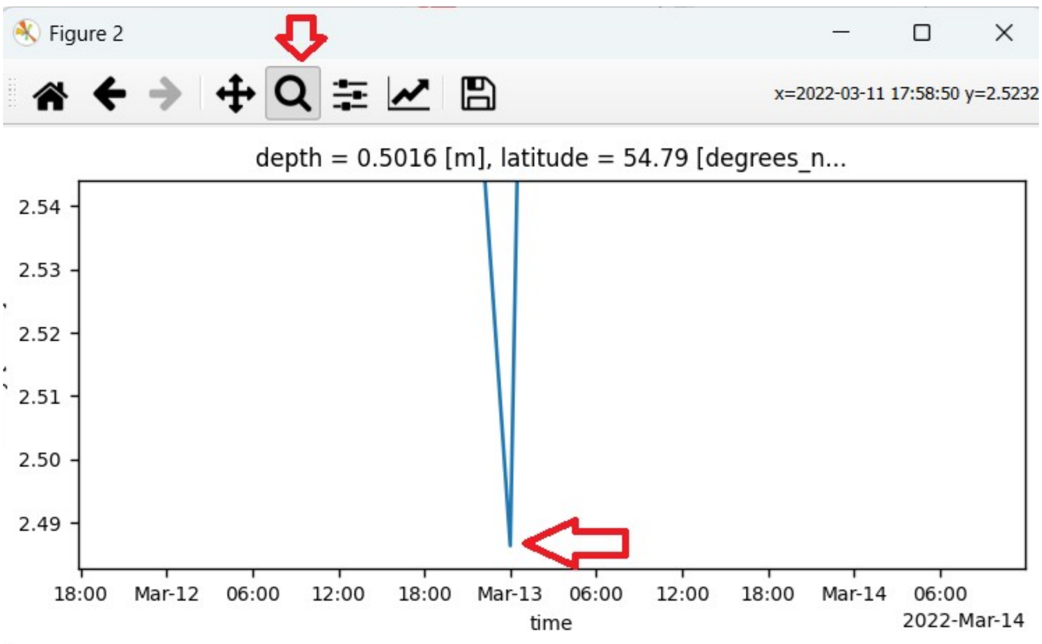


The data type 4,3 means *Point in space, single depth, and time slice*.

6.6 We go to the FIGURES tab and click PLOT (the current data type produces a time series plot).

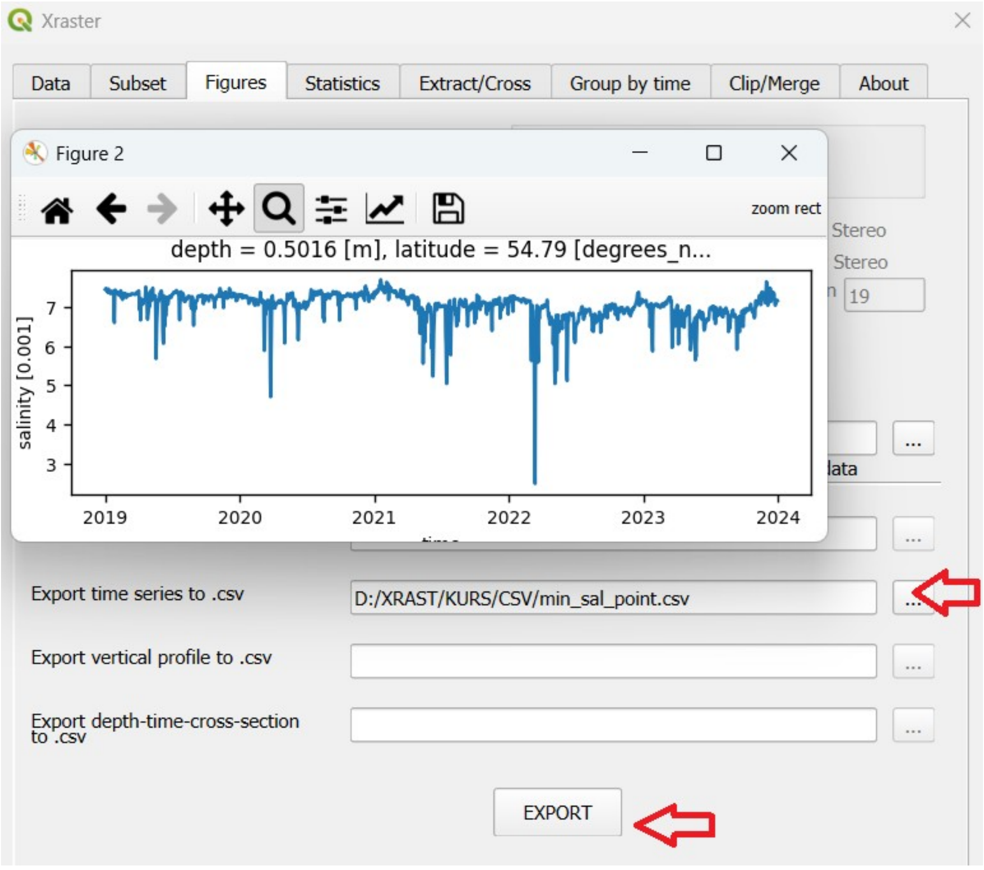


We zoom in on the part of the plot with the minimum value (using the magnifying glass – by drawing a box), and read the corresponding date.



The date we are looking for is **March 13, 2022**.

We can also find this date by exporting the time series as a .csv file. Enter the file name (by clicking the button to enter the name), and after typing it, click EXPORT.

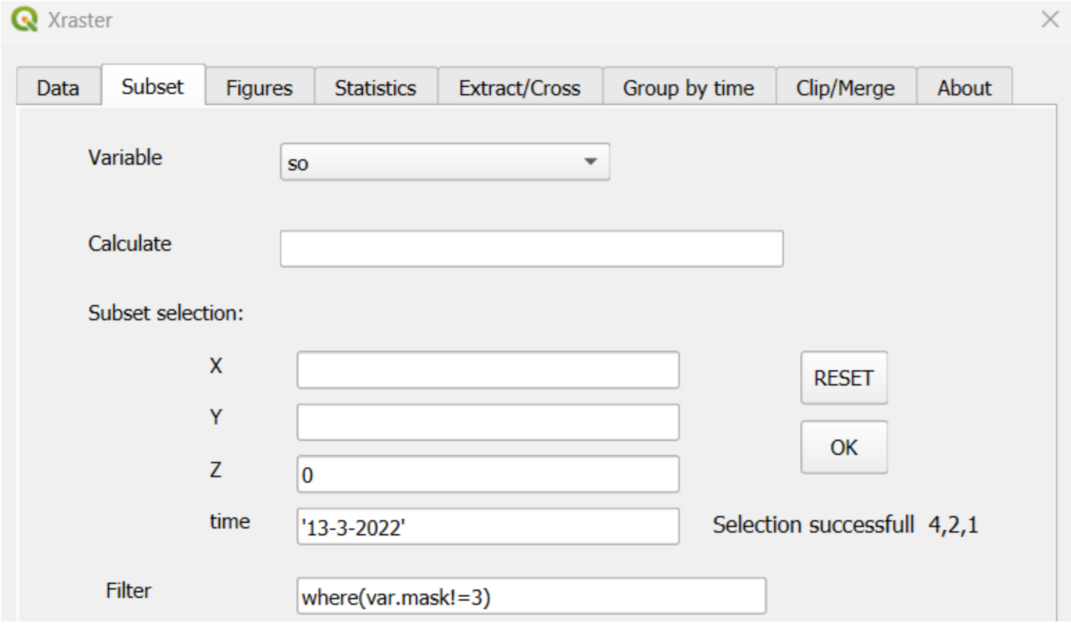


In the file, we locate the value we are looking for.

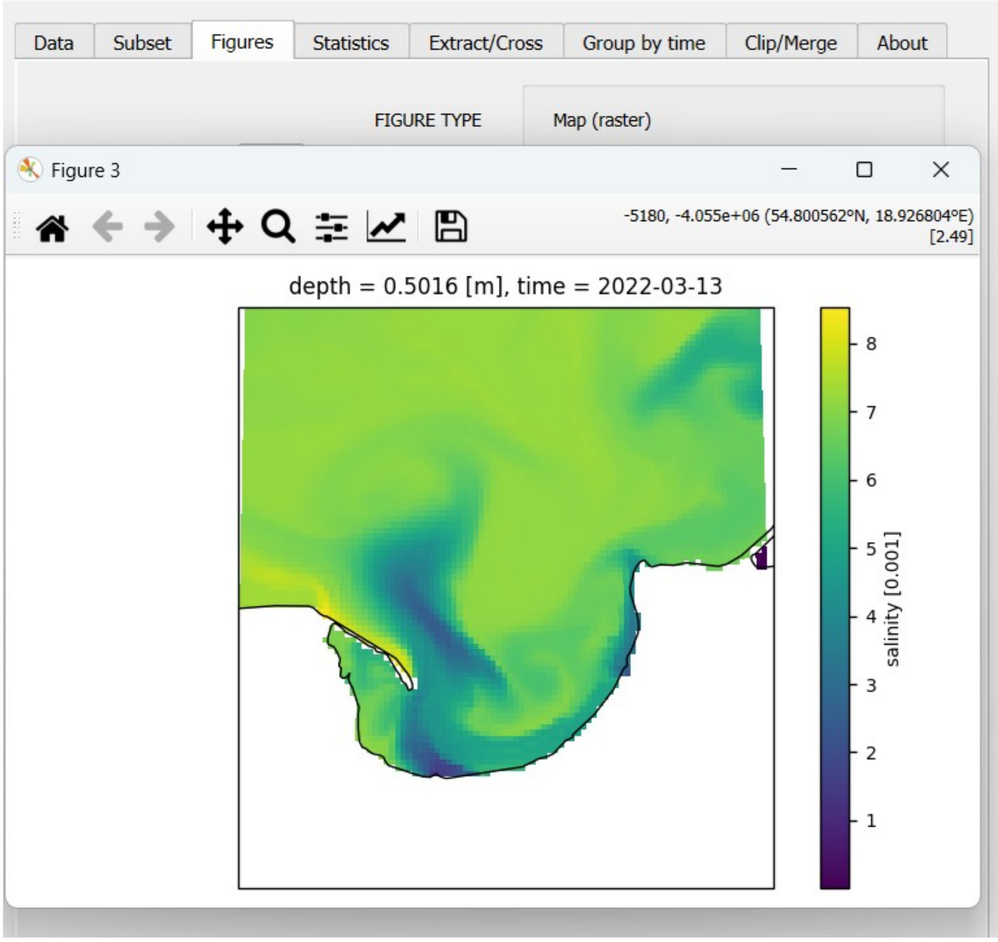
time,so
2019-01-01 00:00:00,7.4539
2019-01-02 00:00:00,7.4693
2019-01-03 00:00:00,7.4518
....

2022-03-10 00:00:00,6.5357
2022-03-11 00:00:00,4.7982
2022-03-12 00:00:00,3.2688
2022-03-13 00:00:00,**2.4863**
2022-03-14 00:00:00,5.3881
2022-03-15 00:00:00,5.924
2022-03-16 00:00:00,6.9057
2022-03-17 00:00:00,6.9404
....

6.7 We are creating a subset for the area and the selected date.

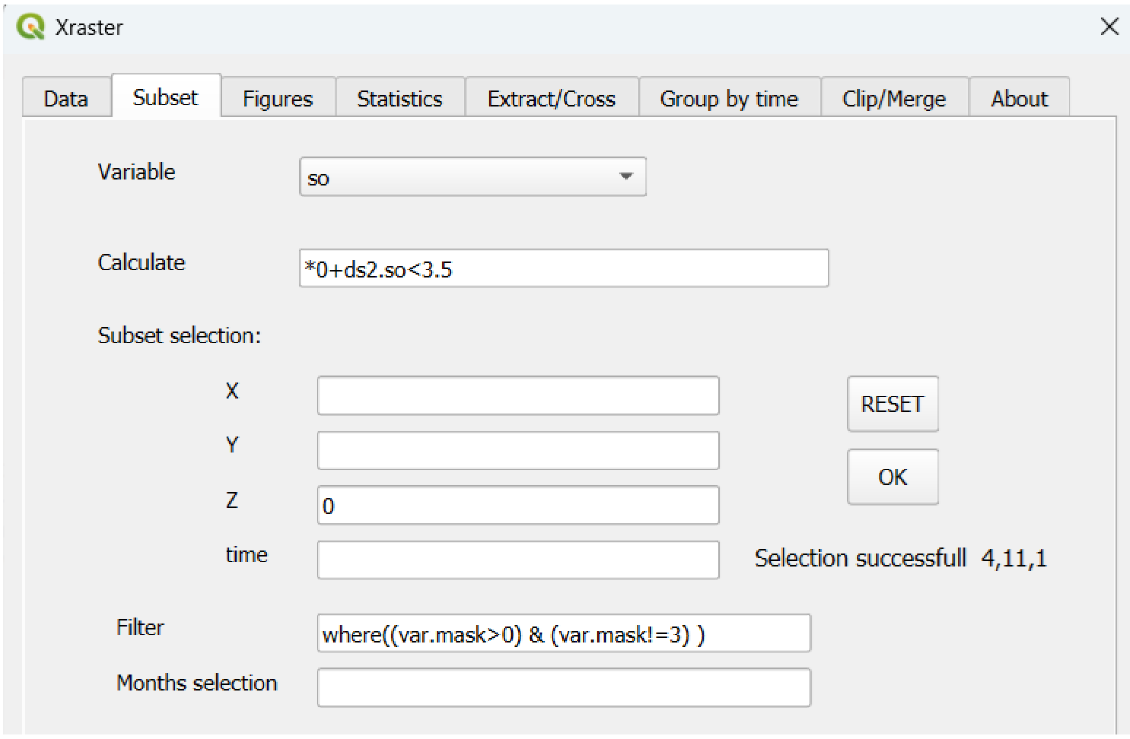


6.8 In FIGURES, we create a map using PLOT.

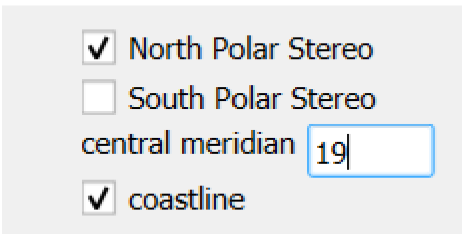


This map can be saved (also in high resolution), elements can be modified, and it can also be exported as a raster layer (.tif) to QGIS.

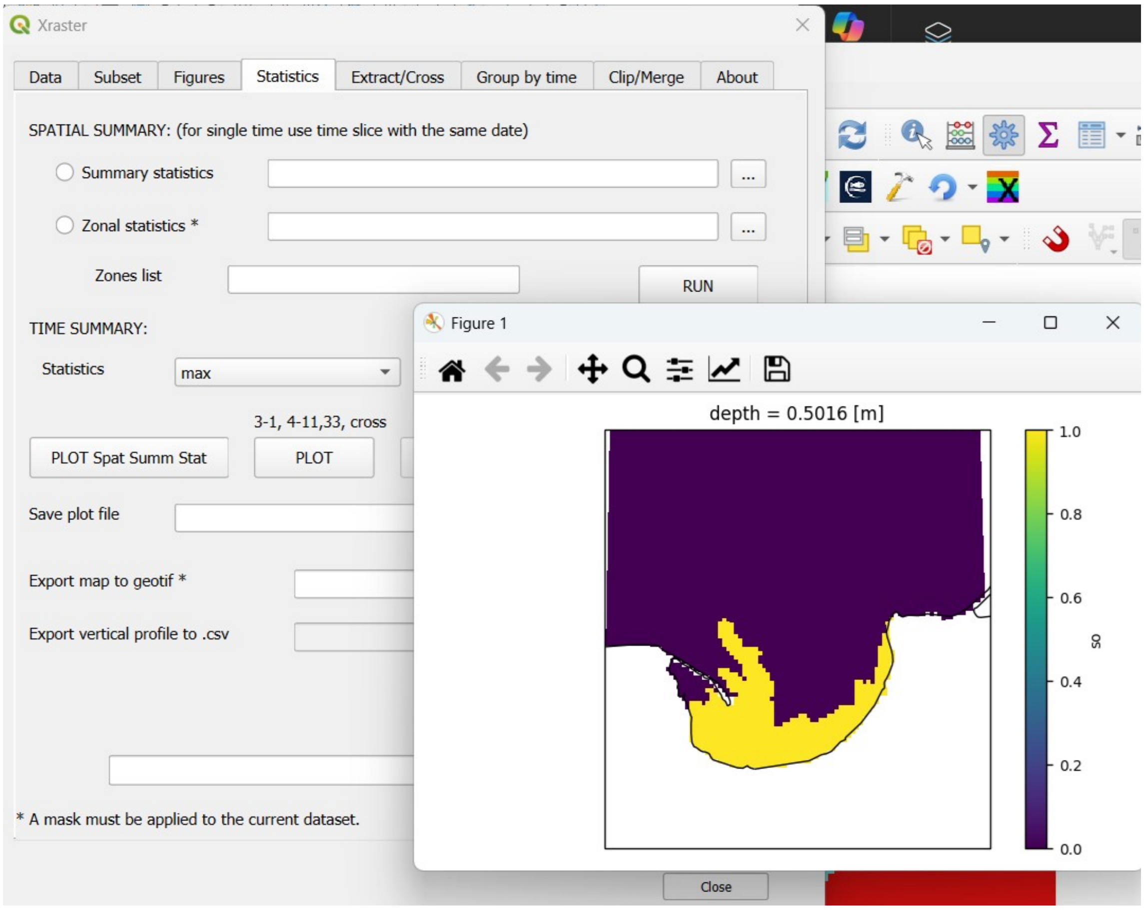
6.9 We will now create a map showing the area where surface salinity reaches a value below 3.5. To do this, we perform a reclassification of salinity values by assigning 1 to values below 3.5 and 0 to the rest. We create a new Subset with the expression in the Calculate field: ***0 + ds2.so < 3.5** . Multiplying the current variable by zero resets all data, and we add the result of the conditional operation. If the condition is met, the result is 1; if not, it is 0. Python expression rules apply. Additionally, the Filter field eliminates land and the area with id=3.



Additionally, in the FIGURES tab, we set the projection, central meridian, and enable the coastline.

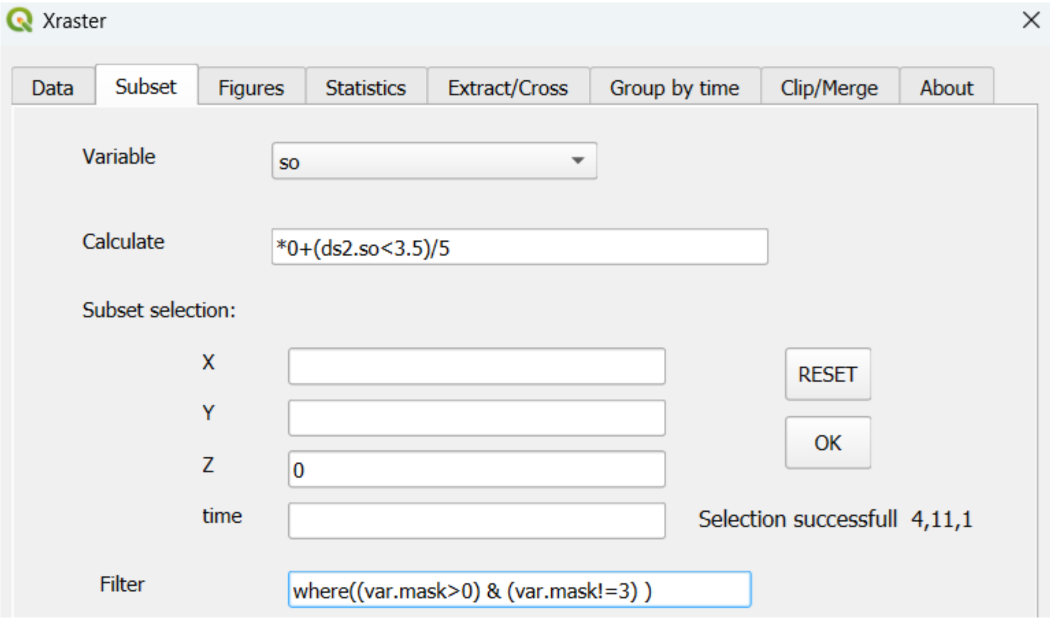


6.10 We go to the STATISTICS tab. In TIME SUMMARY, in the Statistics field, we set (max), the maximum value in a given cell. We click PLOT.

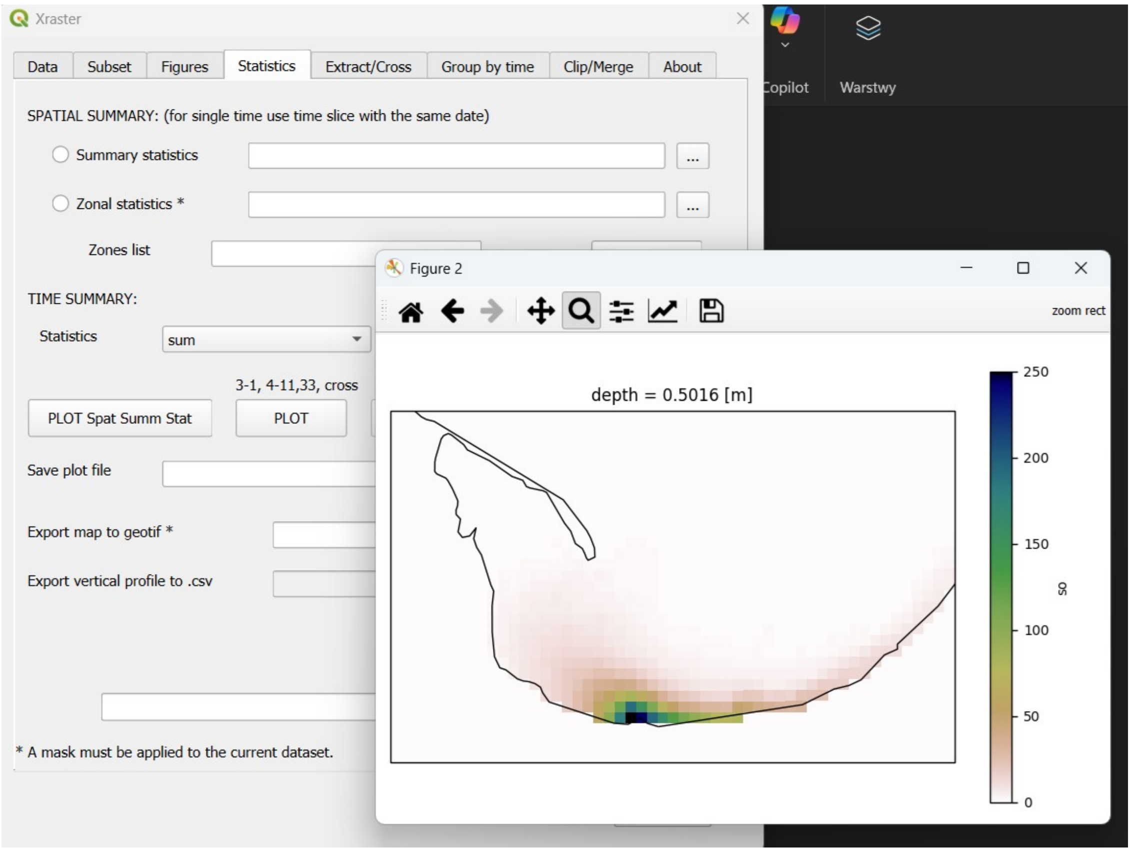


The resulting map has only two values: 1 – if salinity below 3.5 occurred at least once in that cell, and 0 – if such a situation did not occur.

6.11 We will create a map showing how many times on average per year salinity below 3.5 occurred. Since our data covers 5 years, we divide the result of the comparison by 5 (which gives 0.2). The five-year sum will show a value of 1 when the phenomenon occurred once per year on average. We create a new subset.

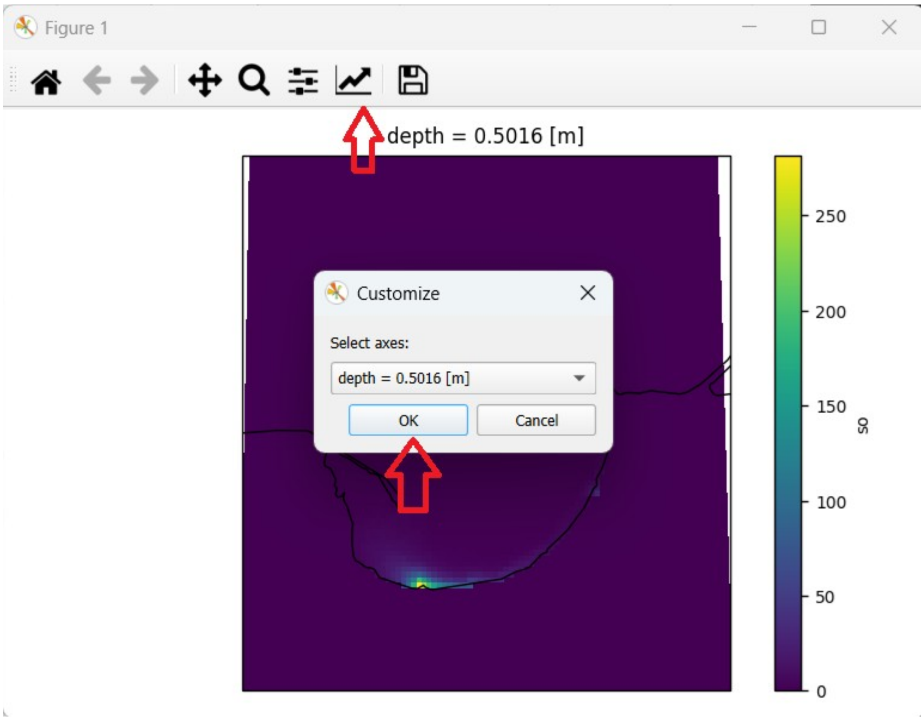


6.12 We go to the STATISTICS tab, set the Statistics field to **sum**, and click PLOT.

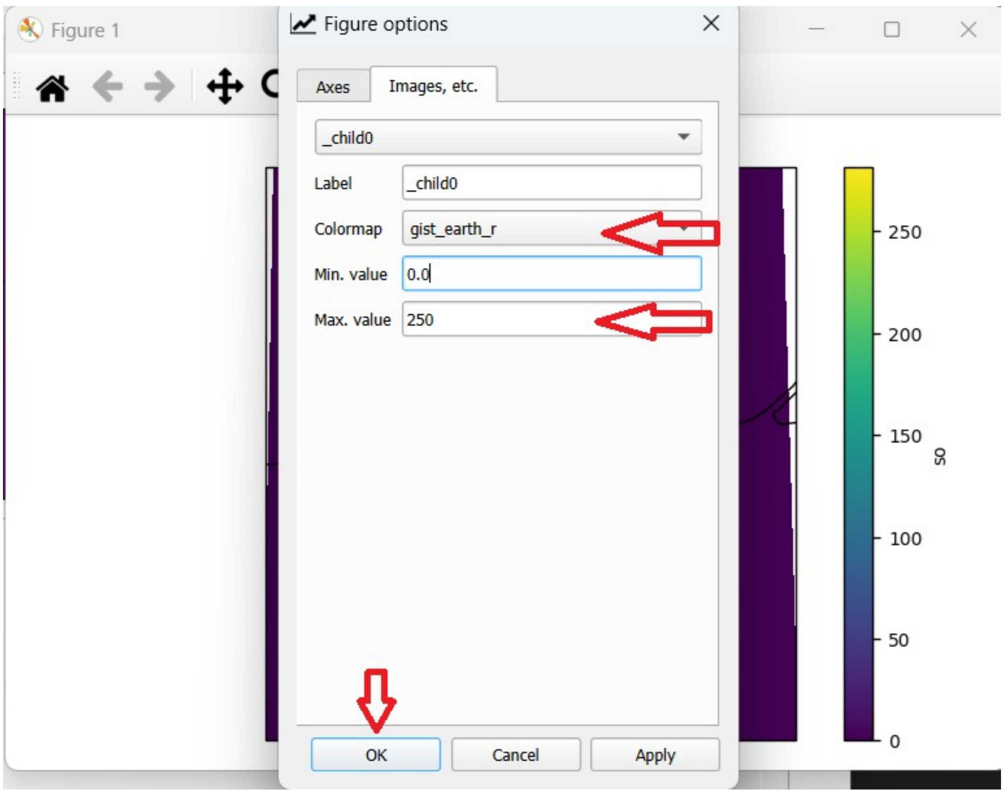


The colormap **gist_earth_r** and its zoom (magnifier) were applied when creating the figure.

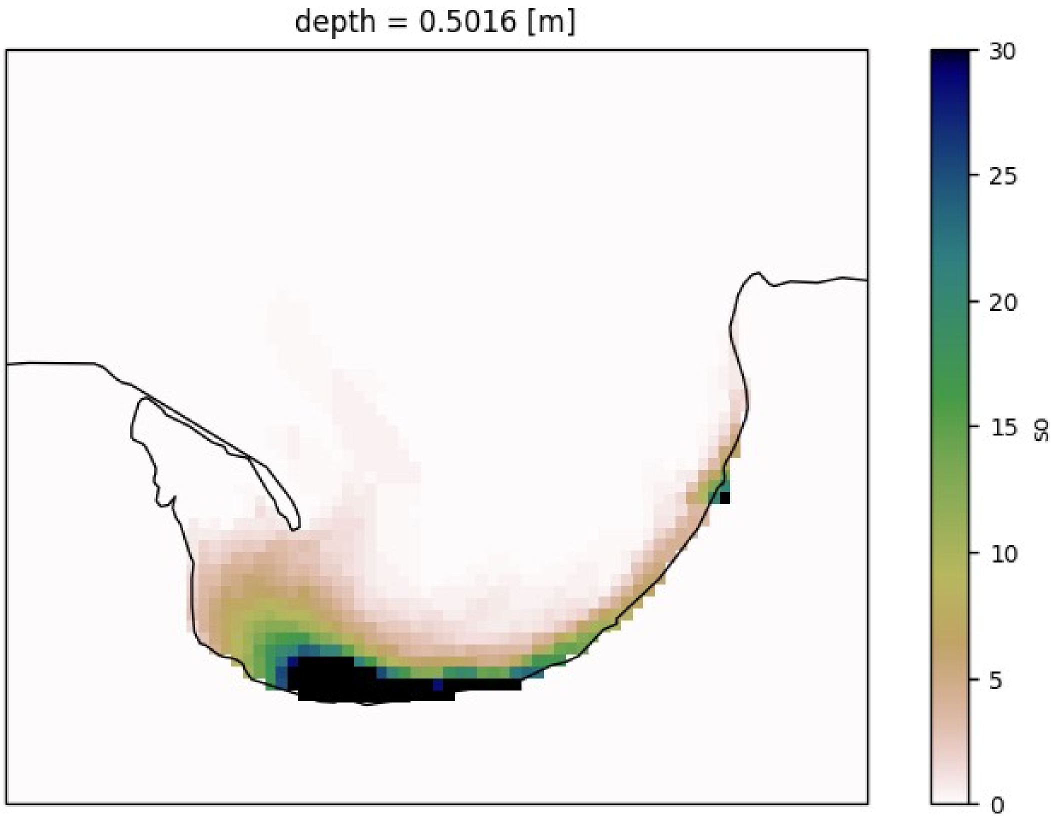
To do this, we click on the second-to-last icon and press OK.



We go to the Images field, etc., and select the colormap **gist_earth_r,** change Max. values to 250 (to increase the range of smaller values), and click OK.



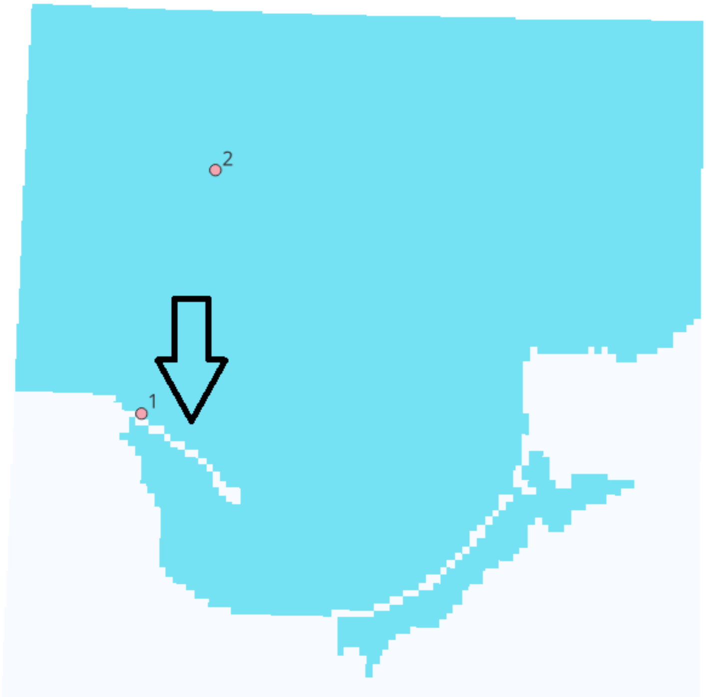
We can reduce the Max value from 250 to 30, and the resulting map will take the following form.



The dark blue area indicates at least 30 times during the year.

7. Upwelling analysis using cross-sections.

In the analyzed area, upwellings occur (including in the region marked by the arrow), indicated by occasional drops in temperature in the coastal zone.



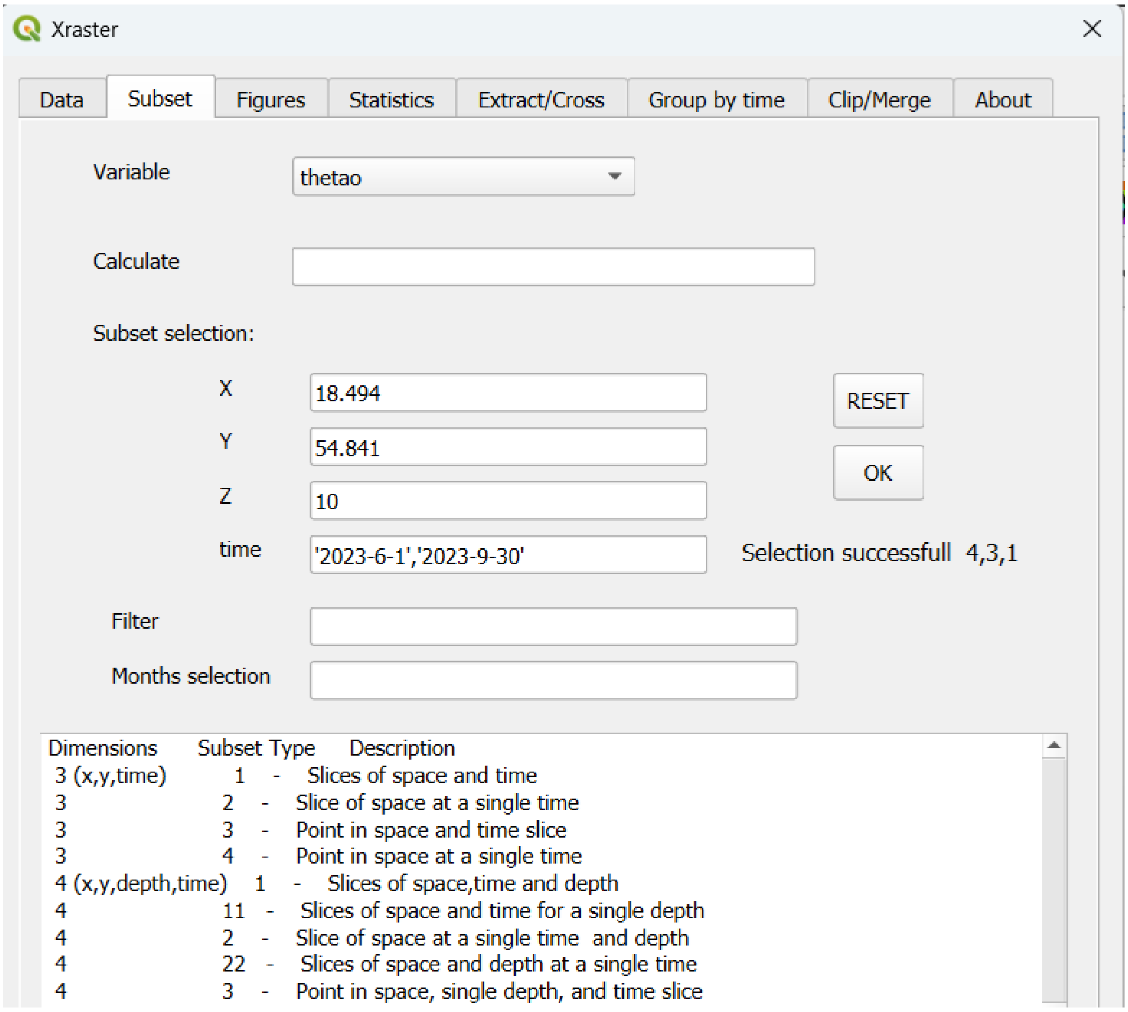
We will perform a cross-section temperature analysis in the coastal zone by creating a set of cross sections for each day from June to September 2023. The cross section will be drawn from the first point to the second. The points were created in QGIS as a point shapefile with a coordinate system identical to the data, along with a mask (coordinate system in geographic coordinates with WGS84 datum). The attribute table contains the point identifiers.

	id
1	1
2	2

We will start by identifying the days when the upwelling was exceptionally strong. To do this, we will specify the coordinates of a point on the cross section near point 1, taking 18.494° E and 54.841° N at a depth of 10 meters. Next, we will create a subset of the cross sections and visualize them for the selected days. We will also perform a basic statistical analysis of the created cross section dataset using the STATISTICS and GROUP BY TIME tabs.

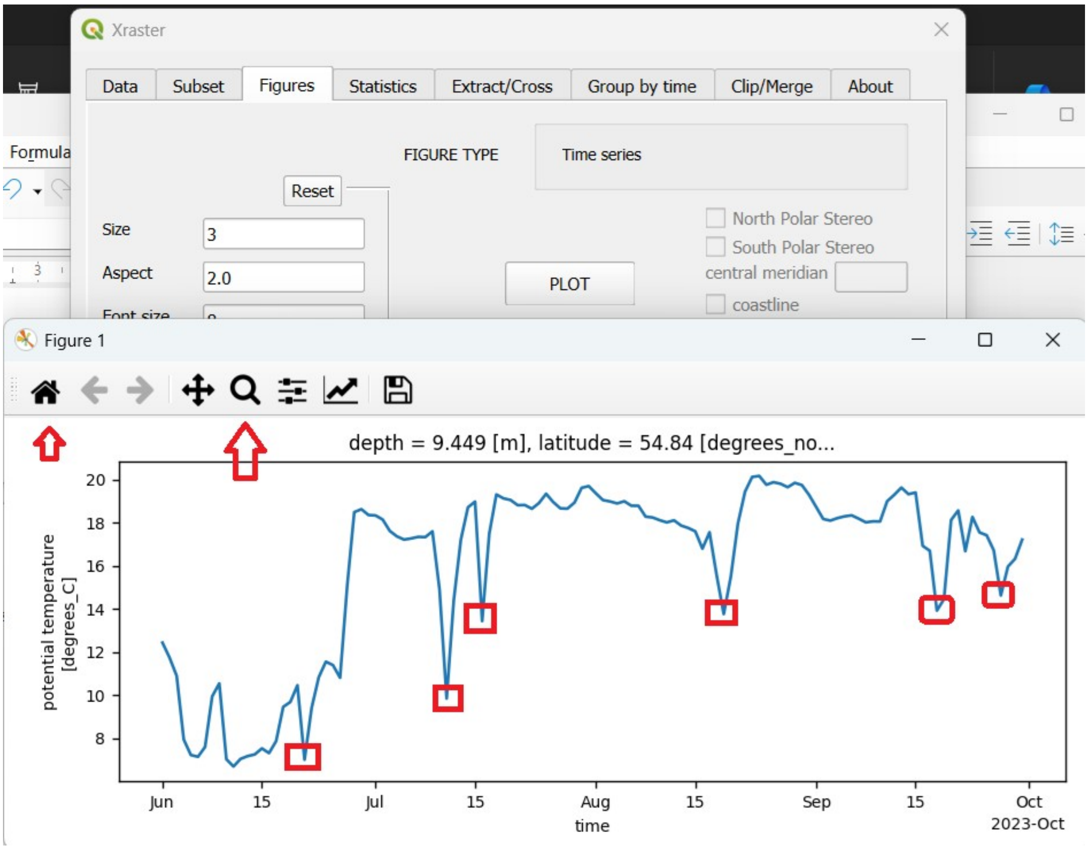
(the point layer is included in the provided data – **points_2.shp**)

7.1 We enter the data and mask. We analyze the variable *thateo* (daily average water temperature). We go to the SUBSET tab and enter the point coordinates, depth of 10 m, and the required time range.

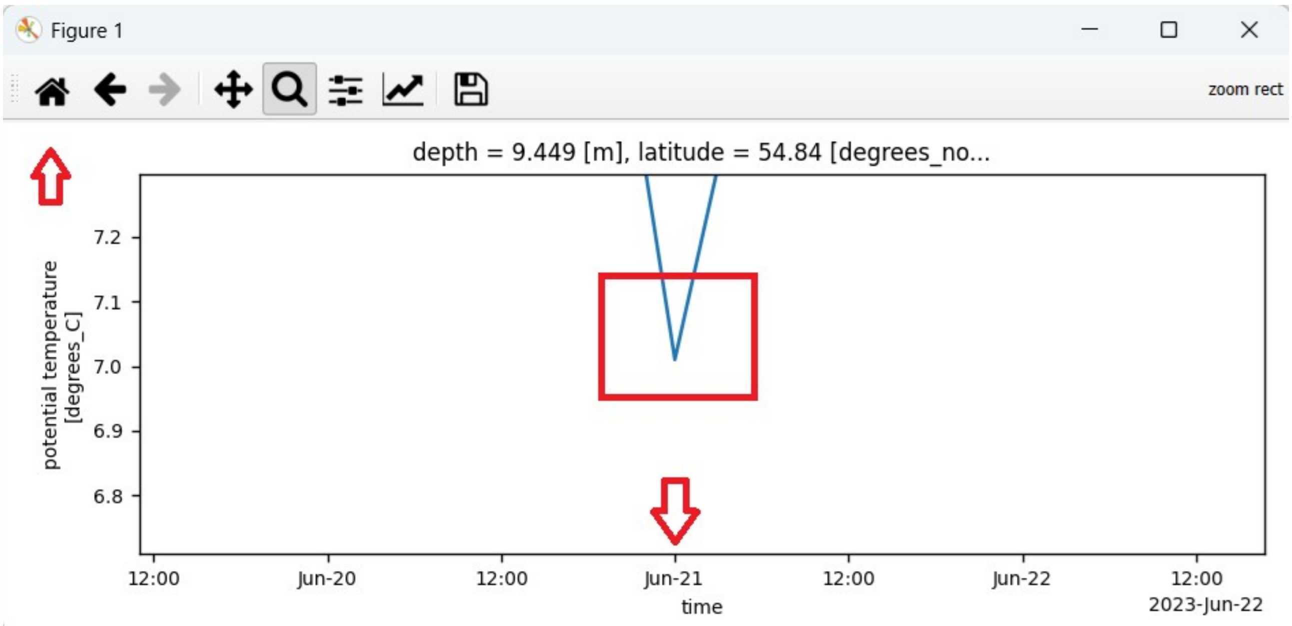


The type of created data 4,3 is *Point in space, single depth, and time slice* .

7.2 We go to the FIGURES tab and create a time variability plot of the temperature by clicking PLOT.

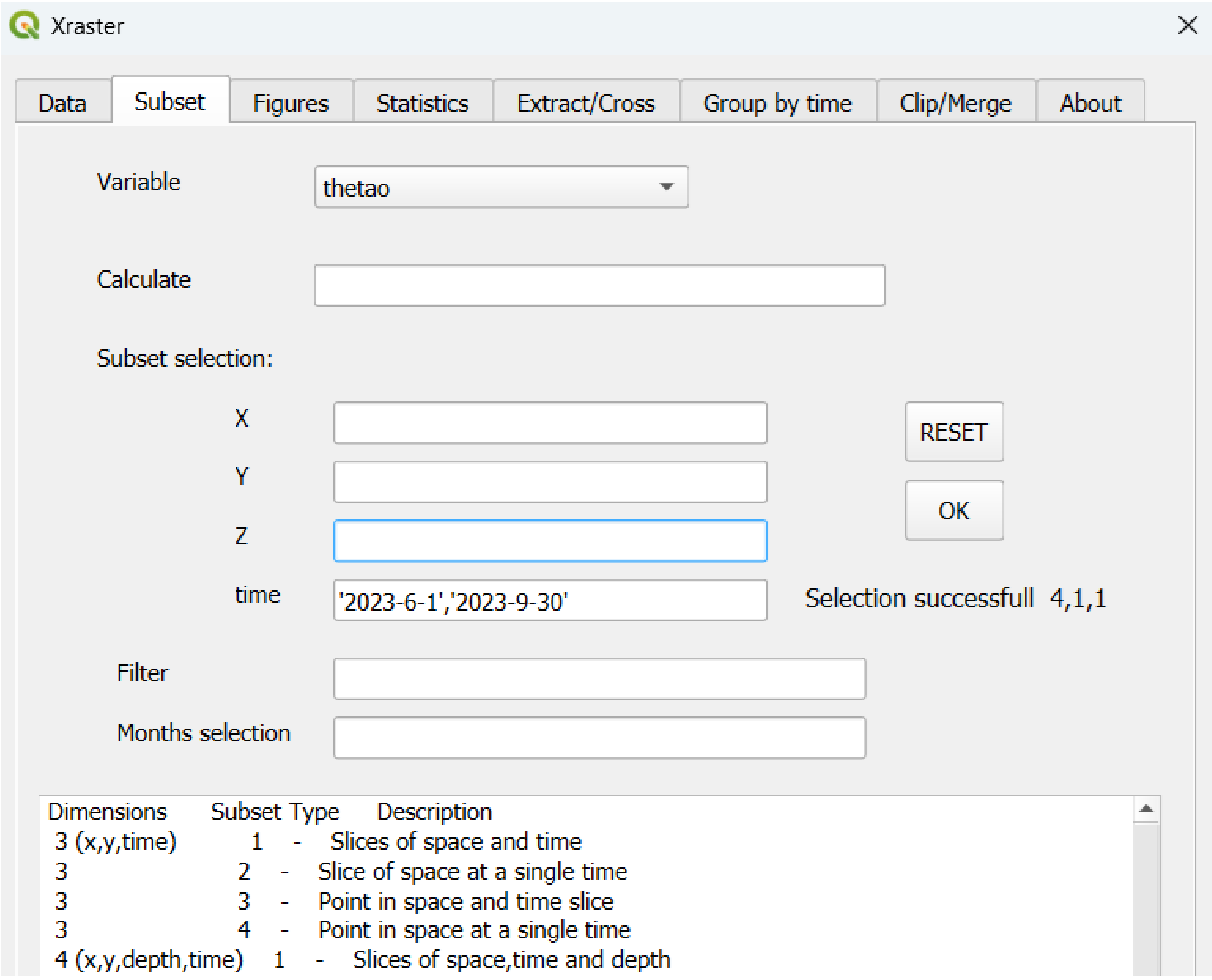


Using the magnifier, we zoom in on the minimum peaks in the plot showing temperature drops and read off the date of the minimum.



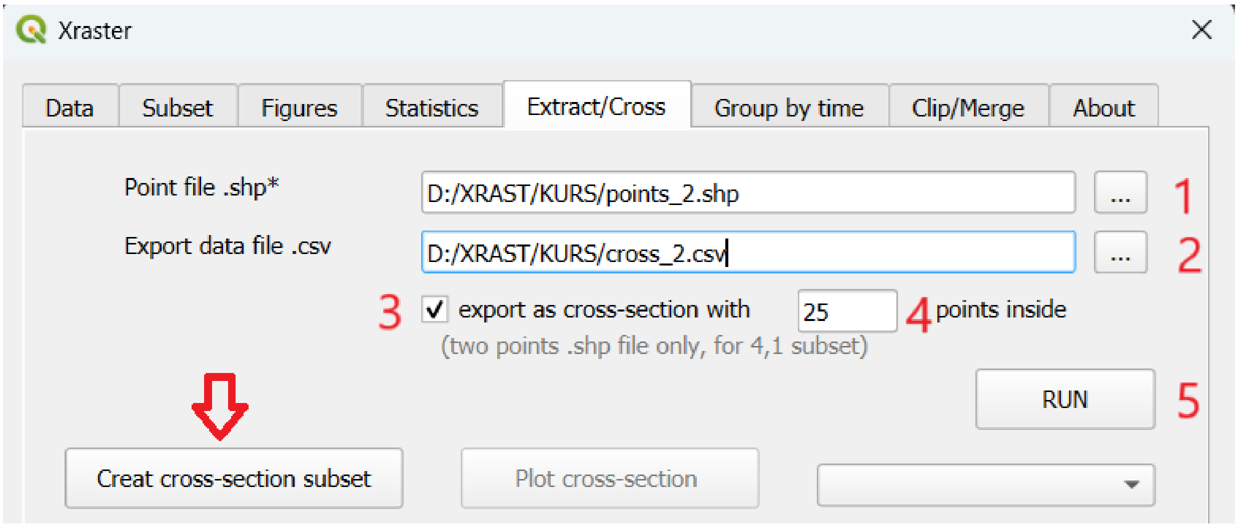
The next minima indicating upwellings occurred on **June 21, July 11 and 16, August 19, and September 18 and 27.** We can also save the plot as a text file and read the dates of the minima (upwellings) from it.

7.3 We return to the SUBSET tab and create a subset of data type 4.1.

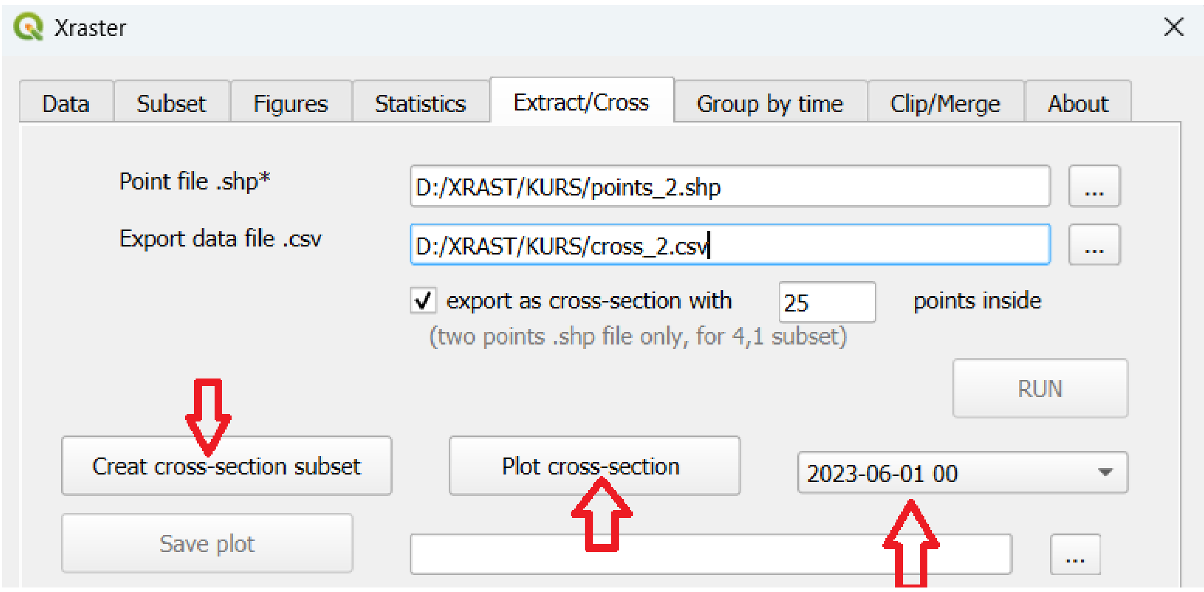


7.4 We will now create a cross-section data subset for this period along the line defined by points 1–2. <u>This subset will replace the one created in the previous step</u>. We go to the **Extract/Cross** tab. Then:

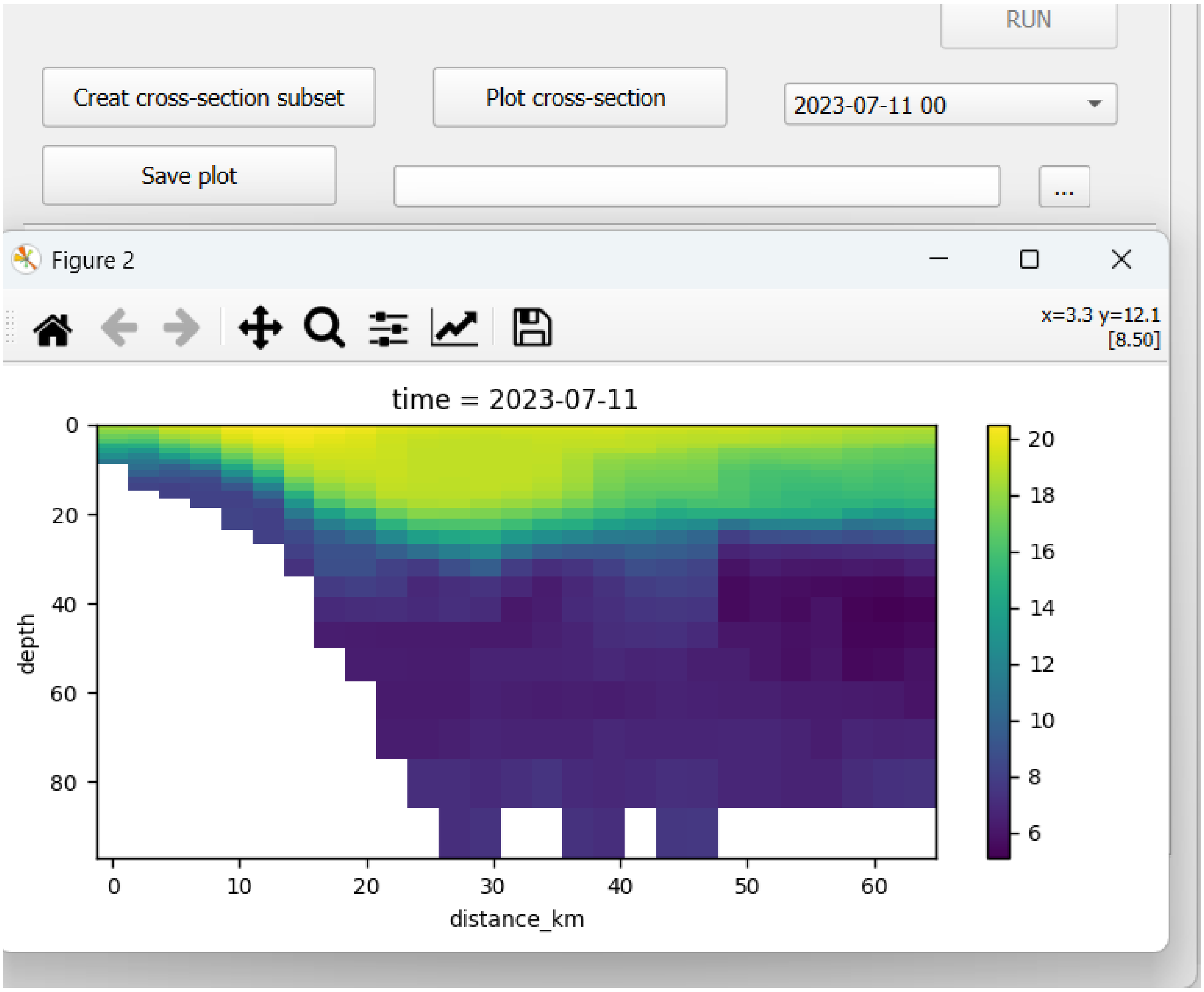
1. Enter the path and name of the existing point file (which defines the start and end of the cross section).
2. Enter the path and name of the text file to which data from points along the profile will be exported (the number of points is set in the **points inside** field).
3. Check the **export as cross-section** box. This ensures data will also be collected from points distributed along the profile.
4. Enter the number of profile points.
5. Click the **RUN** button – the **Create cross-section subset** button will become active



Click the **Cross-section subset** button. After about 30 seconds, the **Plot cross-section** button will become active, and the dropdown menu will be populated with all the dates.



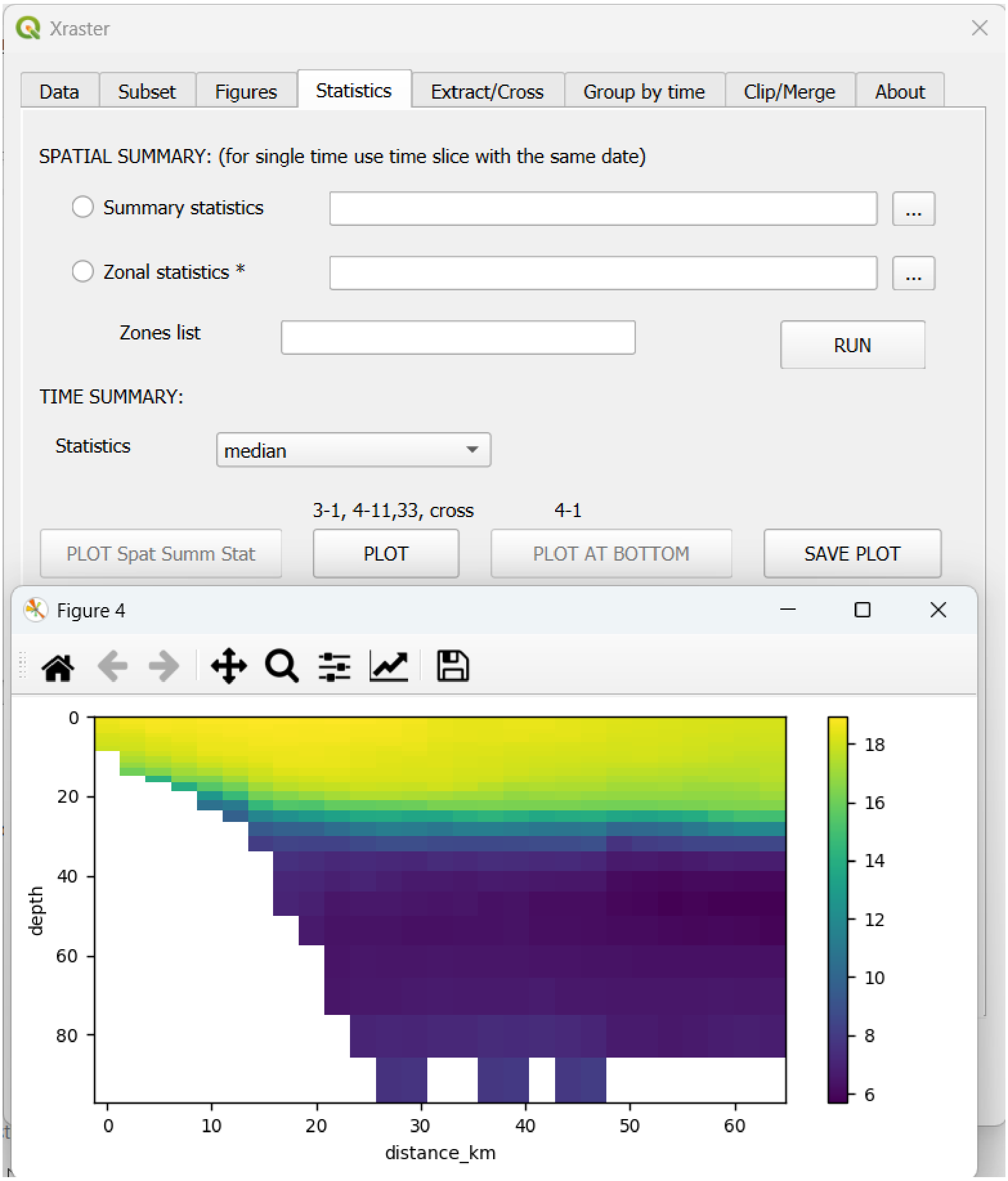
7.5 You can now select any date and, by clicking **Plot cross-section**, display its diagram. The diagram can be saved using the **Save plot** button.



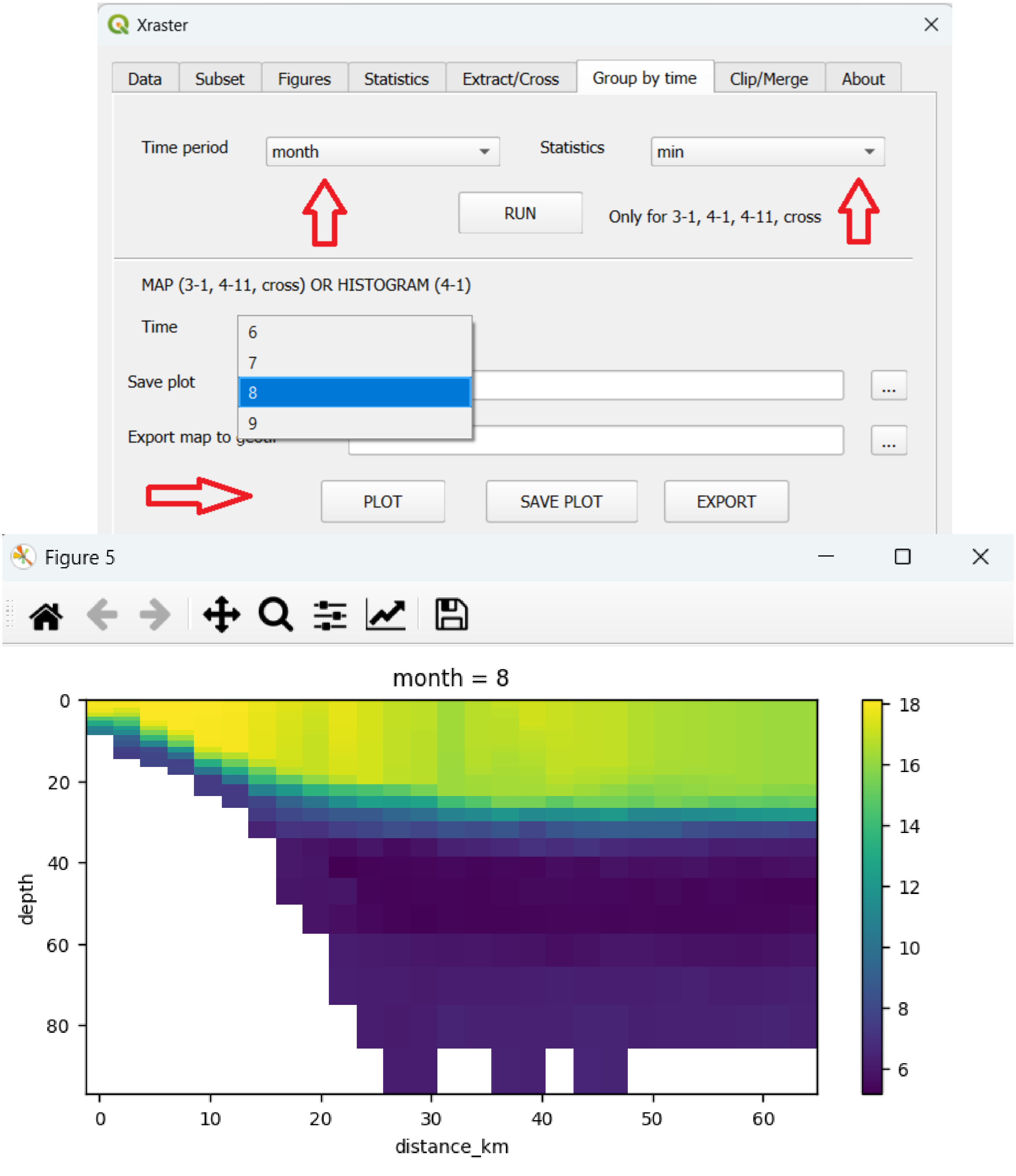
The cross-section represents a two-dimensional raster, where the x-axis is labeled with distance in kilometers, and the y-axis with depth in meters.

7.6 The created Cross-section subset is a type of subset and can be analyzed like any other subset. Using the STATISTICS tab, we can generate a statistics map from the entire cross-section subset.

We select the desired statistic in the **Statistics** field and click **PLOT**.



7.7 Statistical analysis can also be performed in the **Group by time** tab. We divide the cross-sections into groups defined by time (Time period), select a statistic (Statistics), and click **RUN**. The statistics will be calculated for each month and can be visualized as maps. Clicking **PLOT** will generate a cross-section plot of minimum values in August (for each raster cell).

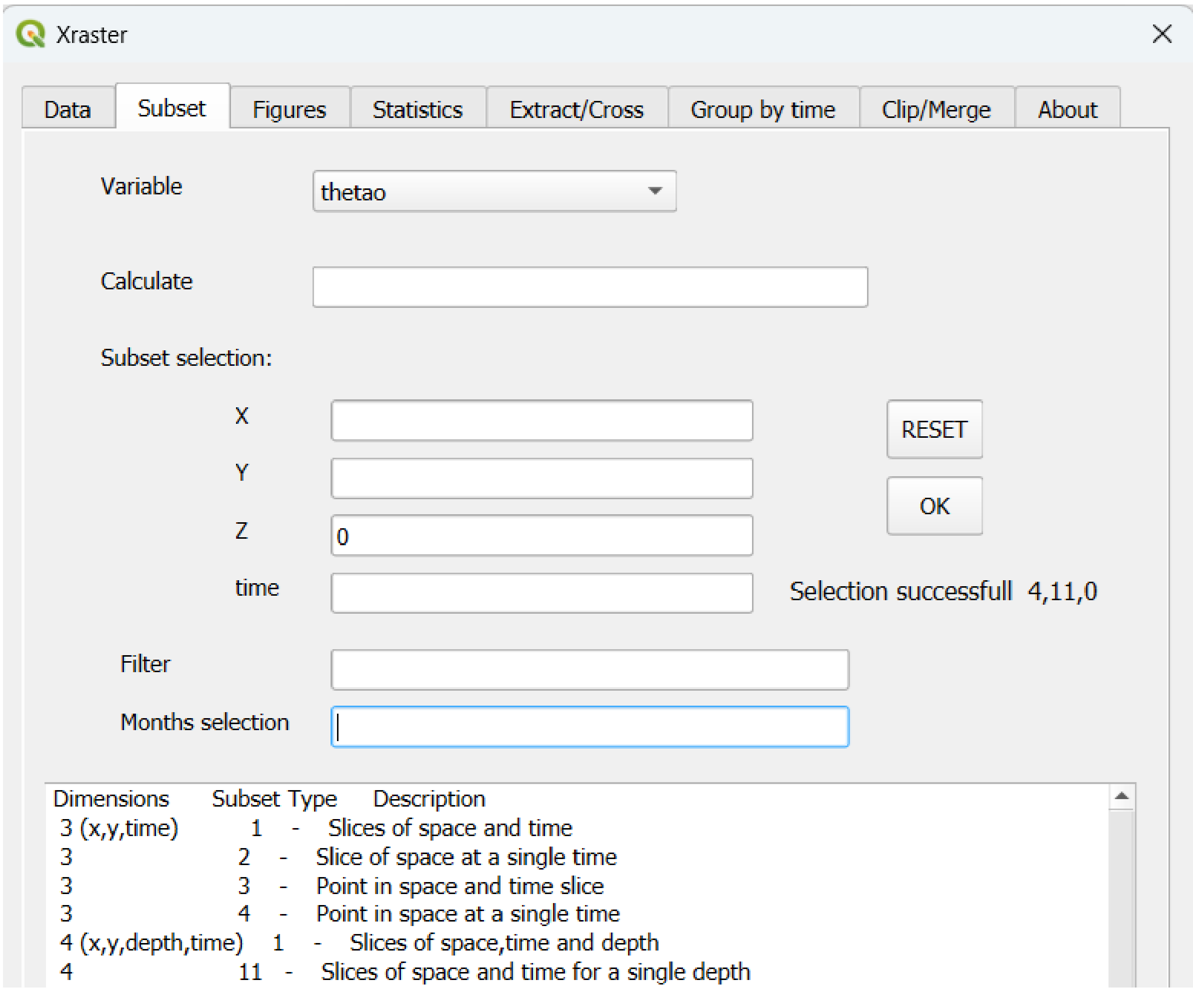


8. Reduction of NetCDF data for GIS processing using grouping.

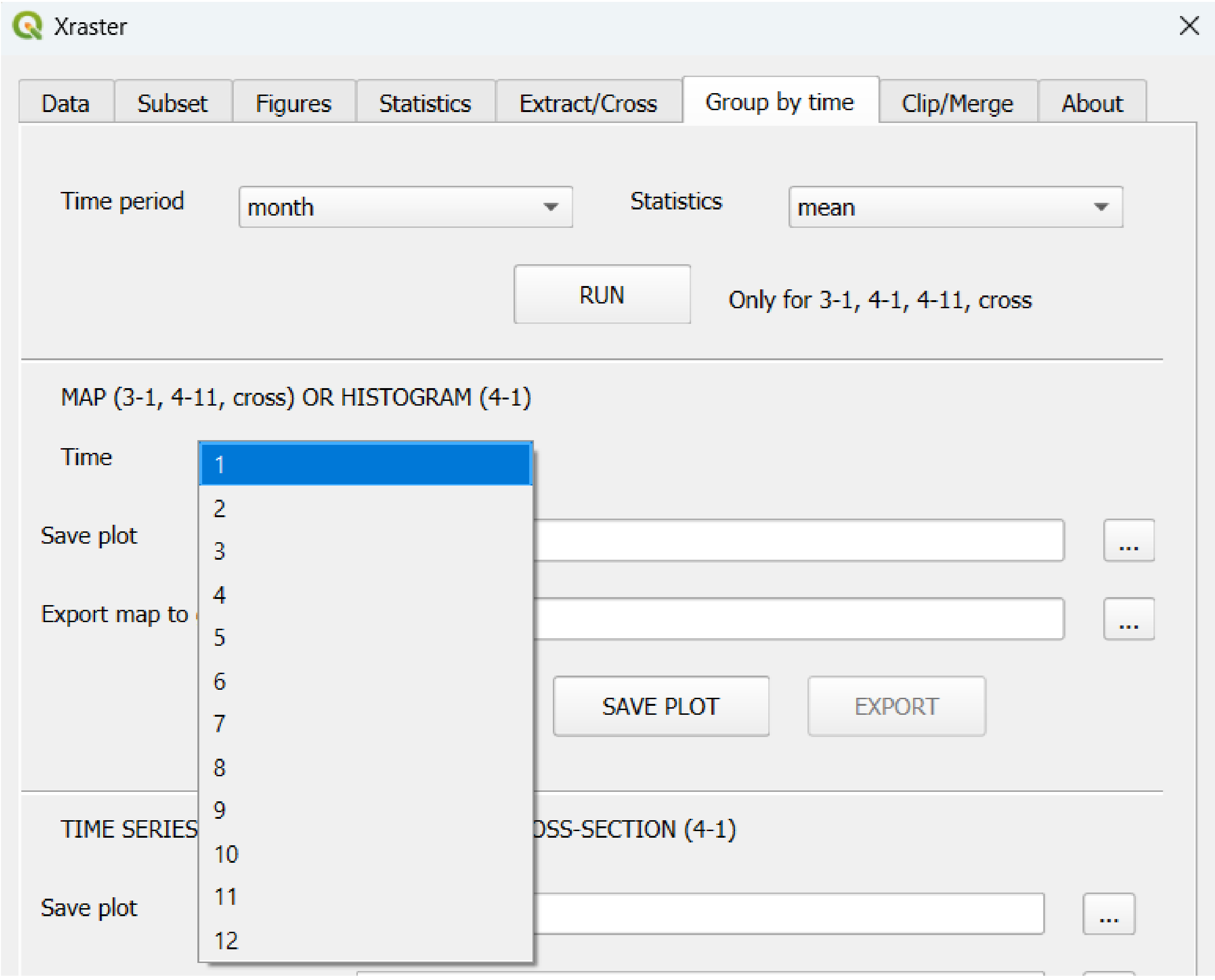
The file **BayGd_TS_2019_2023.nc** contains 54,780 two-dimensional rasters for each of the three variables, and although QGIS allows opening NetCDF files, since it imports these rasters as separate bands of a multiband raster, trying to open such a number of bands is pointless.

The proposed solution involves preliminary geoprocessing of the data. Let's assume we want to obtain the data in NetCDF format consisting of average surface temperature maps for each month. Further analysis will be carried out in QGIS. For this purpose, we can use grouping and export the resulting subset from the grouping as a `.nc` file.

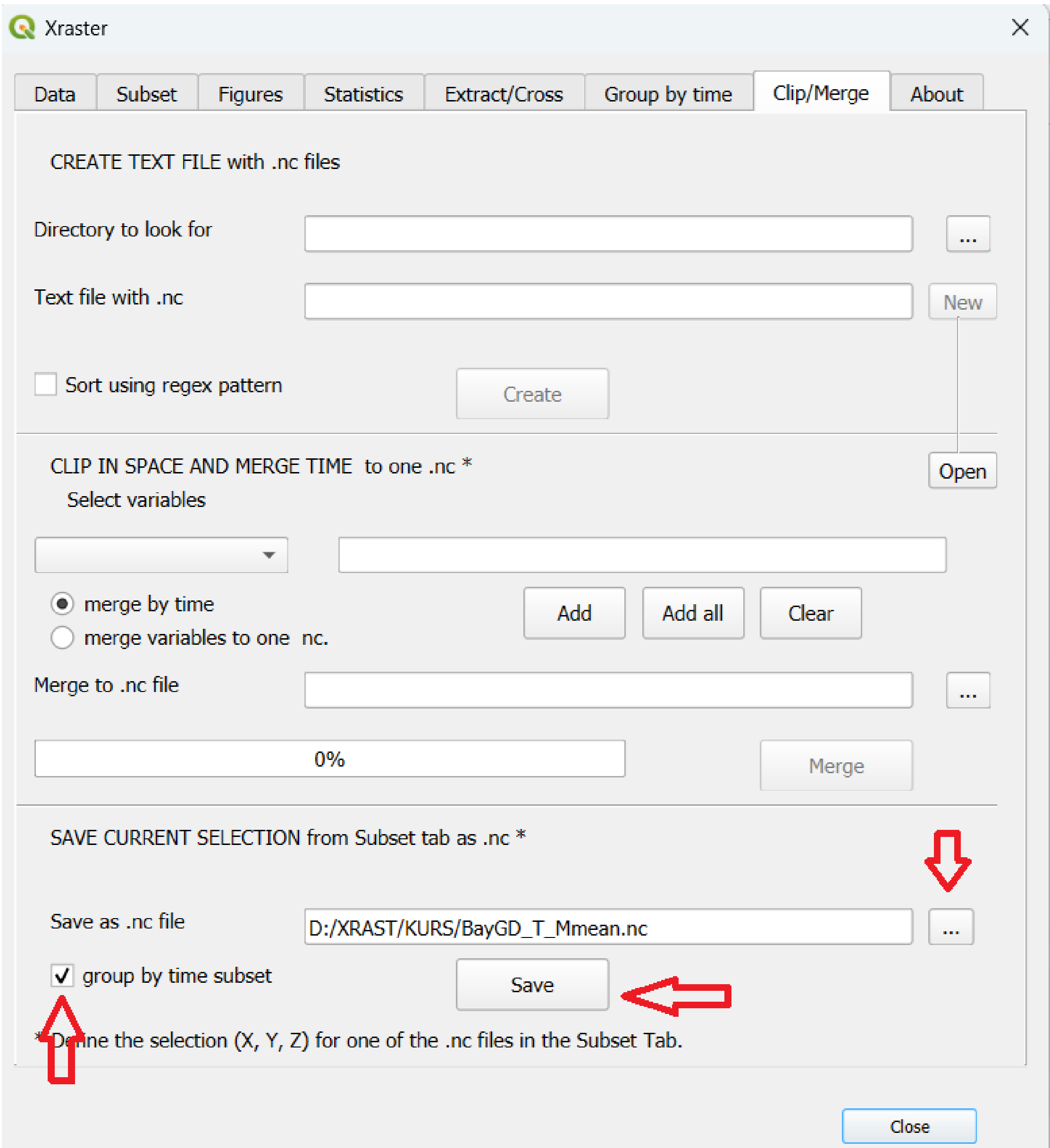
8.1 We create a subset for the temperature variable and depth 0. We set the variable as **thetao**, **Z** as **0**, and click OK. A subset of type 4.11 – *Slices of space and time for a single depth* is created.



8.2 We go to the **Group by time** tab, set **Time period** to **month** and **Statistics** to **mean**. Click **RUN**. A subset of 12 layers (one for each month) with the average value is created.



8.3 We go to the Clip/Merge tab. In the third section, SAVE CURRENT SELECTION, we check the box group by time subset, enter the name of the new `.nc` file, and click SAVE.



8.4 We can now open the created NetCDF file. It will have 12 bands corresponding to the average temperature layers for each month. In order for the layers to be displayed correctly, the coordinate reference system must be specified.