**GIS-intensive Advanced Lesson 1**

**Studying Topography, Orographic Rainfall, and Ecosystems (STORE)**

*Advanced Lesson 1: The Effects of Climate Change on Vegetation Considering Precipitation*

**Introduction**

National Center for Atmospheric Research (NCAR) is a national research and development center for the atmospheric and related sciences. NCAR provides climate predictions at the local and regional scales based on the global Community Climate System Model (CCSM). The data provided in this lesson and the next lesson come from predictions for the California Study Area based on the Intergovernmental Panel on Climate Change emissions scenario A2. The scenario assumes high population growth and the worst-case scenario emissions of greenhouse gas, resulting in the largest expected change in climate of the various scenarios studied.

In projecting changes in precipitation and temperature, the model is somewhat sensitive to the physiographic features of individual sub-areas of the greater California study area. So for example, an area getting an average of 30 to 40 inches per year of precipitation near the Pacific coast may be projected to get a decrease of 2 inches per year of precipitation in 2050 yet an area getting the same range of precipitation (30 to 40 inches per year) in a different part of the California study area, such as somewhere in the Sierra Nevada mountains, may be projected to get more of a decrease in 2050.

This lesson analyzes climate change projections for the years 2050 developed to investigate effects on biomes that can be expected in these years. Students use ArcGIS Explorer to compare projected year 2050 precipitation to recent precipitation, analyze the relative amount of precipitation changes within the California Study, and compare recent and year 2050 spatial distributions of vegetation communities in the Sierra Nevada Mountains based on precipitation changes in the eastern portion of the California Study Area. This lesson focuses on the two vegetation communities: deciduous and evergreen forests.

**Objective**

To map the projected change in precipitation within the California Study Area (i.e., between the Sonora and Twin Lakes Weather Stations) in the year 2050 and investigate the resulting impact on vegetation.

**Lesson Duration**

1 class period, 45 to 55 minutes
Requirements

- ArcGIS Explorer software
- Downloaded and unzipped “ArcGIS Explorer files for STORE GIS-intensive lessons” folder. Note this folder contains map layers, add-ins and function cards.
- “CA Study Area Map.nmf” ArcGIS Explorer map [i.e., Explorer map (*nmf) created in Basic Lesson 4]
Part 1 - Comparison of current precipitation to projected Year 2050 precipitation at each of the five California weather stations

**Question 1:** Based on lessons 2 and 4, would you expect the change in precipitation to be uniform across the California Study Area? Why or why not?

1. Open the “CA Study Area Map.nmf” ArcGIS Explorer map created in Basic Lesson 4.

2. Add the “ca_2050_average_annual_precipitation.shp” shapefile (point). Your map will look like the view below. This shapefile contains data from NCAR CCSM projections for the year 2050.

   *Hint: Add files to your map by clicking on the “Add Content” button and selecting from the type of data file listed in the drop down list (see Basic Lesson 2, Part 1).*
3. Change the size and color of the ca 2050 average annual precipitation points. Select “ca_2050_average_annual_precipitation” in the “Contents” panel. When a layer is selected, the layer’s name will be highlighted in the “Contents” panel.

4. Change the point symbology to a purple sphere. Your map will appear as below.

⚠️ Hint: Change points by selecting different symbology under the “Appearance“ tab (see Basic Lesson 2, Part 1).
5. Go to the “Appearance” tab. Under “Size”, click on the small circle with an arrow pointing down repeatedly until the points are the smallest possible. Your map will appear as below.
6. If the “ca weather stations” are not visible, use “Manage Layers” to move this layer upwards. Your map will appear as below.

⚠️ Hint: See Basic Lesson 2, Part 4 to learn how to manage layers to increase visibility

7. The next step is to modify the popup properties of the “ca_2050_average_annual_precipitation” layer. Highlight the layer in the “Contents” panel. Right click on the layer name and select “Properties” from the menu.
8. The “Layer Properties” window will appear. Select “Popup Content” from left-hand column. In the “Title and Parameter Field”, use the pull down menu to select “ANN_PRC_50”. Click “OK” to apply.

9. Click the year 2050 data point (i.e., purple sphere) on the map closest to the Sonora Weather Station. You will see a popup window like below. The number shown below “ca_2050_average_annual_precipitation” is the projected amount of precipitation in inches in year 2050.
10. Click on the weather station red dot to pull up the current weather data, including the current mean annual precipitation (i.e., ANN_PRECIP). Calculate the change in precipitation at the Sonora Weather Station.

\[
\text{change} = \text{Year 2050 precipitation} - \text{current mean annual precipitation}
\]

A negative value indicates a projected decrease in precipitation and a positive value indicates a projected increase.

11. Repeat steps 10 and 11 for the remaining four weather stations in the California Study Area. Note that NCAR projects an increase in precipitation at one station and decreases at four stations.

**Question 2:** How does projected year 2050 precipitation within the California Study Area compare to recent precipitation? Does precipitation increase or decrease, and is the change in precipitation uniform across the California Study Area?
Part 2 - Create new map layers showing Projected Year 2050 precipitation

1. This part will focus on the portion of the study area located between Sonora and Twin Lakes Weather Stations. We will extrapolate the projected change in precipitation at these two stations to the area between the stations.

2. In the year 2050, NCAR CCSM projects precipitation will decrease by 4.1 in/yr in the year 2050. Therefore, the area currently receiving 20 to 30 in/yr will get only 15.9 to 25.9 in/yr. To map this area, highlight the “ca average annual precipitation” shapefile (polygon) layer in the “Contents” panel. Query this layer for the current average annual precipitation of “20.01-30.00” inches per year. A new layer will be created and your map will look similar to the view below.
3. Rename the new layer based on the projected year 2050 precipitation. Highlight the layer file name, right click with your computer mouse and choose “Rename” from the menu. Type “2050_precipitation_15.9-25.9 in/yr” in the layer name box. Your map will look similar to the view below.
4. To map the 2050 annual precipitation range for the Twin Lakes area, repeat Steps 2-3 for the Twin Lakes area. The Twin Lakes Weather Station is at the area is near the western boundary of the 50.01 to 70.00 in/yr band and most of the nearby area is within the 50.01 to 70.00 in/yr band. Would the station’s location in a narrow valley explain this pattern? Extrapolate the projected year 2050 slight decrease in precipitation at Twin Lakes - 0.2 in/yr to the 50.01 -70.00 band and rename this map layer similar as you did Step 3. Your map should appear similar to the view below with a new layer named “2050_precipitation_49.8-69.8 in/yr”.

5. Next map the year 2050 precipitation ranges between the Sonora and Twin Lakes weather stations (i.e., the current 30.01-40.00 in/yr and 40.01-50.00 in/yr bands). In these areas, year 2050 precipitation will be between 26.0 in/yr and 49.7 in/yr, as they occur between then 2050 precipitation bands at Sonora and Twin Lakes layers you just created. Subtract 26 from 49.7 to get 23.7. Divide 23.7 by 2 to get 11.85. The two new ranges each will span 11.85 in/yr. Therefore, the two new year 2050 precipitation bands will be:
   - 26.0 in/yr -37.8 in/yr, and
   - 37.9 in/yr - 49.7 in/yr.
Rename the layers appropriately.
6. Zoom back to the area between the Sonora and Twin Lakes weather stations.

7. Change the colors of the 2050 precipitation layers from lighter to darker to indicate greater precipitation. Turn off the “ca average annual precipitation” layer package and shapefile (polygon) layers. Your map should appear similar to the view below.
Part 3 - Create new map layers showing spatial range of deciduous in Year 2050 based on projected future precipitation

1. Add the California Study Area shapefile to your map. Navigate to the California folder and choose “ca_study_area.shp”. Change the outline color to “black” and the fill color to “No Color”. Your map will appear similar to the view below.

2. Manage layers to move the deciduous forest layer upward until it is above the precipitation layers.

3. Turn off the “ca_2050_average_annual_precipitation” shapefile layer by deselecting the checkbox in the “Contents” panel.
4. Draw a polygon around existing deciduous forests. In the “Create” group under the “Home” tab, select the “Area” tool.

5. Click at the edge of the deciduous forest area to start drawing the area polygon. Drag the cursor to draw the boundary, and click when you wish to change direction. Enclose the entire deciduous forest area and double click when you return to the starting point.
6. You will notice that a new layer has been created called “Note”. Rename this layer “existing deciduous forest”. Your map will appear similar to the view below.

7. To measure the area of “existing deciduous forest,” go under the “Home” tab in the “Find” group and select the “Measure” tool.
8. The “Measure” panel will appear. Select the area icon 🏙️ (i.e., the middle icon on the top row).

![Image of Measure panel]

9. From the pull down menu select “Acres”.

![Image of Measure panel with Acres selected]

10. Retrace the “existing deciduous forest” polygon. When you double-click the last point of the polygon the number of acres will appear in the “Measure” panel.

![Image of Measure panel with Acres showing the area measurement]
11. Click the “Add to Map” button.

12. A new layer “Measured Area (622592.588 Acres)” has been added to your map. Rename this layer “Existing_deciduous_forest_Measured Area_[actual value]”.
13. Using the ranges of precipitation where deciduous forests occur in the study area, (determined in Basic Lesson 4), draw a polygon showing the year 2050 range of deciduous forests in the California Study Area.

14. Turn off all layers except “ca_study_area”, “2050_precipitation_15.9-25.9 in/yr”, “2050_precipitation_26.0-37.8 in/yr”, “2050_precipitation_37.9-49.7 in/yr” and “2050_precipitation_49.8-69.8 in/yr”.

15. You determined in Basic Lesson 4 that deciduous forests exist in areas of 20-50 inches of precipitation. Draw a new polygon representing the future distribution of deciduous forests within the California Study Area based on projected 2050 precipitation. 

   **Hint:** Use the year 2050 precipitation bands as a guide as to where 20 to 50 in/yr of precipitation will occur in year 2050.

16. Rename this layer “2050 deciduous forest”. Your map should appear similar to the view below.

![Map showing 2050 deciduous forest](image)

17. Measure the area of the year 2050 deciduous forest using the measure tool as in Steps 7-12 above.

**Question 3:** You may notice that the range of deciduous forest will decrease. Will the range move eastward or westward? Why might it move in this direction?
18. Before exiting ArcGIS Explorer and beginning Advanced Lesson 2, turn off all layers with the exception of “ca_study_area”, “ca weather stations”, and “ca vegetation (“Landcover” = ‘Deciduous Forest’).

**Exercise 1 (optional):**

The following scientific article describes the projected change in California vegetation patterns due to climate change, based on a very sophisticated model developed by a number of scientists from Duke University; California Polytechnical University at San Luis Obispo; Texas Tech University; the University of California at Berkeley; and the Monterey Bay Aquarium Research Institute. You can compare future projections of deciduous forests in your map to the projections provided in this article.

*Climate Change and the Future of California's Endemic Flora* (Research Paper)
http://www.ncbi.nlm.nih.gov/pmc/articles/PMC2481286/

**Exercise 2 (optional):**

Provide evidentiary support (online scientific article) for why some deciduous tree species might be able to adapt faster than others and why some may not be able to adapt to changing precipitation conditions.