GIS Tutorial for

Atmospheric Sciences

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Exercise 5

Coordinate Systems and Map Projections

Use Case: Climate simulations in ArcGIS Pro

In this exercise you will be working with a wide array of data in ArcGIS Pro. ArcGIS Pro allows you to overlay these layers to perform GIS analysis and mapping. When overlaying two or more layers, however, aligning them correctly is not an automatic or arbitrary function. Geographic layers need particular information about their origins to overlay correctly with other datasets. This information is referred to as *coordinate systems* or *spatial reference information*. This information varies depending on your location and area of interest. Layers often have different coordinate systems and need to be processed using tools in ArcGIS Pro so that they overlay correctly. In this section you will learn more about different coordinate systems and why they are important when working with spatial data.

Sub-Sections in Exercise 5:

1. *Understanding Basic Coordinate System Information*
2. *Using Tools to Manually Alter the Coordinate System Information of a Layer*

Understanding Basic Coordinate System Information

A coordinate system is a reference system used to determine the location of geographic features. There are two common reference systems: geographic coordinate systems, and projected coordinate systems. In Step 1 you will explore these two types of coordinate systems.

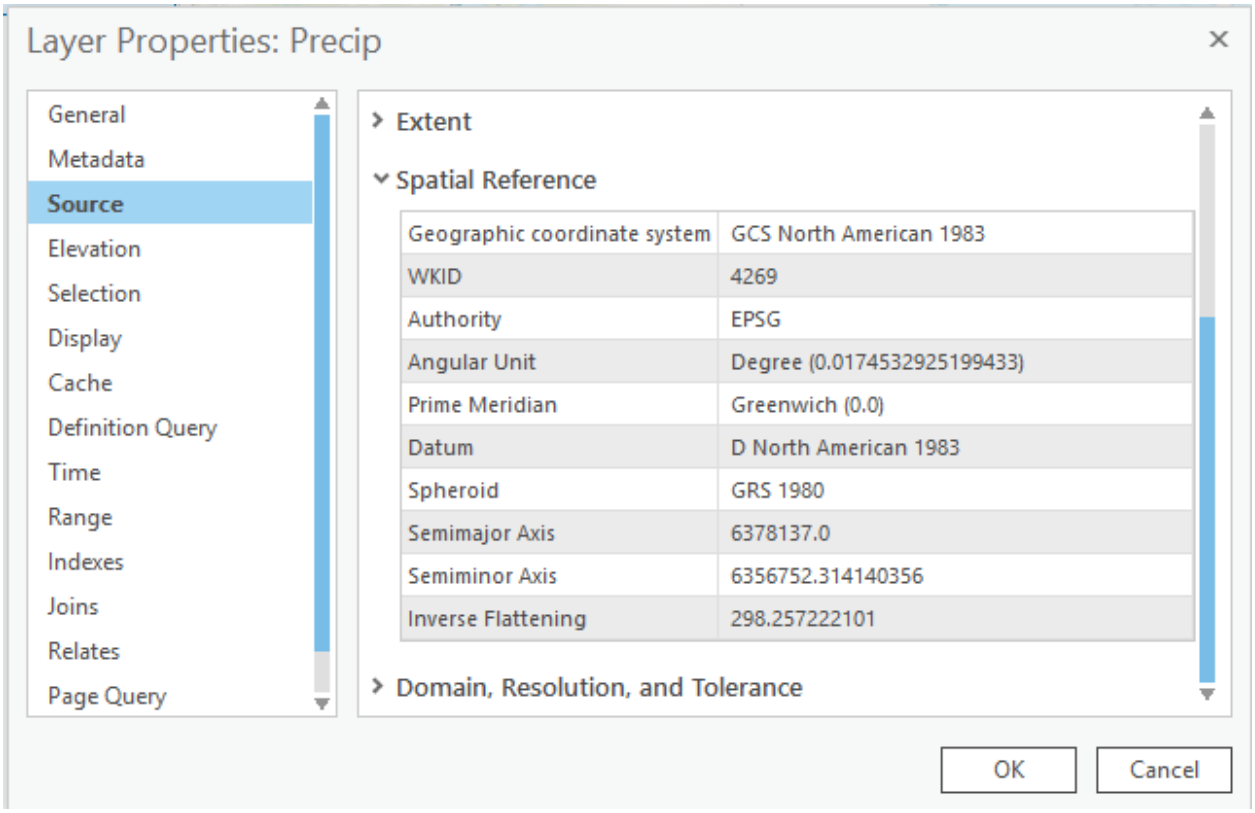
Step 1 Viewing a layer's coordinate system information in ArcGIS Pro

When you begin to work with a new dataset, it is a good idea to view its spatial reference information stored in the metadata.

- Start ArcGIS Pro.
- Create a **New Map**.
- Set the name to ***Exercise 5***.
- Set the location to ***C:\Exercise 5\Exercise5_Pro\Maps_Data.***
- Uncheck the box that says **Create a new folder for this project.**
- Change the name of your map to ***Precipitation_Data.***
- From the Catalog pane, navigate to ***Folders > Maps_Data.***
- Add the file ***Precip.shp*** to the map.

The *Precip* layer is a point data layer that contains precipitation data from a climate model. This data is from the emission scenario RCP 2.6 (https://sedac.ciesin.columbia.edu/ddc/ar5_scenario_process/RCPs.html).

- Right click on the layer ***Precip*** in the **Contents** pane, and select **Properties**.
- Click the **Source** tab.
- Expand the Spatial Reference section and look at the **Geographic Coordinate System** information.



The coordinate system here is a Geographic Coordinate System (GCS). The datum used is North American 1983. A datum is the shape of the Earth upon which the coordinate system is based. The prime meridian is Greenwich and the angular unit is degrees. Because GCS units are degrees of latitude and degrees of longitude, they are measurements of the angles from the prime meridian. This angle would change depending on the shape of the Earth from which it is referenced. Therefore, knowing the datum from which data are referenced is very important.

- Close the Layer Properties window.
- Add the ***States*** layer to the map from Catalog pane.
- Open the Layer Properties window for the layer ***States*** and inspect this layer's spatial reference information from the **Source** tab.

What is the GCS of the States layer?

- Close the Layer Properties Window.

The two layers above are in the exact same coordinate system so they overlay correctly without any medication needed.

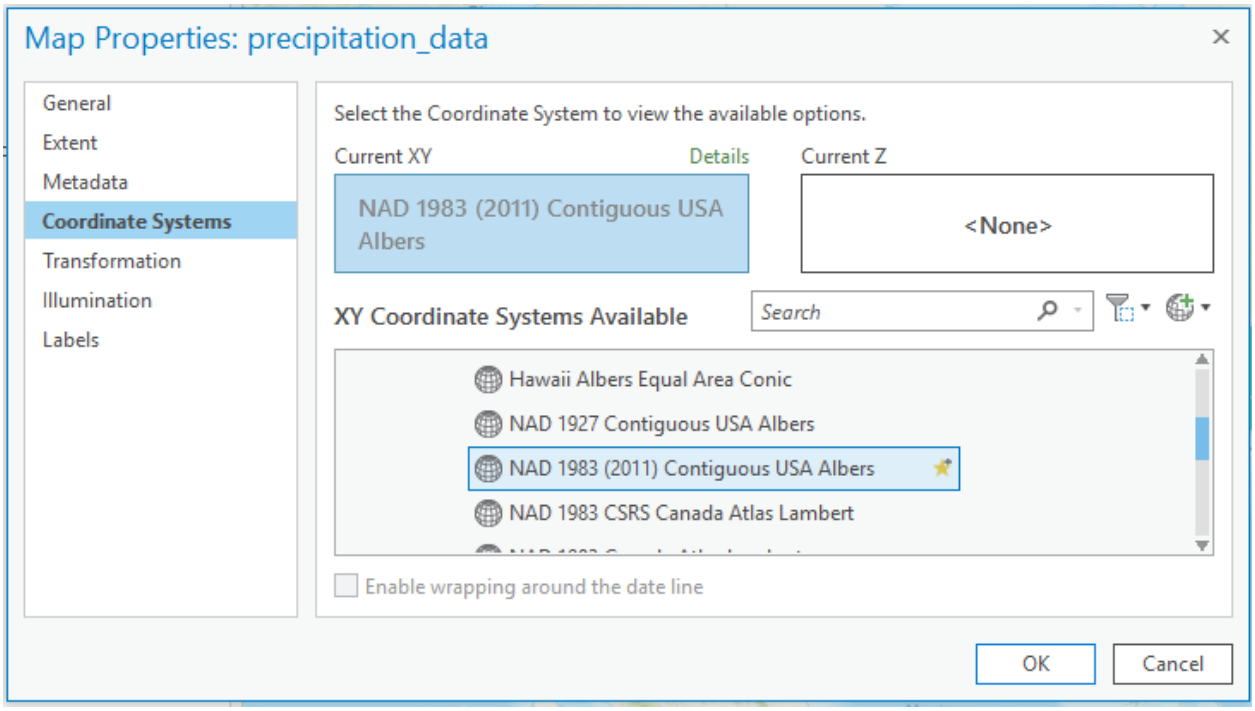
Step 2 Changing the coordinate system of the Map

Maps contains a Coordinate System property, which is inherited from the coordinate system of the first layer added to ArcGIS Pro. In this case we added Precip first, which has a GCS North American 1983 (NAD83) coordinate system defined. Therefore, our map will be NAD83 as well.

- Right-click on the map name ***Precipitation_Data*** and select **Properties.**
- Click on the **Coordinate System** tab.

When the map's coordinate system is different from the data layers' coordinate system(s), then the data will be "projected on the fly" to match the map's coordinate system. The actual data will not change but the way the data are viewed will change. We will now change the coordinate system for the map to a projected coordinate system and see how our map changes.

- In the Coordinate Systems tab.
- In the Search box type in ***USA Albers***.
- Expand ***Projected coordinate system > Continental***. > ***North America***.
- Click the projection ***NAD 1983 (2011) Contiguous USA Albers***.



- Click **OK** to apply the changes and close the Properties window.

Notice that the map has now changed its appearance. You have not changed the underlying data but you are simply viewing the data in a different manner. The map is now displayed in an Albers projection. Changing the coordinate system of the map is a way to display data from diverse coordinate systems in one common system.

ArcGIS Pro tries to resolve the issue of layers with different coordinate systems when they are first added to the map. This is referred to as "projection on the fly" and is ArcGIS Pro's way of recognizing that two or more layers may have different coordinate systems but still need to overlay correctly with each other.

Step 3 Projection on the Fly

- Go to the Insert tab on the top ribbon.
- Name the map "***US Precipitation***"
- Add the ***Precip*** layer to the map from the Catalog pane.
- Examine the Coordinate System Properties of the map as you did in Step 2.
- Add the ***States_AWIPS_48*** layer to the map.

Notice that this dataset lines up perfectly with the Precip layer in the map.

- Open the Layer Properties window and examine the spatial reference system information in the Layer Properties window.

What is the projection of this layer?

- Close the Layer Properties window.

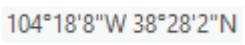
This layer is in the projection ***Albers Equal Area Conic***. The data, however, is projected on the fly to GCS North American 1983 geographic coordinates because this is the projection of the map. A map projection is a way of representing three-dimensional Earth coordinates in a two-dimensional planar surface.

At the bottom of the map, notice the units are in Decimal Degrees.

TIP: "Projection on the Fly" only works if the coordinate system information of the layer is already defined. If the layer is missing the coordinate system information, ArcGIS Pro will not be able to project the layer on the fly.

- Open the Properties window for the map ***USA Precipitation***.
- Click the ***General*** tab.
- Change the Display Units to **Degrees Minutes Seconds**.
- Click **OK**.

Move your cursor around the map and watch the units change. These units are referred to as *display units*.



Using Tools to Manually Alter the Coordinate System Information of a Layer

In this section you will look at different ways to change the coordinate system information of layers to ensure that all layers you are working with have the same coordinate system definition.

Step 4 Using the Define Projection tool to add coordinate system information to a layer

It is not uncommon to have a layer that has no coordinate system defined. You can still view such a layer in ArcGIS Pro, but it won't align correctly with your other layers that do include coordinate system information.

- Insert a new map, and name it ***RCP 4.5.***
- Add the ***CMIP5_RCP45_Temp_Annual*** to the map.

The *CMIP5_RCP45_Temp_Annual* layer is point data layer from the CMIP5 RCP 4.5 annual temperature dataset. It is global in coverage.

- Open the Layer Properties window and click the **Source** tab.

Notice that the Coordinate System is "Undefined." Also notice that the display units that you saw in Step 2 are shown as unknown units.

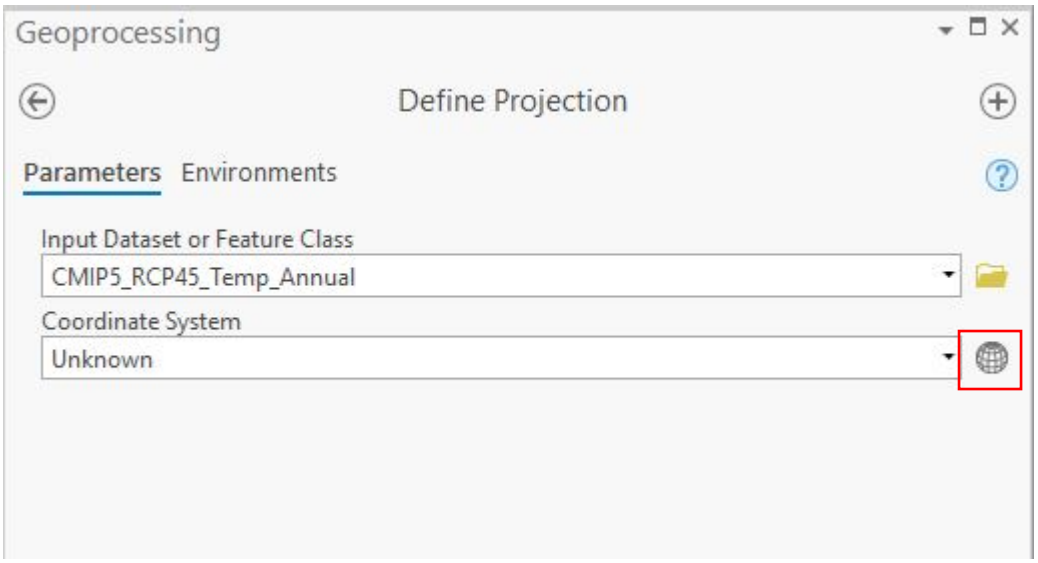
- Close the Layer Properties window.
- Add the ***CONUS_Sates_GCS*** layer to the map.
- Right click on ***CONUS_States_GCS*** and select **Zoom to Layer**.

Examining the coordinate system information would tell you that the layer is in geographic coordinates. You will now manually apply a projection to the *CMIP5_RCP45_Temp_Annual* layer so it will align correctly with the state boundary layer.

- From the **Analysis** tab, click the **Tools** button.

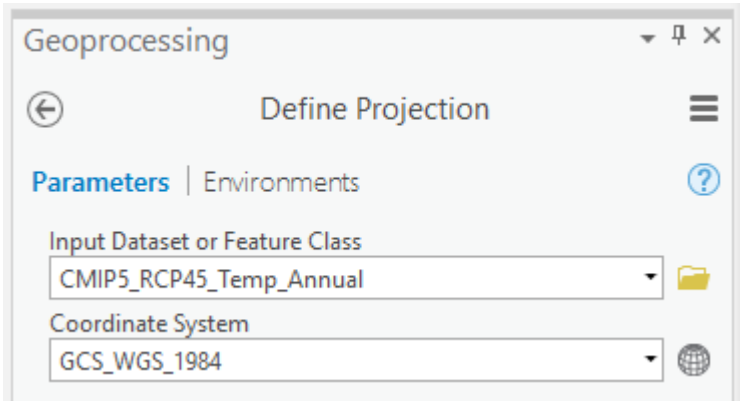
The Toolbox is a collection of tools designed for editing, processing, and working with GIS data. These tools are used to perform a variety of operations on vector and raster data. We will explore more functionality of theToolbox in later exercises.

- In the search box type, **Define Projection.**
- Double click **Define Projection.**
- Click the dropdown arrow in the **Input Dataset** or **Feature Class** box and select the ***CMIP5_RCP45_Temp_Annual layer***.
- Click the icon to the right of the **Coordinate System** box to open the **Spatial Reference Properties** window.



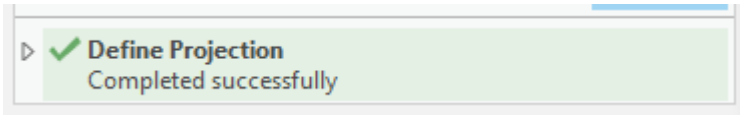
- Click to expand the ***Geographic Coordinate Systems*** folder.
- Click to expand the ***World*** sub-folder.
- Select the ***WGS 1984***, and click **OK**.

Your **Define Projection** window should now resemble the example below:



- Click **Run**.

When the tool has completed, you should see a green box appear momentarily in the lower right side of the tool window



The coordinate system information is now in WGS 1984, indicating that it is a geographic coordinate system.

- Close the Geoprocessing tool by clicking the X in the upper right corner.

The two data layers now align correctly.

TIP: You should always create a copy of the original layer before you define a projection for it with the Define Projection tool. The Define Projection tool is a permanent edit to the original layer and **does not** create a new layer like most other tools. If you apply the incorrect coordinate system, it will be permanently changed.

Step 5 Using the Project tool to change the coordinate system of a vector layer

Unlike the previous steps, it is more likely that data you work with will already have a coordinate system defined. However, for a number of reasons you may wish to change the coordinate system. The Project tool is used to "project" a layer from one geographic or projected coordinate system to another, or for switching between the two types of coordinate systems.

- Add the ***NCA_Regions_CONUS*** layer to the Map
- Examine the coordinate system information of this layer.

The coordinate system of this layer is USA Contiguous Albers Equal Area Conic, indicating the layer is in projected coordinates. You will now change this to a geographic coordinate system.

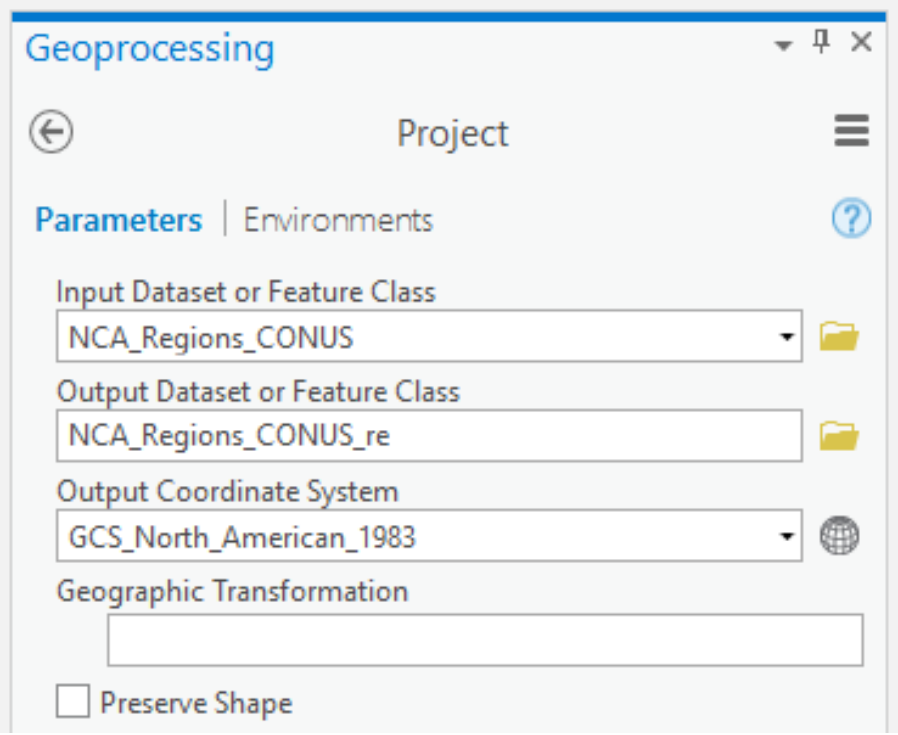
- Close the Layer Properties window.
- Open **Tools** from the **Analysis** tab.

- From the Toolboxes tab, navigate to the **Data and Management Tools** toolbox and then to the **Projections and Transformations** tool tray.
- Expand the Projections and Transformations tool tray.
- Open the **Project** tool.

The Project tool window appears.

- Click the dropdown arrow in the **Input Dataset** or **Feature Class** box and select the ***NCA_Regions_CONUS*** layer.
- Enter the output layer name as *NCA_Regions_CONUS_re*.
- Click the icon to the right of the **Output Coordinate System** box to open the **Spatial Reference Properties** window.
- Click to expand the **Geographic Coordinate Systems** folder.
- Click to expand the **North America** sub-folder and then USA and territories
- Select the *NAD 1983* coordinate system and click **OK**.

Your Project window should now resemble the example below:



- Click **Run**
- Close the Geoprocessing window once the tool is complete.

The tool automatically added this new layer to the map. However, the new layer looks exactly the same as the original layer. This is because when it was added, ArcGIS Pro automatically projected it on the fly to align with the original layer in your map.

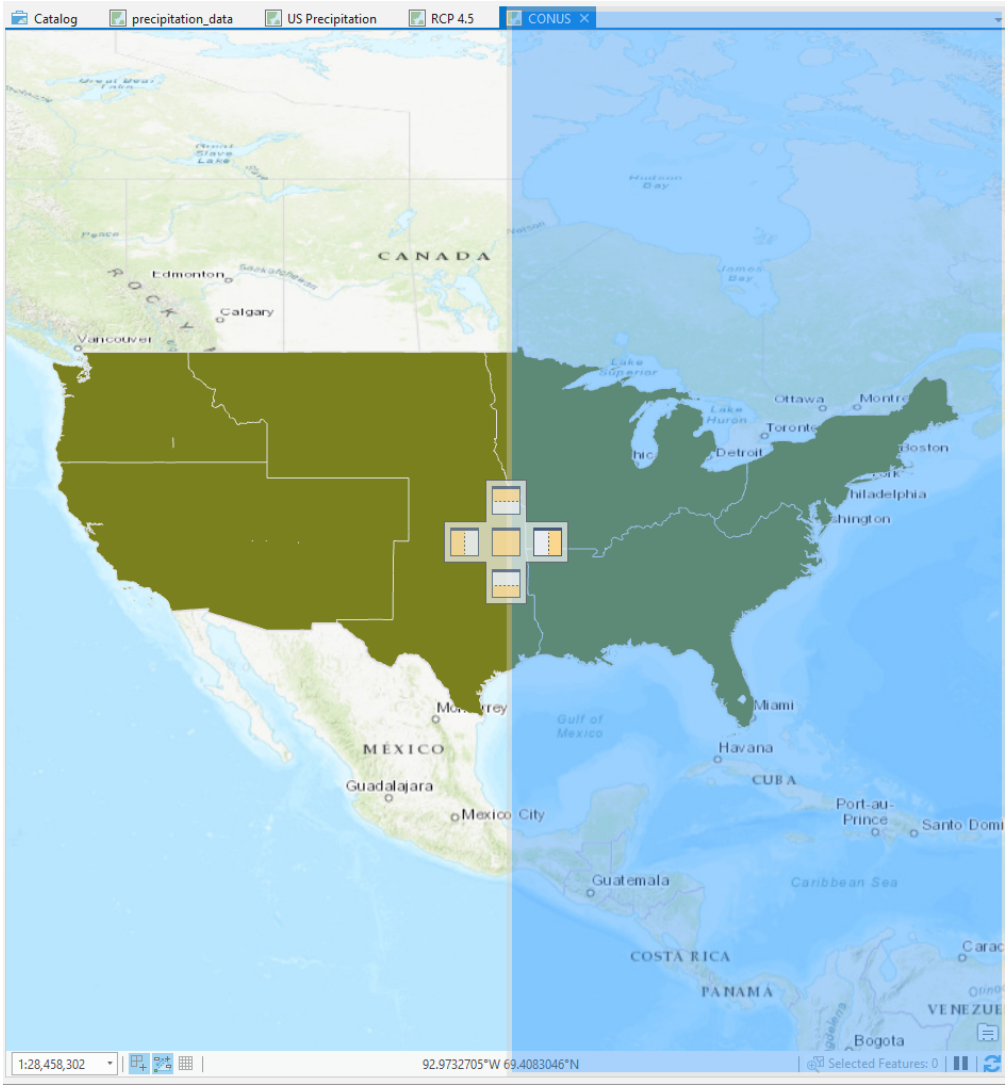
- Examine the spatial reference information of the new layer by opening the Properties and clicking the **Source** tab and then expanding **Spatial Reference**

The Project tool did in fact work and the new layer is no longer in projected coordinates, just geographic coordinates using the NAD 1983 coordinate system.

- Click **Insert > New Map.**
- Name the map **CONUS**
- Add the ***NCA_Regions_CONUS_re*** layer to the new Map.

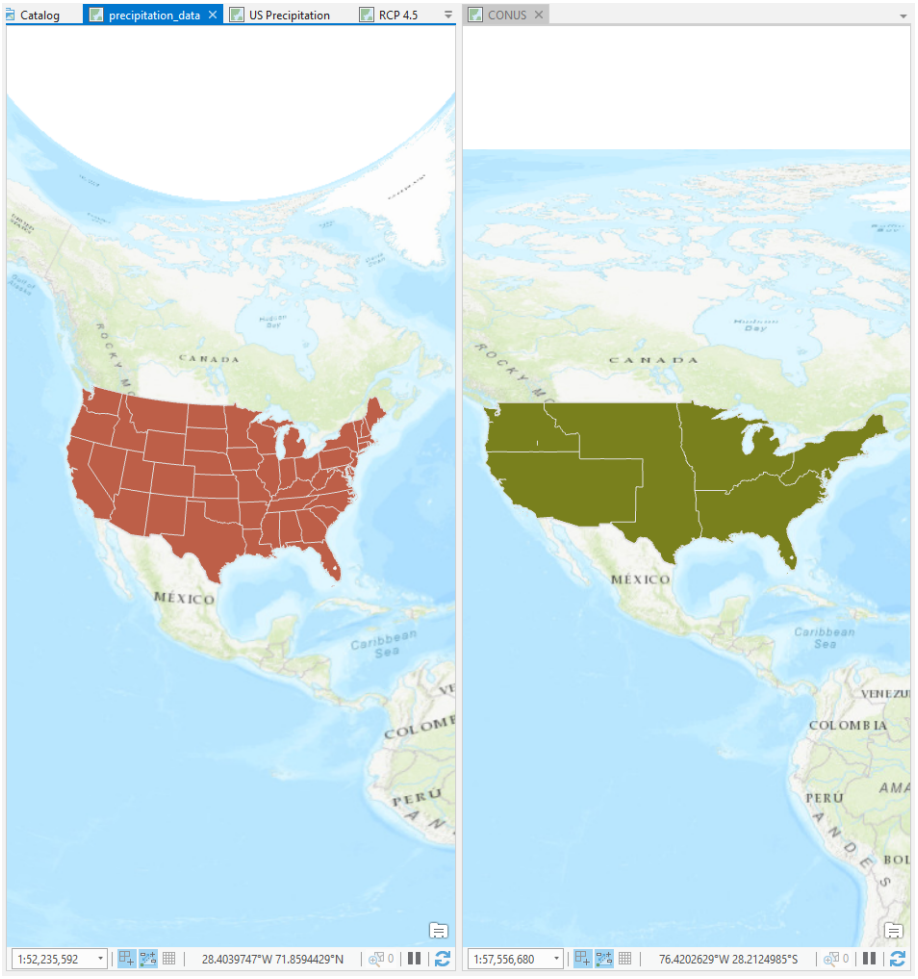
You can add the layer to the map by copying the layer from the USA Precipitation map and pasting it in the CONUS map. Or you can refresh the Folder Maps_Data and you will find this layer in the Exercise5.gdb.

- Now, to compare between our previous map projections, drag the tab of the CONUS map to the right of the screen and dock it such that it displays on half of your mapping area

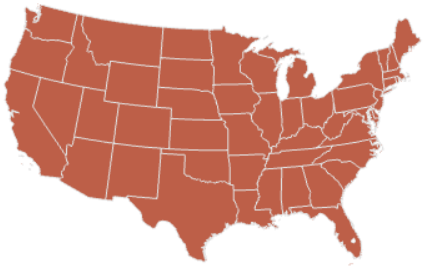


- On the left side of the screen, select the ***precipitation_data*** map we started the exercise with. Uncheck the Precip layer if it is activated. If needed, zoom to layer on the States layer.

- Your screen should look like so:



Now you see the difference between the two layers of the geographic and projected coordinate systems.



Projected Coordinate System: NAD 1983 Contiguous USA Albers

Geographic Coordinate System: North American 1983

- **Copy** and **paste *NCA_Regions_CONUS_re*** onto the ***precipitation_data*** map.

The *NCA_Regions_CONUS_re* layer is now projected on the fly to align with the states layer in the map.

- **Save** project.
- Close all maps except ***CONUS***.

Step 6 Using the Project Raster tool to change the coordinate system of a raster layer

When changing the coordinate systems of layers, there are different sets of tools for working with your data depending on the data format. Vector and raster data each have their own set of tools for working with and changing coordinate systems.

- Add the ***cmip5_precip*** raster layer to the ***CONUS*** map.

This is a raster layer showing the CMIP5 RCP 8.5 projected annual precipitation difference for 2021-2050.

- Turn off the layer ***NCAR_Regions_CONUS_re***.
- Examine the spatial reference information of this layer within the Layer Properties window under the **Source** tab.

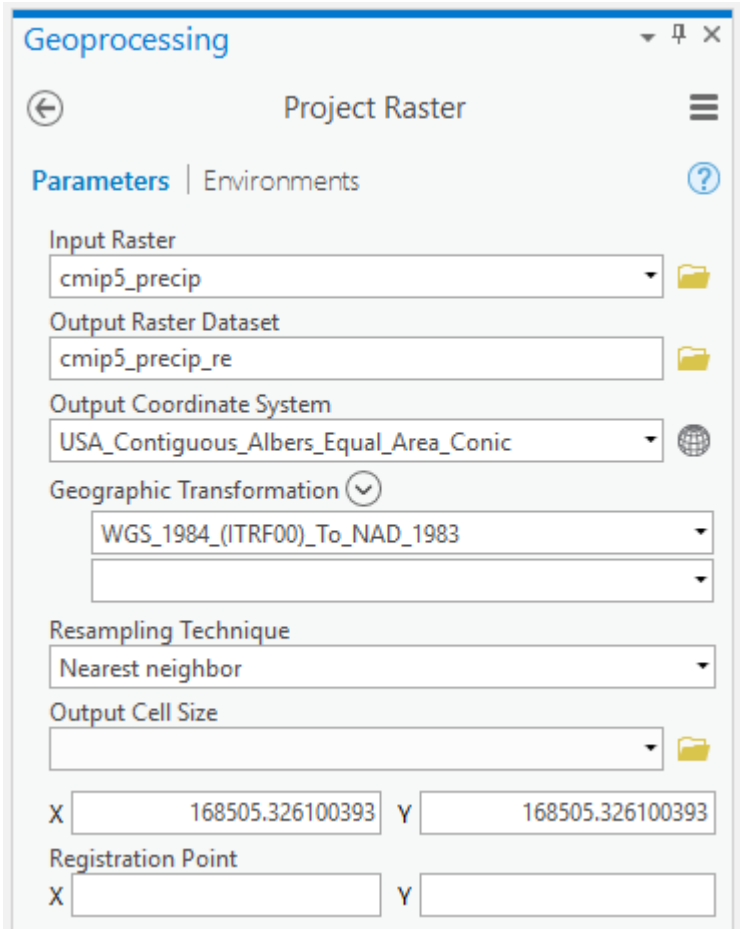
The raster layer contains the geographic coordinate system of WGS 1984. Now you will change this layer to a projected coordinate system.

- Click the ***Analysis*** tab, then ***Tools***.
- Navigate to the **Data Management Tools** toolbox.
- Expand the **Projections and Transformations** tool tray.
- Expand the tools under the **Raster** sub-tool tray.
- Open the **Project Raster** tool.

The Project Raster tool works essentially the same way as the Project tool did for vector.

- Click the dropdown arrow in the **Input Raster** box and select ***cmip5_precip.***
- In the **Output Raster Dataset** box save the file to ***cmip5_precip_re.***
- Click the icon to the right of the **Output Coordinate System** box to open the **Spatial Reference Properties** window.
- Click to expand the **Projected Coordinate Systems** folder.
- Click to expand the **Continental** and then the **North America**.
- Scroll down and select the ***USA Contiguous Albers Equal Area Conic*** and click **OK**.

Your Project Raster window should now resemble the example below.



- Click **Run**.

The tool automatically adds the new layer to the map.

- Close the Geoprocessing tool.

The map is in geographic coordinates due to the initial layer that was added to the map. All other layers are projected on the fly to match this coordinate system.

- **Insert** a New Map.
- Copy and paste ***cmip5_precip_re*** layer that you just created to the new map.

The raster layer now appears as it should for a layer with an Albers Equal Area Conic projection, which is a projected coordinate system.

- Save and close your project

TIP: While there are different projection and transformation tools for working with vector and raster layers, the Define Projection tool, is the tool that works with both types of data.