Exercise 2: Predict coral reef bleaching with multidimensional data

How can I print an exercise to PDF format?

Software Requirements:

- ArcGIS Pro 3.1
- ArcGIS Image Analyst

Introduction

In ArcGIS Pro, you can use powerful analysis tools to model real-world conditions. You can visualize and analyze multidimensional data in different ways to see how values have changed over time and predict how values may change. Using historical data, models can predict potential future outcomes, which can inform decision makers. Multidimensional data provides a way to view data that has been captured at multiple instances—and sometimes at multiple depths or heights, in the form of a data cube. The dimensions define which slice or view of the data is visible at a given collection instance. Many atmospheric or oceanographic datasets can be viewed this way. Multidimensional data gives you insight into how values may have changed by including the aspect of time or other dimensions, such as depth with oceanographic data.

Scenario

Many marine species depend on healthy coral reef ecosystems for food, shelter, and reproduction. One of the biggest threats to coral reefs is increasing temperatures. When water is too warm, coral experience bleaching; bleaching leaves coral stressed and vulnerable to other threats. In this exercise, you will use multidimensional data of sea surface temperatures in and around the Gulf of Mexico and Caribbean Sea from 1980 to 2022. You will use this data to predict which coral reef areas may be affected by increased warming.

Note: This exercise provides a simplified starting point for what is often a much more in-depth workflow. The data and parameters that are used in this exercise are not intended to be a comprehensive list of what might be required for this type of analysis.

Note: The exercises in this course include View Result links. Click these links to confirm that your results match what is expected.

Estimated completion time in minutes: 45 minutes

Expand all steps | Collapse all steps

- Step 1: Download the course data

In this step, you will download and extract the data for the exercise.

a In a web browser, go to the Multidimensional Data item provided by Esri.

Note: The complete URL to the exercise data file is https://www.arcgis.com/home/item.html?id=efd639b1d97843b59d15473a25225d31.

The size of this dataset is 85 MB, so be sure that your computer has enough space to download the data.

b Near the upper-right corner of the web page, click Download, and then extract the zipped file to the **C:\EsriMOOC\Data** folder.

c When you are finished, close the web browser and close File Explorer.

- Step 2: Create a new ArcGIS Pro project

In this step, you will create a new ArcGIS Pro project to use for your coral reef analysis.

a Restore ArcGIS Pro and your DallasDevelopment project.

b On the ribbon, click the Project tab.

Note: If you exited ArcGIS Pro at the end of the previous exercise, start ArcGIS Pro and sign in with your MOOC credentials, if necessary.

c On the New tab, under New Project, click Map to open a new map.

d In the Create A New Project dialog box, for Name, type **CoralReefPrediction**.

e For Location, browse to **..\EsriMOOC**, select the Projects folder, and click OK.

f Uncheck the box for Create A New Folder For This Project, and then click OK to create the new project.

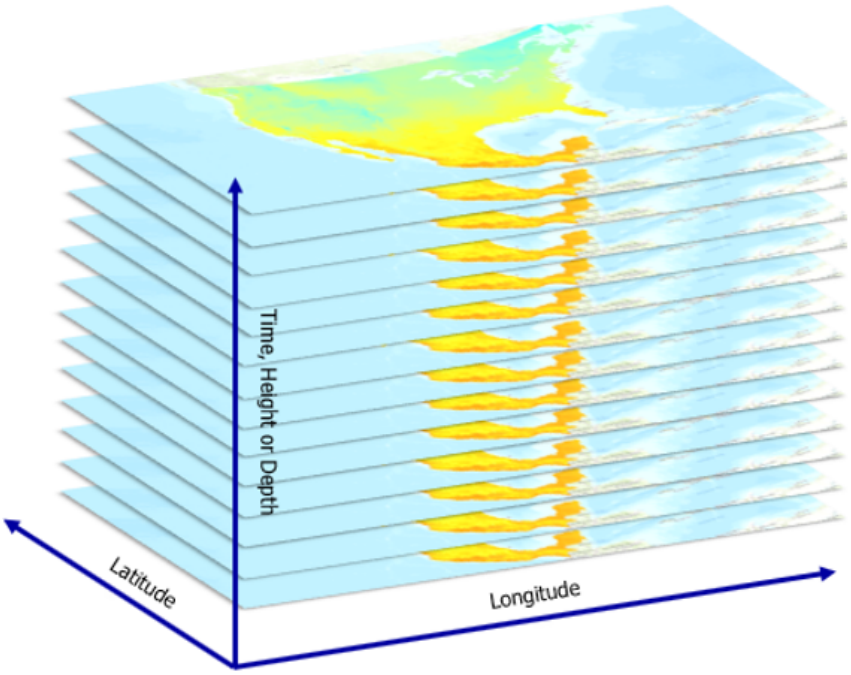
Your CoralReefPrediction project now has a Topographic basemap displayed in the map view and is ready for you to add your data.

- Step 3: Add multidimensional data

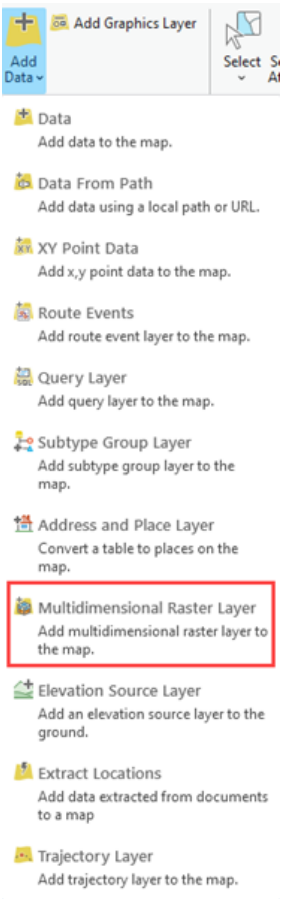
In this step, you will add NetCDF multidimensional data to the map to visualize sea surface temperatures.

Multidimensional raster data can help visualize complex datasets that are captured over multiple times, depths, or heights. The data is organized into a cube of tiles and is visualized through selection of data variables and time slices. This allows you to work with your data in multiple ways. The time component of multidimensional raster data gives you greater insight into changes over time.

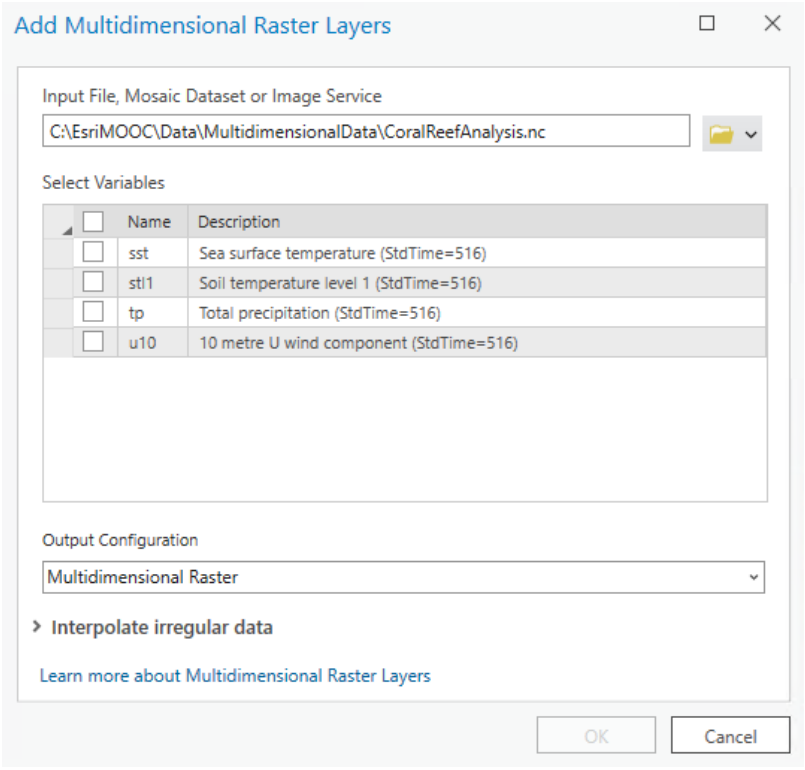
For more information about multidimensional raster data, go to ArcGIS Pro Help: Multidimensional raster data.



a In ArcGIS Pro, on the Map tab, in the Layer group, click the Add Data down arrow and choose Multidimensional Raster Layer, as indicated in the following graphic.



b In the Add Multidimensional Raster Layers dialog box, next to Input File, Mosaic Dataset Or Image Service, click the Import Variables button and browse to **..\EsriMOOC\Data\MultidimensionalData**, and then select CoralReefAnalysis.nc and click OK.

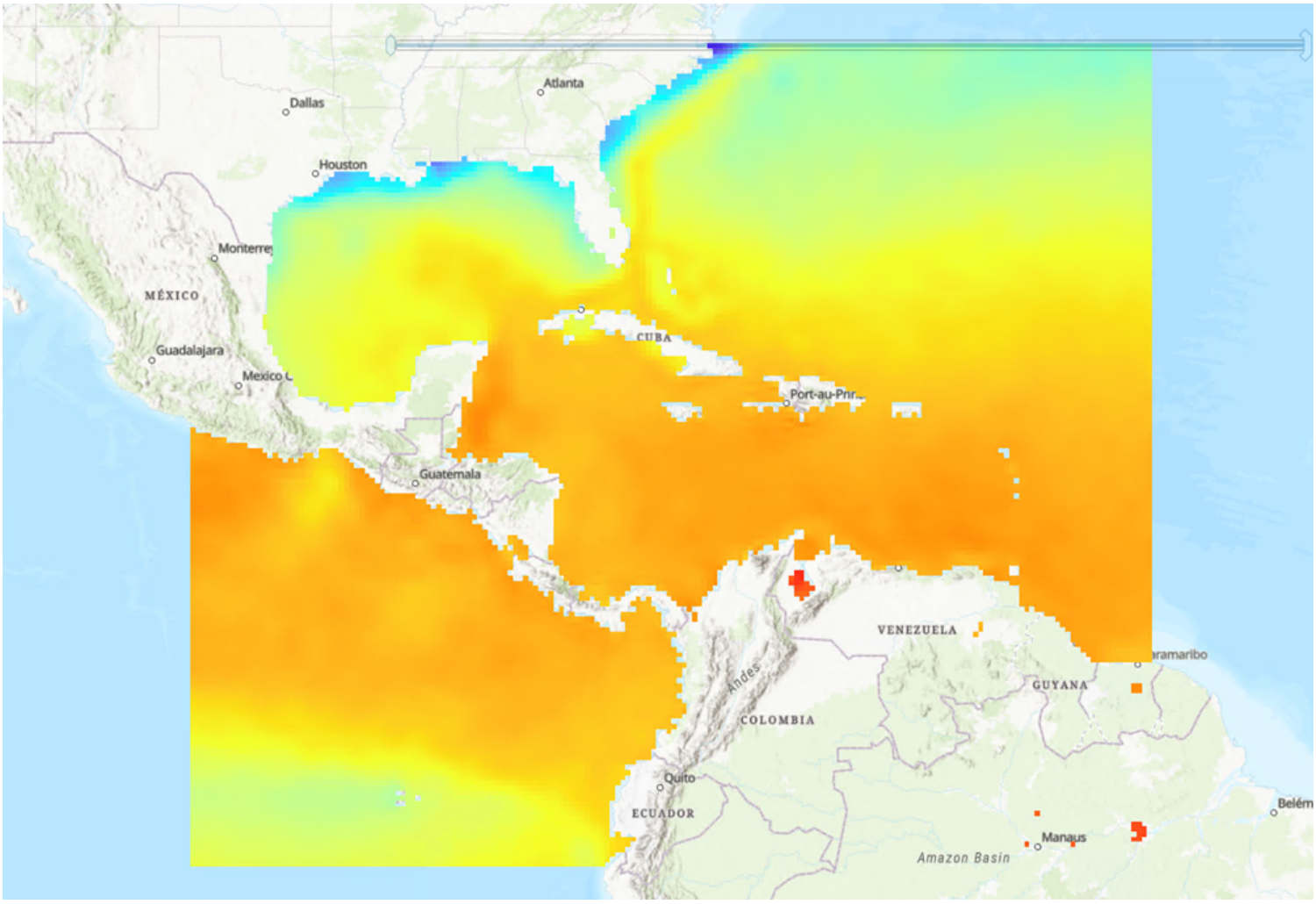


*Step 3b***: Add multidimensional data.*

There are four variables available with this dataset: sea surface temperature, soil temperature, total precipitation, and wind speed.

c Under Select Variables, check the box for sst (Sea Surface Temperature).

d Click OK.



*Step 3d***: Add multidimensional data.*

The multidimensional raster layer is added to the map and displays the sea surface temperature. Sea surface temperature is defined as the water and/or sea ice temperature close to the surface. The water depth ranges from 1 millimeter to 20 meters. The data provider indicates that the temperature units are Kelvin (K). When converted to Fahrenheit (F), the range of values is between 51.69 degrees F and 87.72 degrees F (284.092 K and 304.108 K). For more information about sea surface temperature, go to the S2S Sea Surface Temperature article (https://links.esri.com/SeaSurfaceTemp | https://confluence.ecmwf.int/display/S2S/S2S+Sea+Surface+Temperature).

e On the ribbon, click the Multidimensional tab.

? In the Current Display Slice group, what is the StdTime reported?

- Answer
The time reported is 1980-01-01T00:00:00.

The Current Display Slice indicates which variable is being displayed and which dimension is selected. For this particular multidimensional raster layer, the sea surface temperature is the variable being displayed. The dimension is time, displayed as year-month-day-time.

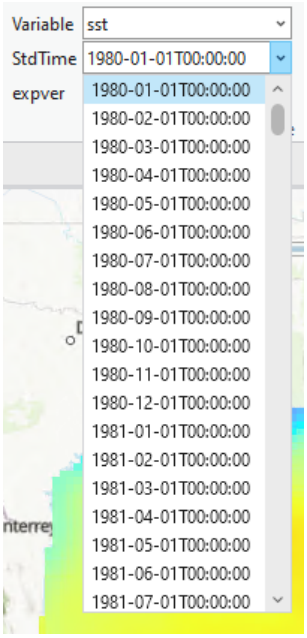
f Save the project.

You added the data that you will use to analyze areas where coral reefs may be affected by prolonged exposure to warmer temperatures.

- Step 4: Visualize the multidimensional raster layer

In this step, you will configure the multidimensional raster layer to see different views of sea surface temperature at various times.

a On the Multidimensional tab, in the Current Display Slice group, click the StdTime down arrow to see the available time slices.



*Step 4a***: Visualize the multidimensional raster layer.*

b In the drop-down list, scroll down to the last available time slice and click it.

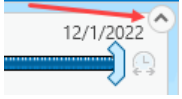
? Which StdTime value is listed in the Current Display Slice group?

- Answer
The value is 2022-12-01T00:00:00.

Note: The StdTime values in the Current Display Slice group indicate the year, month, day, and time. During the creation of the multidimensional raster file, the values were aggregated into each month. Therefore, the portion of the slice represented as 01T00:00:00 indicates that there is only one value per month. If the multidimensional raster layer contained information about individual days or hours/minutes, then the values would indicate which the exact time.

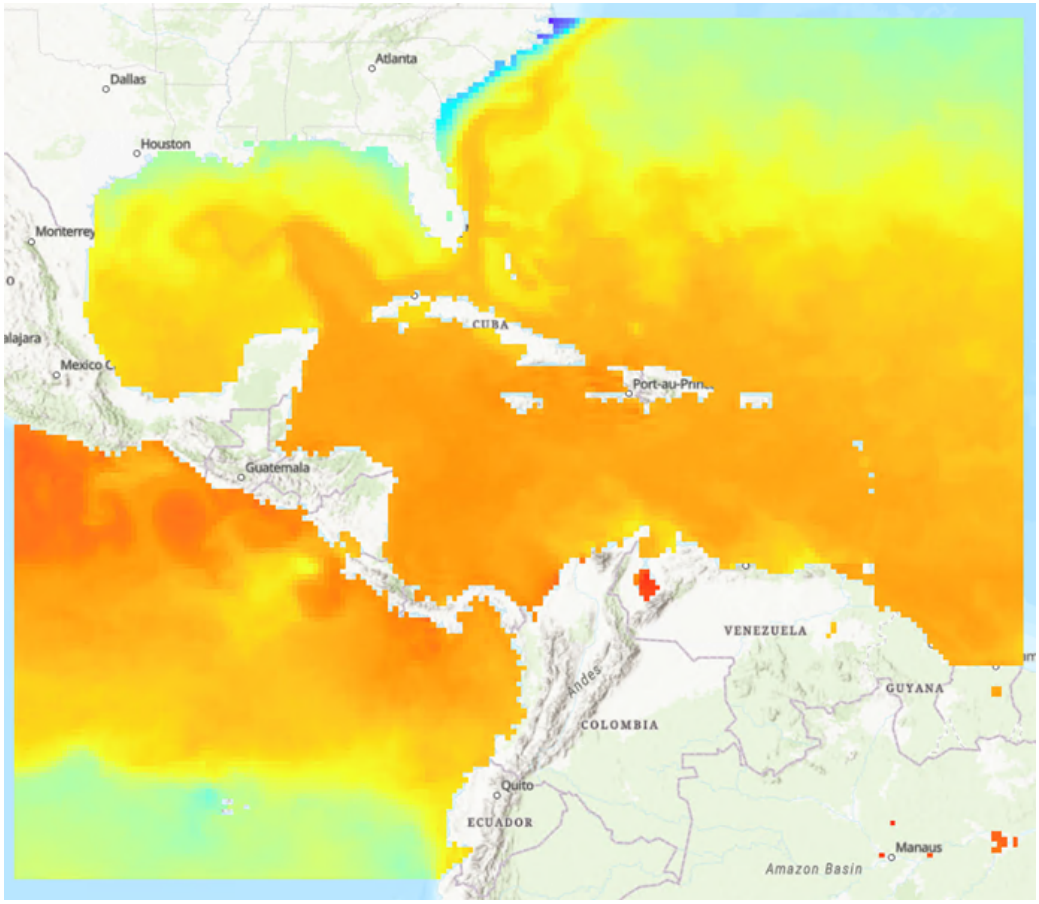
In the upper-right corner of the map view, the time slider is visible. The time slider will not be used for this exercise, so you will minimize it.

c Point to the time slider, and then in the upper-right corner of the time slider, click the Minimize button, as indicated in the following graphic.



In ArcGIS Pro, you can also quickly visualize how the temperatures change over time with animation.

d In the Current Display Slice group, update StdTime to the 2022-01-01T00:00:00 slice.



*Step 4d***: Visualize the multidimensional raster layer.*

e To the right of the StdTime field, click the Play button ▶ to animate the multidimensional raster.

You will see the display change as each 2022 time slice is displayed in the map.

f After you have seen the final time slice of 2022 (2022-12-01T00:00:00), click the Pause button ⏸ to stop the animation.

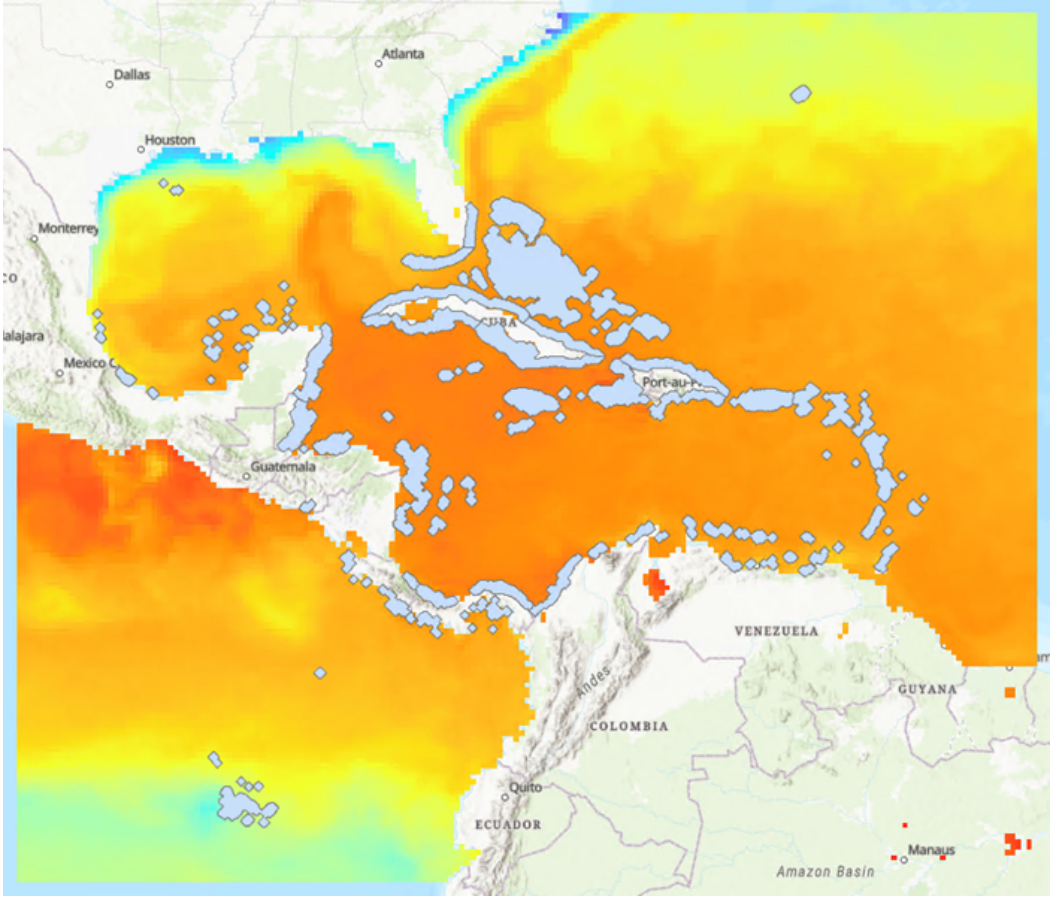
Note: If the animation is not paused on the final time slice, (2022-12-01T00:00:00), reset the time slice to (2022-12-01T00:00:00).

- Step 5: View temperature changes over time

Because the purpose of this analysis is to consider how sea surface temperature changes affect coral reefs, the next step is to add a feature layer to represent the locations of the coral reefs. You will then visualize changes in temperature over time both in the map, focusing in on the coral reefs, and in a chart.

a In the Catalog pane, expand Folders and Data, and then right-click CoralReefAreas.shp and choose Add To Current Map.

Note: Depending on how the data was extracted, it may be necessary to navigate one more folder level to the MultidimensionalData folder to find the CoralReefAreas.shp.



*Step 5a***: View temperature changes over time.*

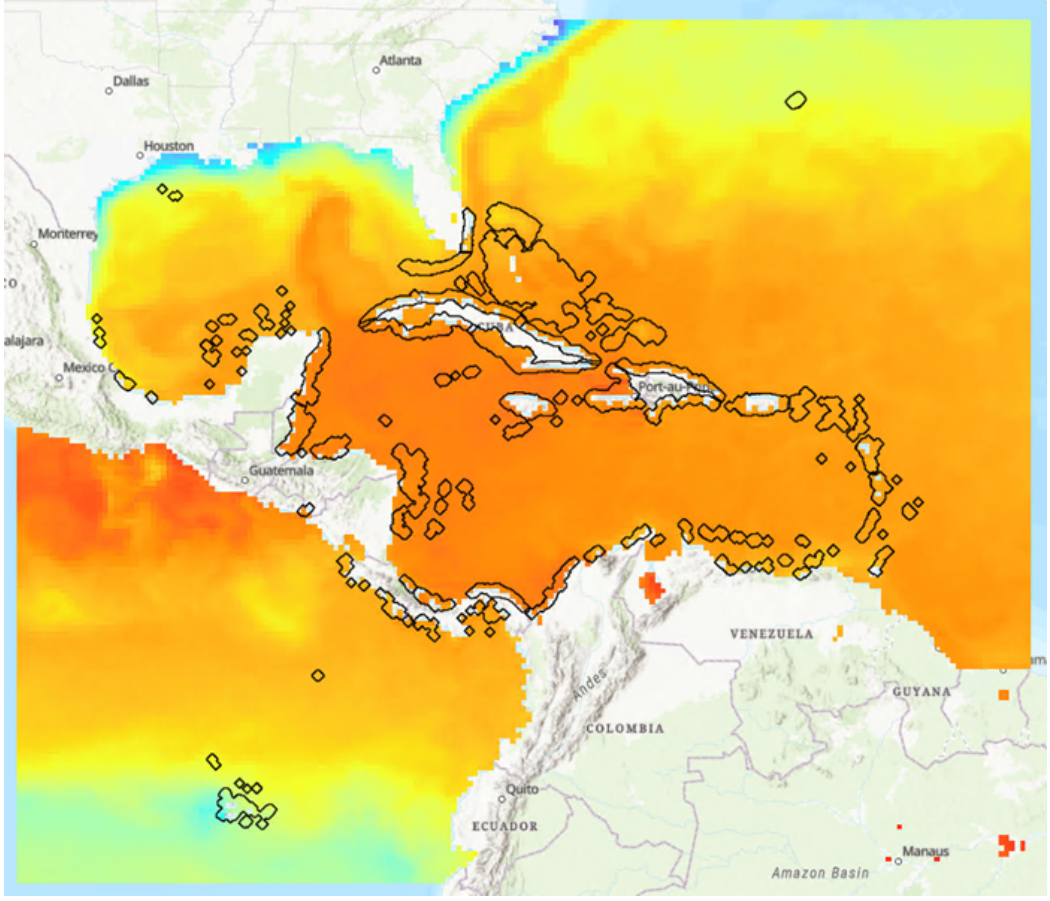
Note: The symbology color that is displayed in your map may differ from the preceding graphic.

If you did not previously create the folder connection to the Data folder, perform the following steps:

1. In the Catalog pane, right-click Folders and choose Add Folder Connection.
2. In the Add Folder Connection dialog box, browse to **..\EsriMOOC**, click the Data folder to select it, and click OK to add the connection.

b In the Contents pane, underneath the CoralReefAreas layer, click the symbol to open the Symbology pane.

c In the Symbology pane, under ArcGIS 2D, click Black Outline (1pt).

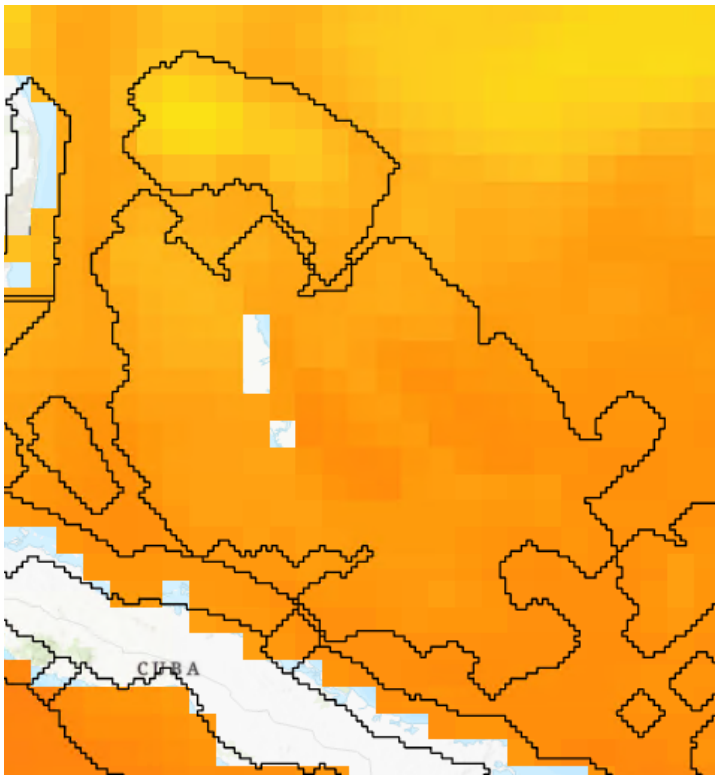


*Step 5c***: View temperature changes over time.*

The polygons indicate areas where coral reefs are located.

d Close the Symbology pane.

e In the map, zoom in near the Bahamas, which are located southeast of Miami, Florida, as shown in the following graphic.

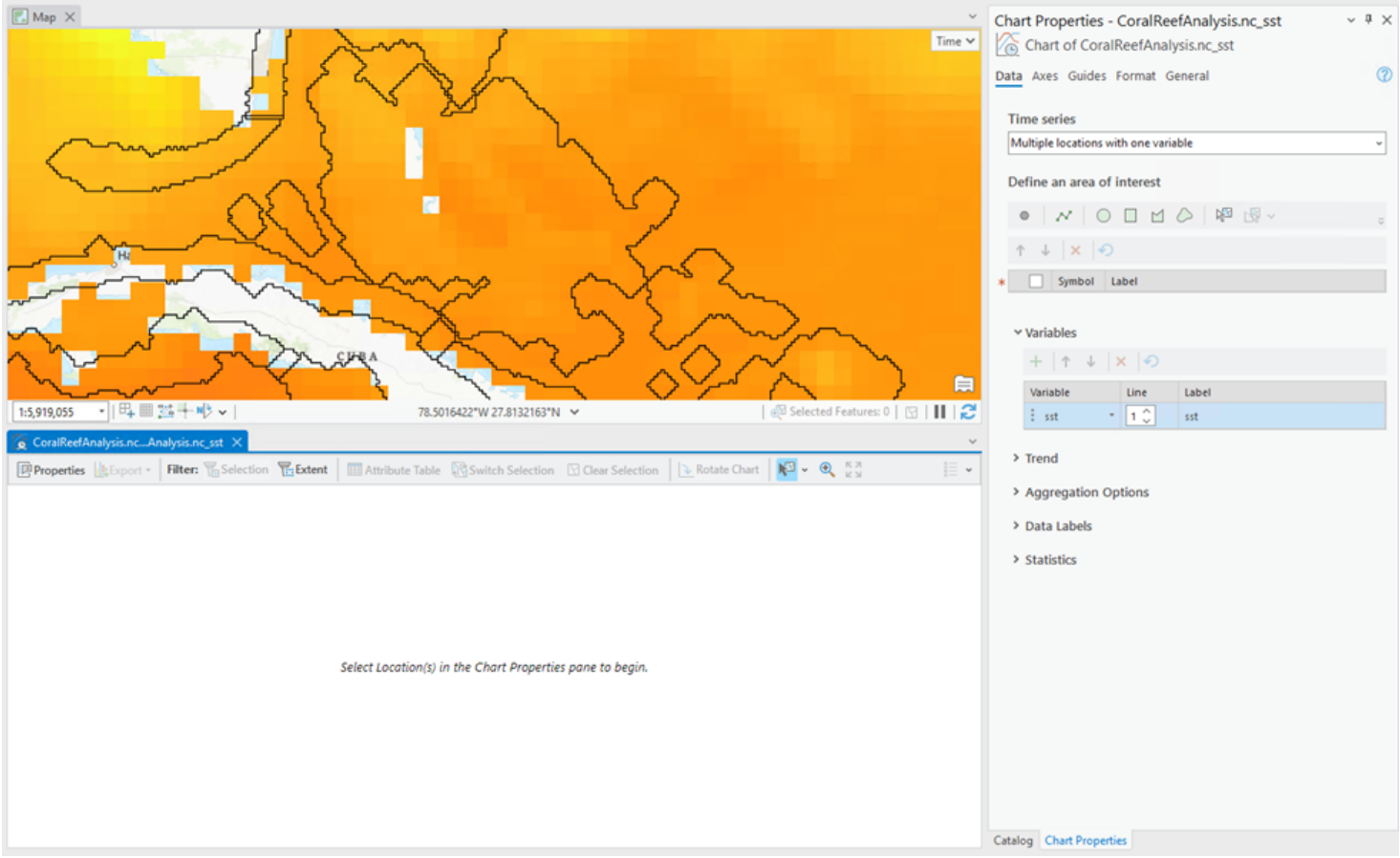


Note: You can turn off the CoralReefAnalysis.nc_sst layer to see the basemap and more easily locate the Bahamas, and then turn the layer back on.

f In the Contents pane, select the CoralReefAnalysis.nc_sst layer.

To view the changes over time, you will create a line graph chart.

g On the Multidimensional tab, in the Analysis group, click Temporal Profile.



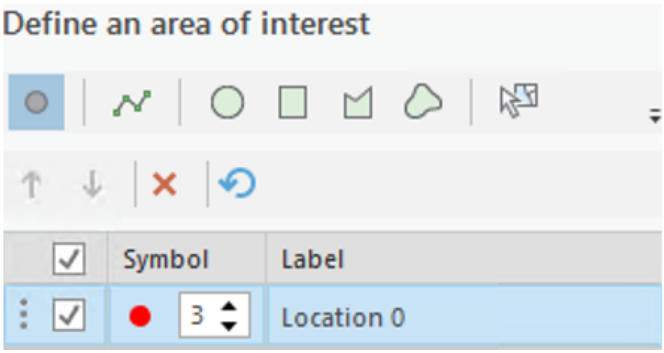
*Step 5g***: View temperature changes over time.*

The Chart Properties pane opens on the right, and a blank chart opens below the map.

h In the Chart Properties pane, under Define An Area Of Interest, click the Point button .

i In the map, click anywhere in the polygon containing the Bahamas to add a point.

j In the Chart Properties pane, in the table row that was created for your point, click the point under Symbol and update the color to red.



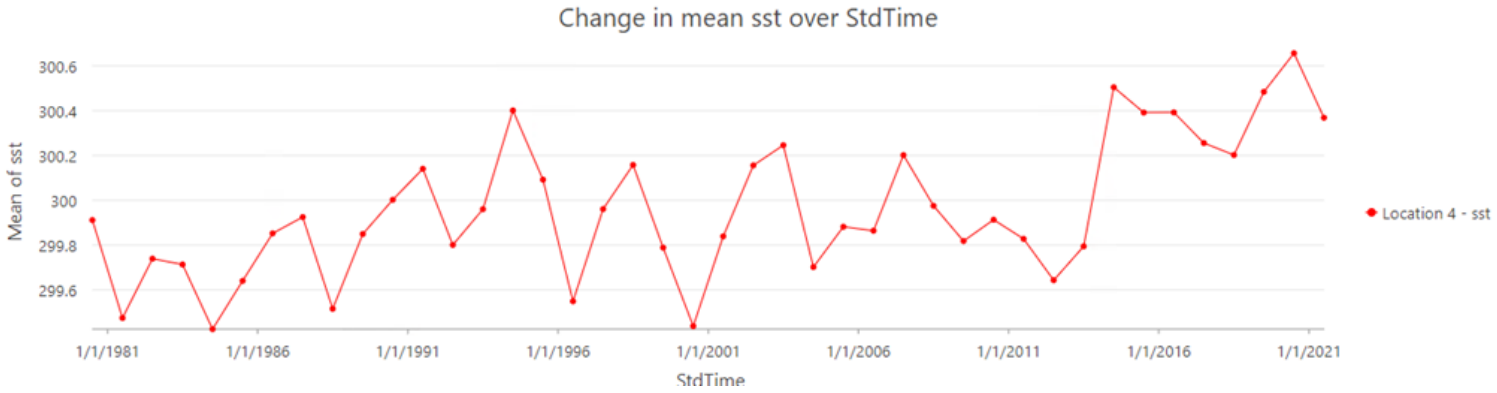
*Step 5j***: View temperature changes over time.*

The chart indicates how the mean temperature value has changed over time. To gain more insight into the changes, you will aggregate the values into yearly totals.

k In the Chart Properties pane, expand the Aggregation Options section.

l Under Time Binning Options, for Interval Size, click the calendar to open the time options.

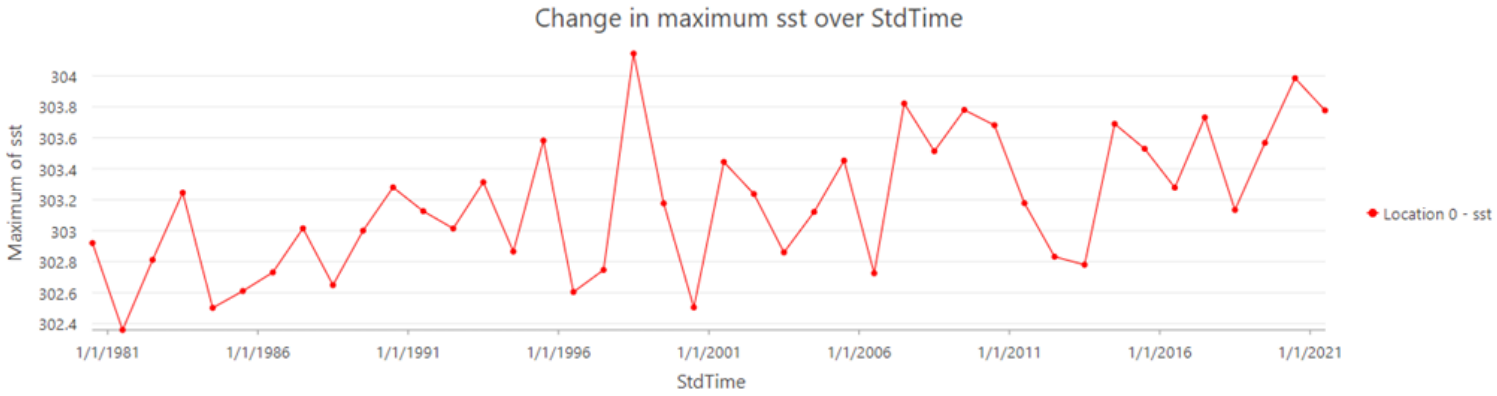
m Update the Interval Size to 1 Years, and then click away from the drop-down list to see the update reflected in the chart.



*Step 5m***: View temperature changes over time.*

The chart can also be altered by changing the time aggregation to see a different statistic.

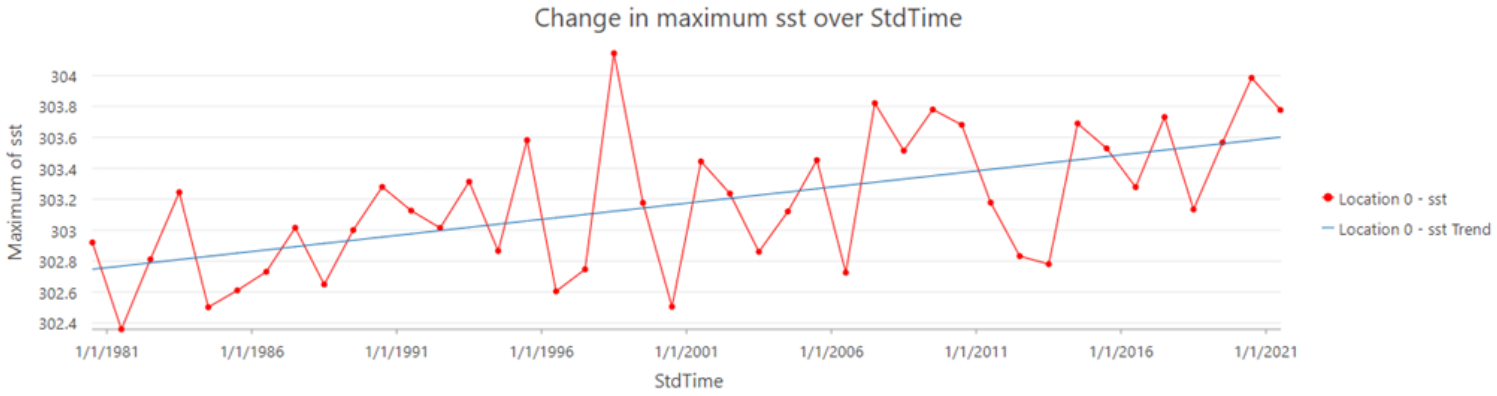
n In the Aggregation Options section, update Time Aggregation to Maximum.



*Step 5n***: View temperature changes over time.*

In the charts, the maximum temperature appears to be rising over the years, but there are still ways to configure the chart to make the trend more evident.

o In the Chart Properties pane, expand the Trend section, and then check the box for Show Trend Line.



*Step 5o***: View temperature changes over time.*

For this particular point, the sea surface temperature appears to rise in value each year. The chart is one way to see the changes in sea surface temperature. There are also ways to determine how these temperatures have trended historically and may trend in the future.

p Close the Chart Properties pane and close the chart.

Note: Closing the chart does not remove it from the project; the chart is still accessible as an item in the Contents pane.

q Save the project.

- Step 6: Visualize the trend as a raster

In this step, you will derive a new multidimensional raster dataset that indicates the trend in sea surface temperatures over time.

a In the Contents pane, right-click the CoralReefAnalysis.nc_sst layer and choose Zoom To Layer.

b On the Multidimensional tab, in the Analysis group, click Trend to open the Generate Trend Raster tool in the Geoprocessing pane.

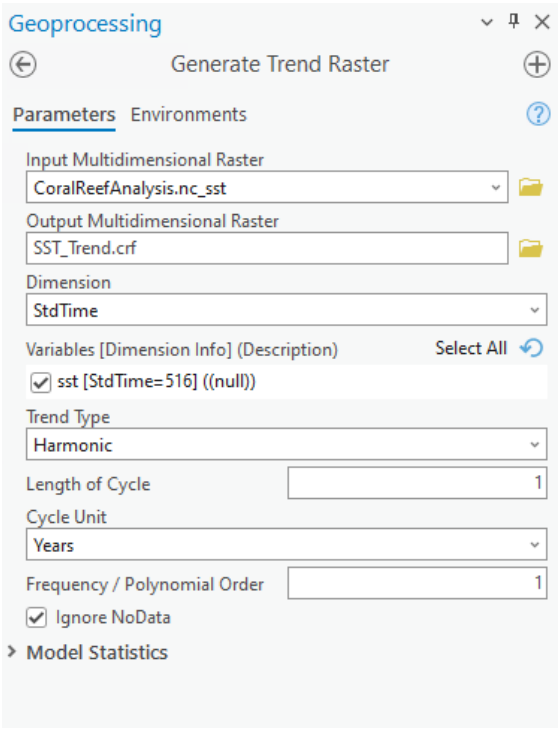
Note: If Trend is not visible, click the down arrow on the right side of the Analysis tools gallery to show all the Analysis tools.

The Generate Trend Raster tool will create a multidimensional raster that estimates the temperature trend for each pixel over the entire time series. To further refine your estimate, you will configure the parameters to adjust for cyclical patterns, such as seasonal variations in sea surface temperature.

c In the Generate Trend Raster tool, set or confirm the following parameters:

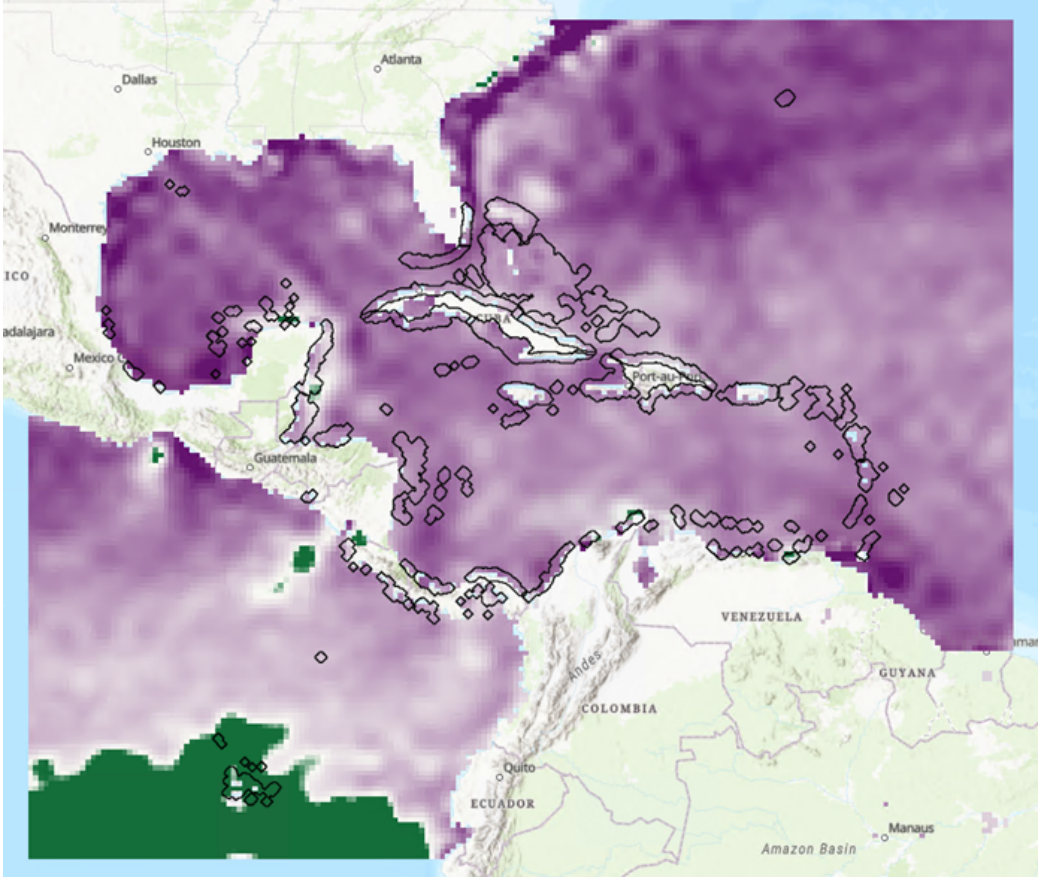
- Input Multidimensional Raster: CoralReefAnalysis.nc_sst
- Output Multidimensional Raster: ..\EsriMOOC\Data**SST_Trend.crf**
(Note: Browse to the Data folder and save the output with the name listed here in bold.)
- Trend Type: Harmonic
- Cycle Unit: Years

Note: The Harmonic Trend Type accounts for the cyclical patterns caused by seasonal temperature changes.



*Step 6c***: Visualize the trend as a raster.*

d Leave the remaining defaults and click Run.



*Step 6d***: Visualize the trend as a raster.*

The output multidimensional raster now indicates the historical direction of change or trend in temperature values between 1980 and 2022.

e In the Contents pane, observe the color ramp symbol beneath the layer and notice that positive and negative values are present.

The positive and negative values represent the slope, or rate of change, in each pixel. Positive values are purple, indicating an increasing temperature trend. Negative values are green, indicating a decreasing trend.

? How many slices are available for display in the map?

- Answer

There is only one slice: 1980-01-01T00:00:00 – 2022-12-01T00:00:00.

- Hint

Current Display Slice group > StdTime down arrow

Now that you have created the trend raster to indicate how the values have changed over time, you are ready to create the prediction multidimensional raster.

- Step 7: Predict future values as a raster

Looking at the multidimensional raster slices individually and viewing the trend as a whole gives you an idea of historical changes to sea surface temperature. In this step, you will derive a new multidimensional raster data that will predict how sea surface temperature values may change in the future.

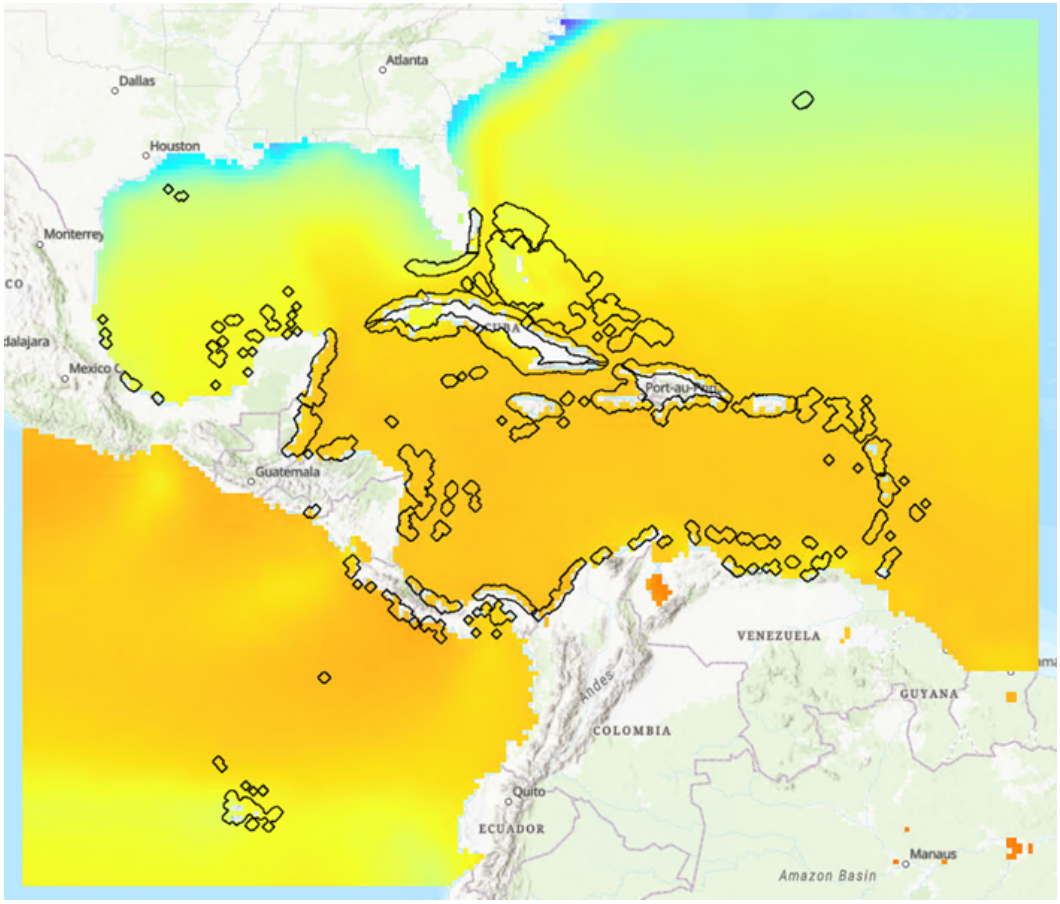
a On the Multidimensional tab, in the Analysis group, click Predict to open the Predict Using Trend Raster tool in the Geoprocessing pane.

The Predict Using Trend Raster tool creates a multidimensional raster that will predict future temperature values based on the trend raster.

b In the Predict Using Trend Raster tool, set or confirm the following parameters:

- Input Trend Raster: SST_Trend.crf
- Output Multidimensional Raster: ..\EsriMOOC\Data**SST_Predict.crf**
- Dimension Definition: By Interval
- Start: **1980-01-01T00:00:00**
- End: **2030-12-01T00:00:00**
- Unit: Months

c Leave the remaining defaults and click Run.



*Step 7c***: Predict future values as a raster.*

The new multidimensional raster contains predictions of values—in this case, temperature—by month, up to the year 2030. Based on the parameters of the input trend raster, the prediction considers the cyclical variation of seasonal sea surface temperatures. You can cycle through the predicted time slices (2023-2030) to see how the predictions change though the seasons and the years.

d Update the current display slice of the SST_Predict.crf layer to be the last time slice in 2030 (2030-12-01T00:00:00).

? In the Contents pane, what is the maximum value listed for the prediction raster?

- Answer

The maximum value listed is 306.38.

? Consider the maximum value of the CoralReefAnalysis.nc_sst layer. How has the maximum value changed from the CoralReefAnalysis.nc_sst layer?

- Answer

The maximum value has increased in the prediction raster.

You used the trend raster to create a prediction of sea surface temperatures up to 2030. You will now use the prediction raster to identify possible anomalies in the prediction values.

- Step 8: Identify anomalies in the prediction

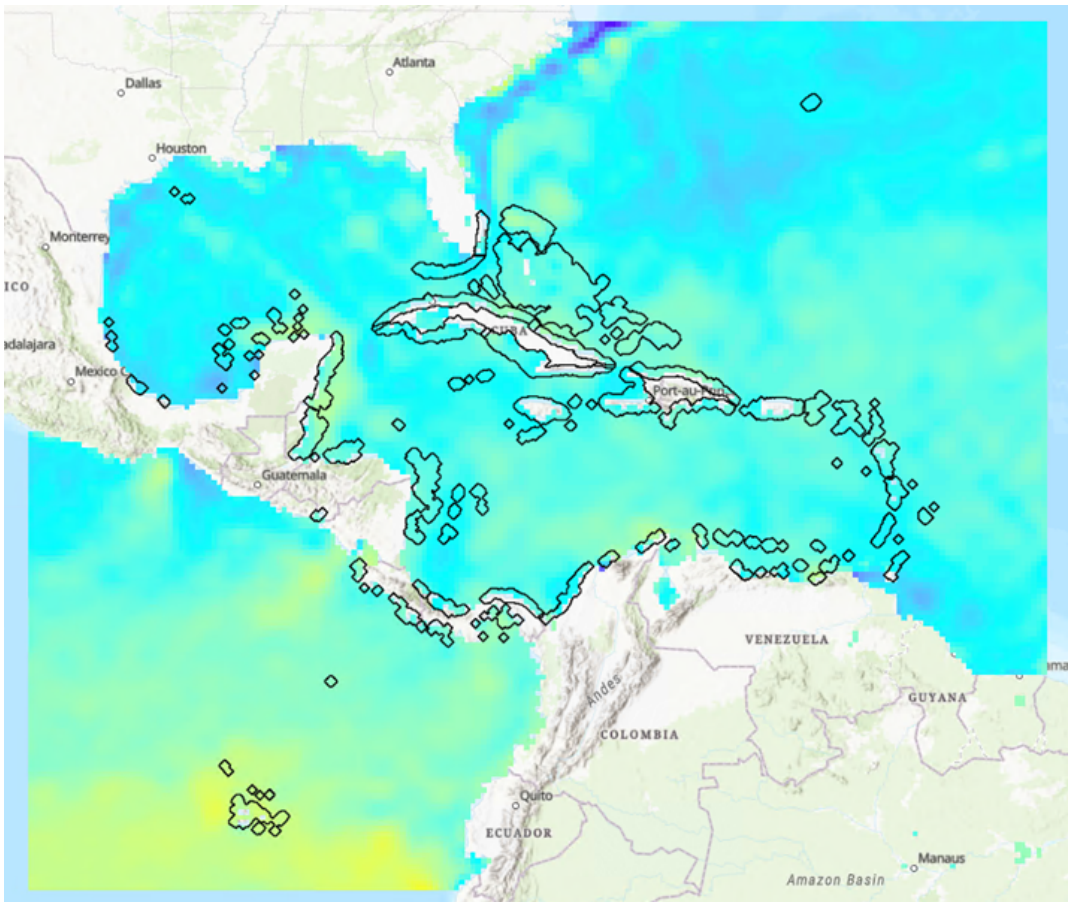
In this step, you will identify potential anomalies where predicted temperature values have deviated above or below the mean, or average, temperature.

Finding areas where the values vary the most from the mean sea surface temperature is a good way to predict which coral reefs may be under the most stress. These variations are considered to be anomalies. An anomaly is something that deviates from what is expected; it is an outlier. Sometimes an anomaly indicates an error in the data, but often, an anomaly is a predictor of change. In this analysis, anomalies can alert you to coral reef areas experiencing higher than average temperatures. With the Generate Multidimensional Anomaly tool, you can calculate anomalies by time slice.

a On the Multidimensional tab, in the Analysis group, click Anomaly to open the Generate Multidimensional Anomaly tool, and then set or confirm the following parameters:

- Input Multidimensional Raster: SST_Predict.crf
- Output Multidimensional Raster: ..\EsriMOOC\Data**SST_Anomaly.crf**
- Anomaly Calculation Method: Difference From Mean
- Mean Calculation Interval: Recurring Monthly

b Click Run.



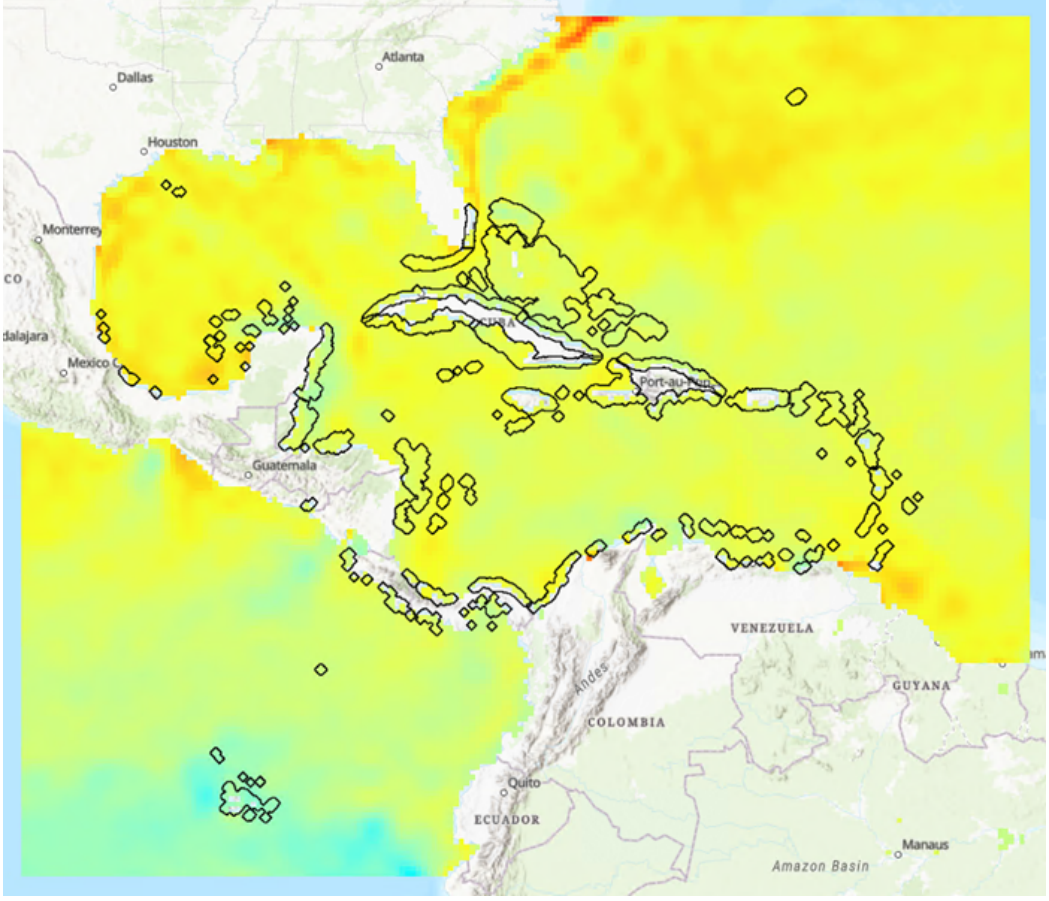
*Step 8b***: Identify anomalies in the prediction.*

Note: If your map does not match the preceding graphic, confirm that the current display slice is set to 1980-01-01T00:00:00.

The anomaly multidimensional raster indicates variation from the monthly mean temperature. Observe the color ramp symbol for the new multidimensional raster and notice the positive and negative values. The positive values are yellow to red, indicating values above the mean. The negative values are shades of blue, indicating values below the mean. In this slice, from January 1980, there are some coral reef areas above the mean, including around Mexico's Yucatan Peninsula.

c Cycle through some time slices to see how the anomalies change over the months and years.

d Update the current display slice to 2030-12-01T00:00:00.



*Step 8d***: Identify anomalies in the prediction.*

In this time slice, you can see that most of the coral reefs are in areas with higher sea surface temperature anomalies. Although rising temperatures may be a cause for concern, it is when coral reefs are exposed to prolonged warming that they will experience bleaching. Now that you have predicted the anomalies, you will determine which areas may be exposed to prolonged rising temperatures and are in danger of bleaching.

- Step 9: Measure the duration of exposure

In this step, you will measure the duration of exposure to warming temperatures, which will help you determine which coral reef areas are at highest risk of long-term exposure to higher temperatures.

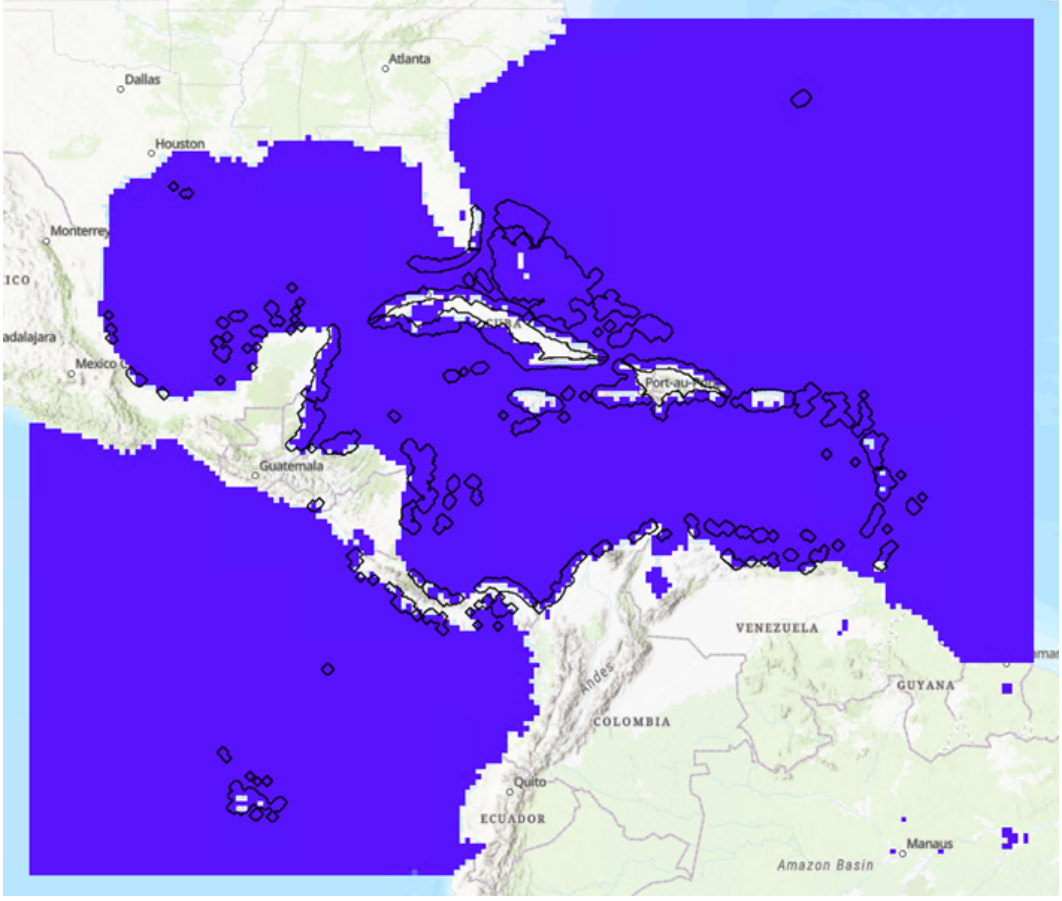
a On the Multidimensional tab, in the Analysis group, click Find Argument Statistics, and then set or confirm the following parameters:

- Input Multidimensional Or Multiband Raster: SST_Anomaly.crf
- Dimension: StdTime
- Output Raster: ..\EsriMOOC\Data**SST_ArgStatistics.crf**
- Statistics Type: Duration
- Dimension Definition: Interval Keyword
- Keyword Interval: Yearly
- Minimum Value: **0.5**
- Maximum Value: **3**

Note: Setting the Minimum Value and Maximum Value parameters to 0.5 and 3, respectively, will find the number of months in a year when temperature is between 0.5 and 3 degrees above average for each location.

Organizations support findings that even if global sea temperatures increase 1.5 degrees Kelvin or Celsius (3.8 degrees Fahrenheit) marine ecosystems, including coral reefs, will be impacted.

b Click Run.



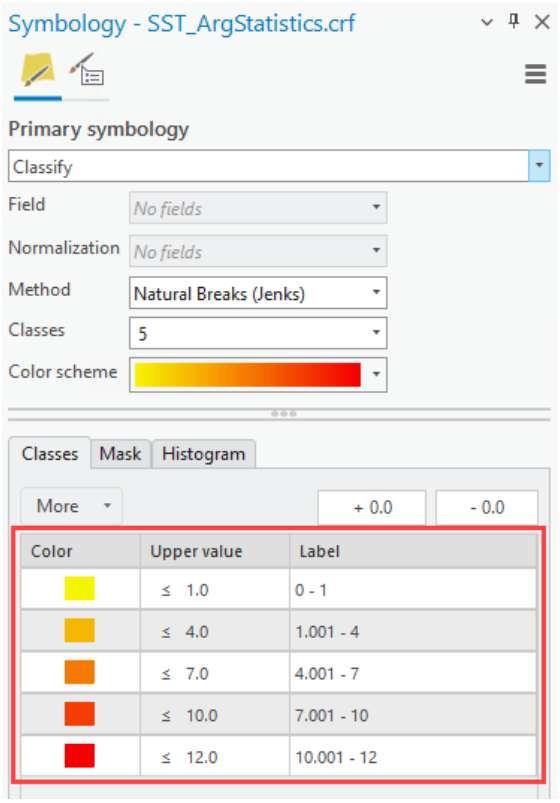
*Step 9b***: Measure the duration of exposure.*

The default symbology of the results of the Find Argument Statistics tool is visualized with the Stretch renderer. To interpret the output, you will change the renderer to Classify.

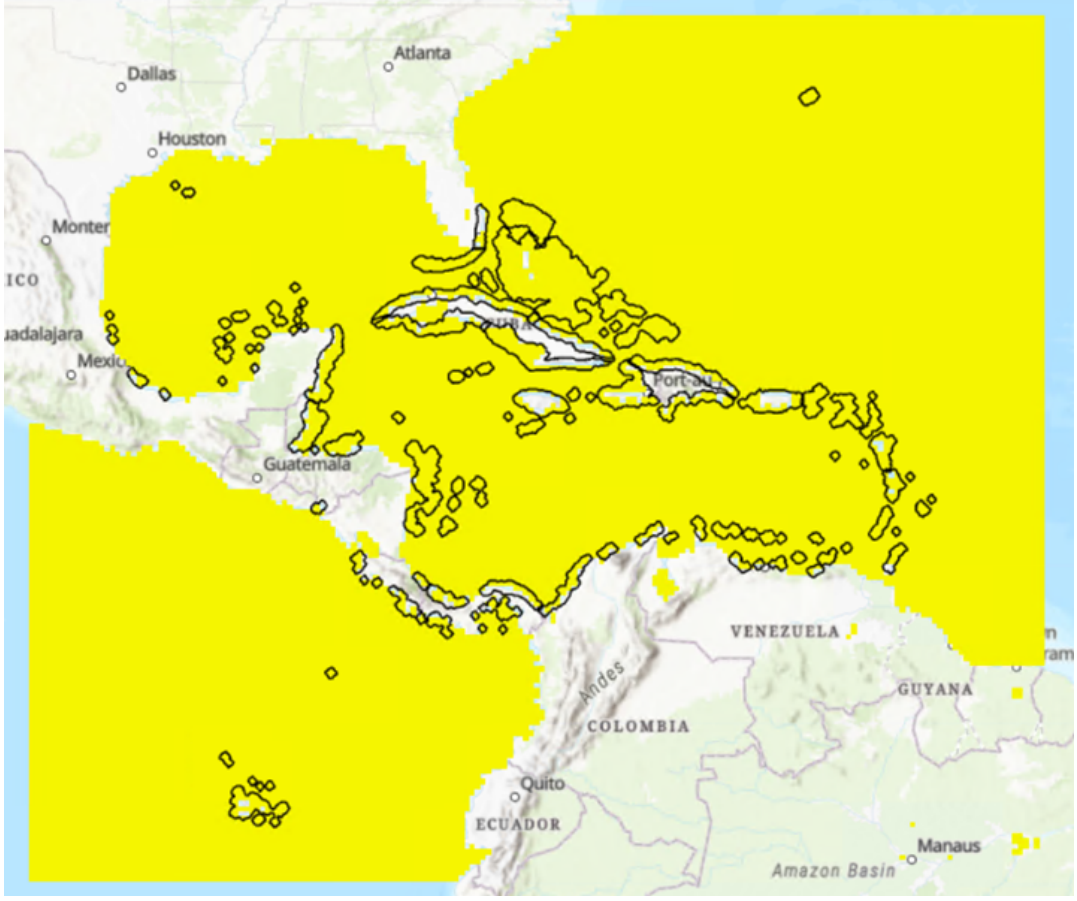
c In the Contents pane, right-click the SST_ArgStatistics.crf layer and choose Symbology.

d In the Symbology pane, update the Primary Symbology from Stretch to Classify.

The raster is now visualized with a set of classes indicating the duration in months of exposure to temperatures above the mean. By default these are separated into 0-1 months, 1-4 months, 4-7 months, 7-10 months, and 10-12 months, as indicated in the following graphic.



e Notice the updated symbology and its corresponding value.

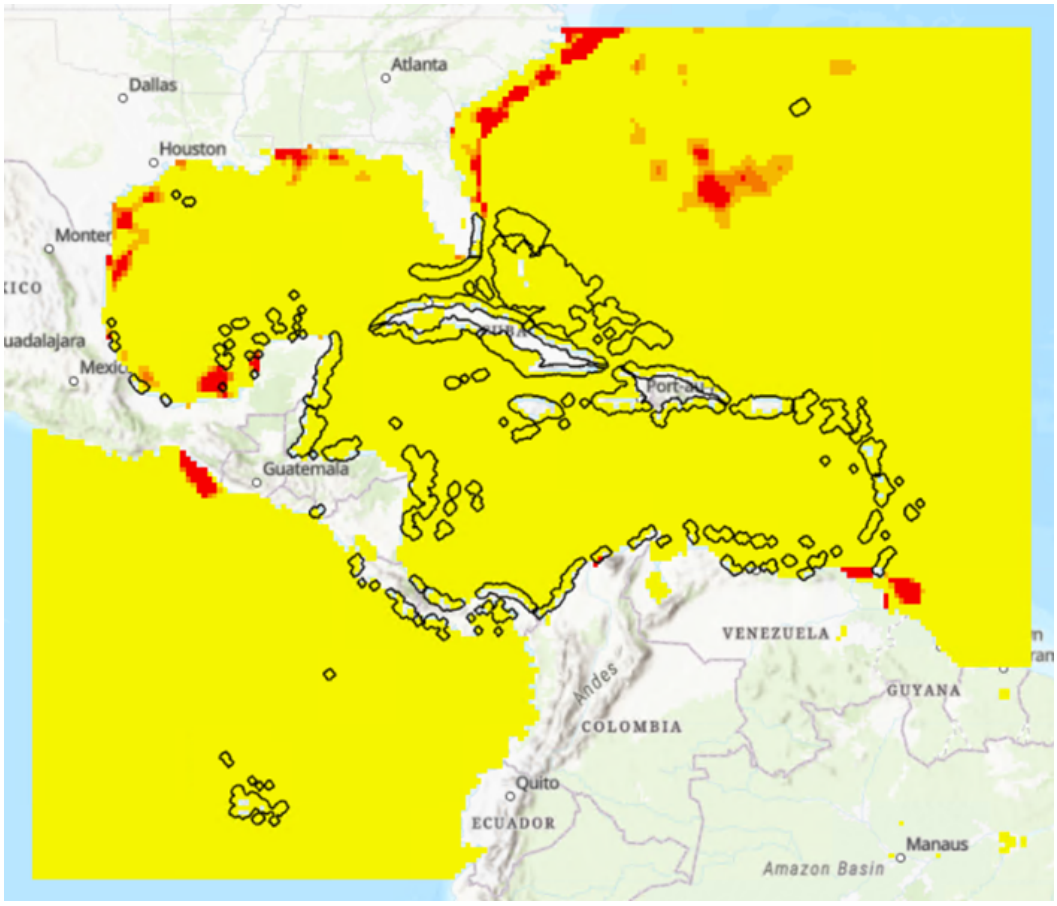


*Step 9e***: Measure the duration of exposure.*

The new multidimensional raster initially shows there are no areas that meet the criteria of prolonged warming. For the first time slice, 1980-01-01T00:00:00 - 1980-12-31T23:59:59.914 1980, the average sea surface temperature either did not meet the set threshold of 0.5 - 3 degrees above average or if it did, the increase in temperature did not last more than a month.

Now you will review some other slices to see if the number of months per year with exposure increases.

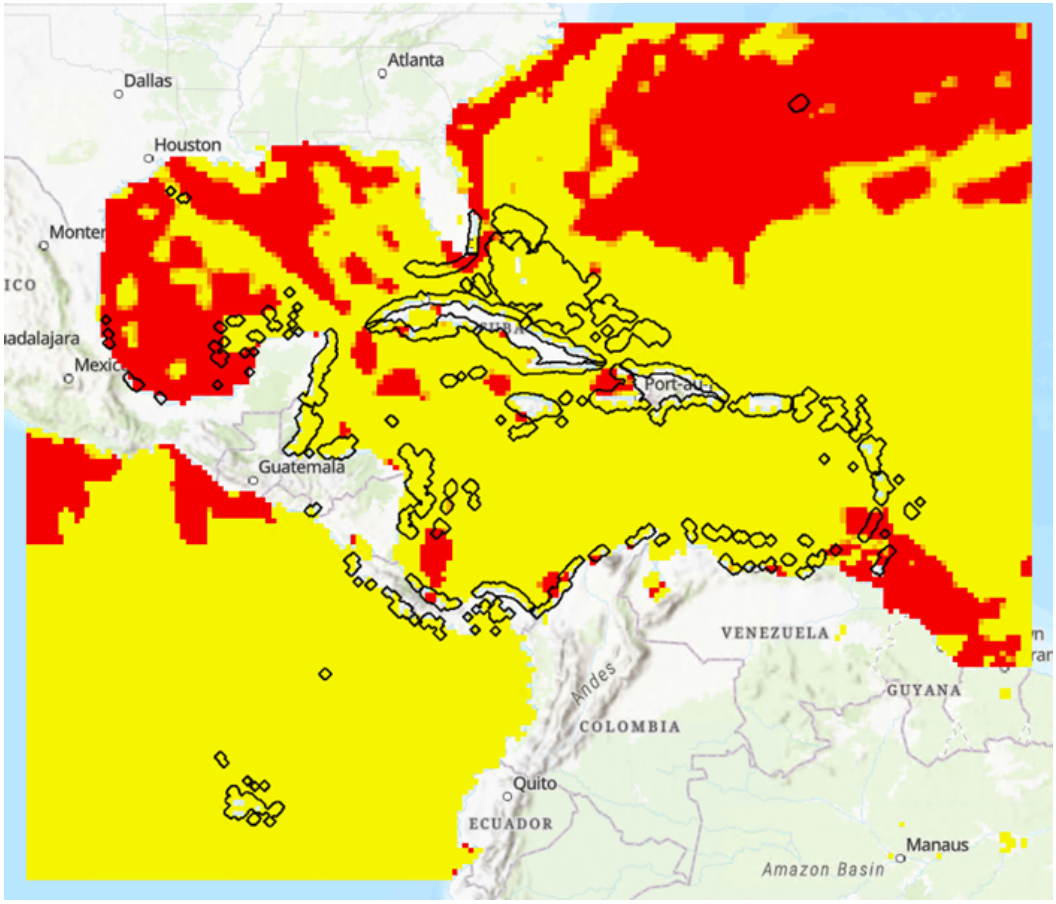
f Change the current display slice to 2023-01-01T00:00:00 - 2023-12-31T23:59:59.914.



*Step 9f***: Measure the duration of exposure.*

Here, you can see some areas near the coast of North America and some areas near the coast of South America experiencing warmer temperatures lasting for 1-4 months to upwards of 10-12 months.

g Change the current display slice to 2030-01-01T00:00:00 - 2030-12-01T00:00:00.



*Step 9g***: Measure the duration of exposure.*

In this time prediction, you can see that many areas are predicted to experience warmer temperatures for a longer duration. To find the most affected areas, you will configure the symbology to highlight the significant areas.

h In the Symbology pane, update Classes to 3.

The classification scheme now visualizes the areas into three distinct classes.

- Values symbolized in red indicate that the average sea surface temperature that met the set threshold (0.5 - 3 degrees above the average) for more than 8 months.
- Values symbolized in orange indicate that the average sea surface temperature that met the set threshold (0.5 - 3 degrees above the average) that lasted between 2-8 months.
- Values symbolized in yellow indicated that the average sea surface temperature either did not meet the set threshold (0.5 - 3 degrees above average) or if it did, the rise in temperature did not last more than 2 months.

In this prediction for 2030, many of the coral reef areas, especially in the Gulf of Mexico will be experiencing prolonged warmer temperatures.

To learn more about monitoring coral reefs at risk of bleaching, go to ArcGIS Blog: Monitor Coral Bleaching Around the World in Real-Time (https://www.esri.com/arcgis-blog/products/arcgis-living-atlas/real-time/coral-bleaching-stations/).

i Save the project, and then exit ArcGIS Pro.

In this exercise, you added multidimensional raster data, visualized the data, looked at historical trends, and created a prediction of the future. There are many more multidimensional data analysis options and possibilities to explore in ArcGIS Pro.