Global Atmospheric Circulation Patterns – Analyzing TRMM data

Eugenio Arima – arima@hws.edu
Hobart and William Smith Colleges
Department of Environmental Studies

Background: Have you ever wondered why rainforests are located in tropical regions? Or why it rains so much in the tropics? Have you wondered why the Sahara and Mohave deserts are roughly on the same latitude? Or why 2000 tourists were stranded in Machu Picchu in 2010 after heavy rains triggered landslides in the region? Answers to these questions are related to global atmospheric circulation patterns, which is the topic of this lab.

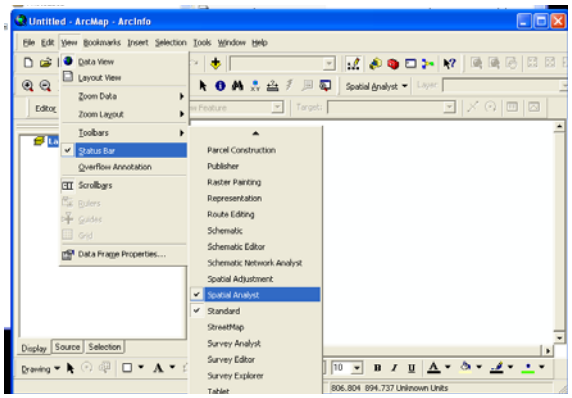
Objectives: In this computer lab, you will analyze worldwide precipitation data in raster format and will be asked to identify major global atmospheric circulation patterns. You will also be introduced to GIS raster algebra by using the 'raster calculator' in ArcGIS.

Overview of Tasks: you will download pre-processed TRMM (Tropical Rainfall Measuring Mission) datasets for the years 2000 to 2009, calculate averages (normal precipitation) and anomalies (i.e. deviations from normal precipitation values), and answer questions related to the atmospheric circulation patterns observed. You **must read** Ruddiman's Chapter 2 to answer these questions.

Turn-in: Write a report answering the questions below. Include at most four maps to help illustrate your answers. Remember the basic cartographic rules: include at least your name, title, north arrow, and legend. You do not have to include scale bars in your maps for this particular exercise because a file showing worldwide lat/long degrees is provided.

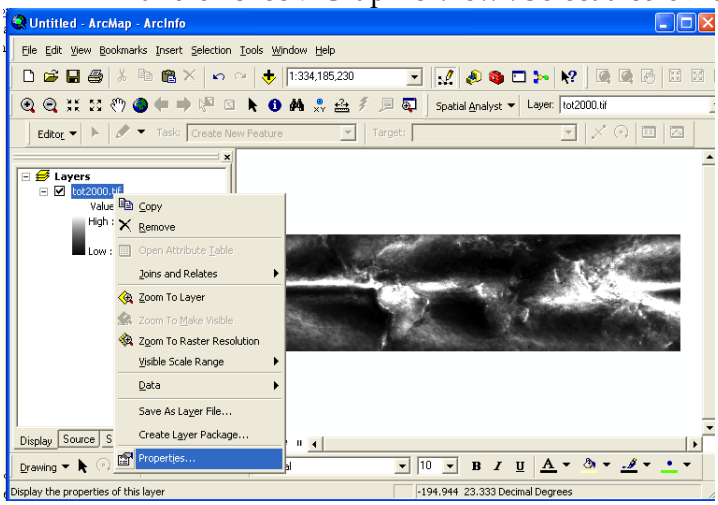
Step 1. Set up

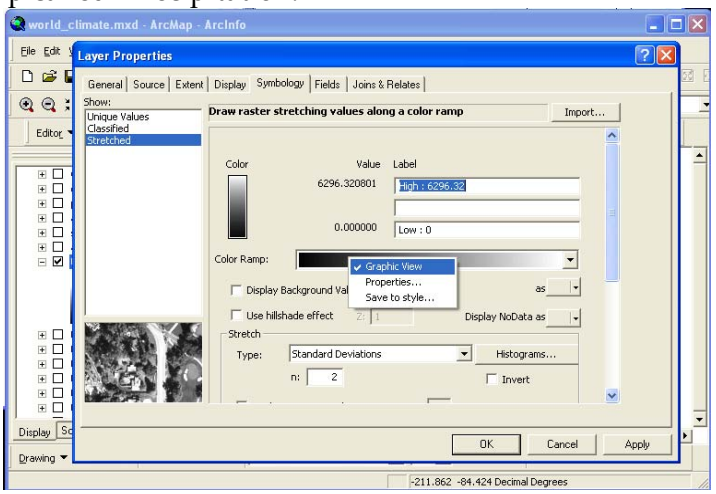
1. Create a `Gislab` folder (no spaces between GIS and LAB) in your Z drive. Make sure your directory path does not contain any space between names (e.g. `C:\My documents` is not an appropriate folder name).
2. Download the trmm.zip file from the appropriate Blackboard site (Main Course → Content → Labs → Gislab folder) and save into your folder.
3. Extract the files (right-click file `trmm.zip` → Izarc → Extract here).
4. You should have a sub folder called `TRMM` with several TIF files in it and other files.
5. Open ArcCatalog and Connect to the Z drive.
6. Open ArcMap. Click on the menu Tools → Extension, and check the extension Spatial Analyst.
7. Click on the menu View → Toolbars and check 'Spatial Analyst'. To 'dock' this menu, just click and drag it to the menu area on top.



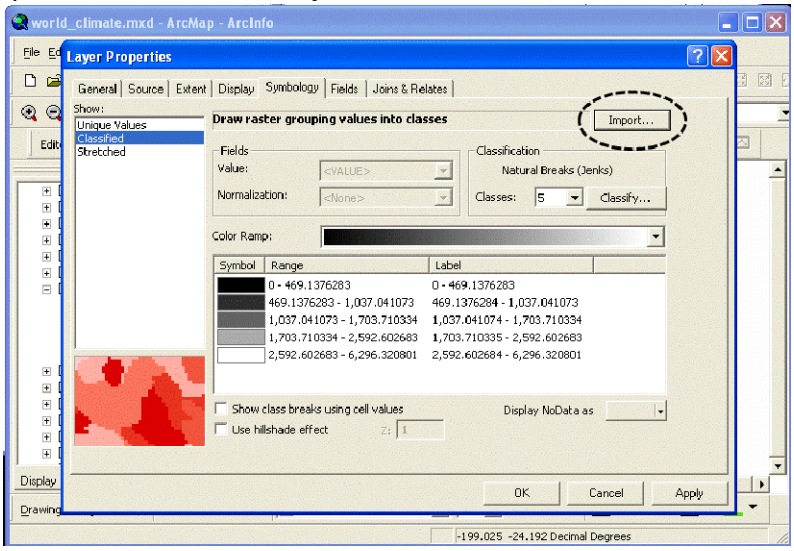
Step 2. Add raster datasets and assign symbology.

8. Click on the icon 'Add Data'  , navigate to your TRMM folder and add the files `tot2000.tif, tot2001.tif, ..., tot2009.tif`.
9. A brief explanation about the files: these tif files show the annual precipitation in mm in each 0.25 x 0.25 degrees cell between 50 degrees south and 50 degrees north of latitude. The original files in hdf format were downloaded from NASA's TRMM ftp site disc2.nascom.nasa.gov, product 3B43, which shows precipitation rates (mm/hour) by month. I first converted hourly rates into total precipitation per month. For example, January has 31 days and each day has 24 hours. Thus, the original file was multiplied by 744 (24x31). Then, all 12 totals for each month of a particular year were summed to generate the yearly precipitation total.
10. Question: What number did I use to multiply the original February 2004 file to get total precipitation for that particular month? [Hint: how many days we had in the month of February 2004?]
11. When you first add these files, they will be automatically assigned a gray color ramp. Let's change it to a "precipitation" color ramp. In the table of contents (TOC) right click on the file `tot2000.tif` → Properties → Symbology tab. Right-click on 'Color Ramp' and uncheck 'Graphic View'. Select a color ramp called 'Precipitation.'

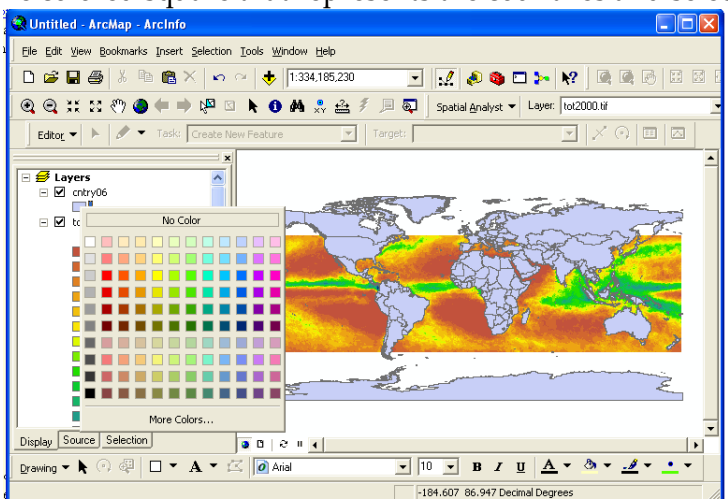




12. Repeat the process for the file `tot2001.tif`. Notice that ArcGIS stretches the color ramp based on the min, max value of each raster. Thus, a dark blue can represent different rainfall[i] levels and visual interpretation of the maps can be very misleading. To avoid that, you have to separate the rainfall values into fixed intervals and assign a color for each interval. I prepared a layer file that breaks rainfall into 15 intervals.
13. Right-click again on `tot2000.tif` → Properties → Symbology. On the upper left side, click on 'Classified' and accepted the message if asked to compute histogram.
14. Click on 'Import…' in the upper right, navigate to your folder TRMM and select the layer '`precipitation_annual.lyr`.' Click Add, OK, and OK.



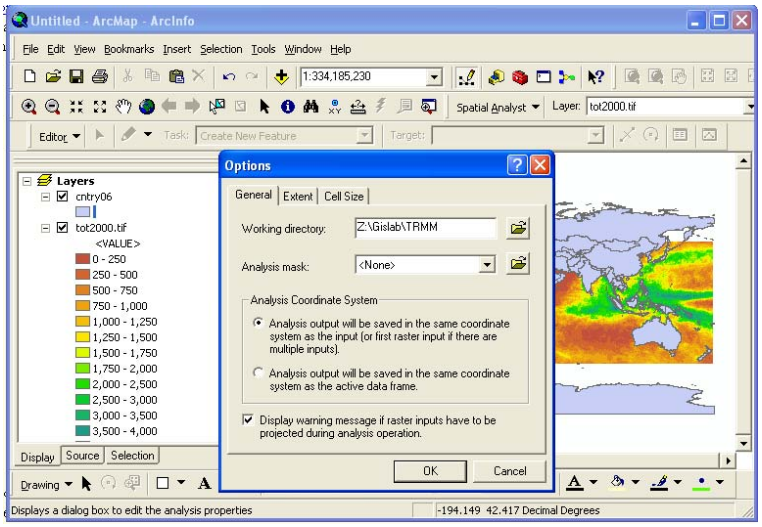
15. Repeat (13 & 14) for all your `totYEAR.tif` files.
16. Add the file `cntry06.shp`[ii]. Let's make the polygon transparent (hollow). In the TOC, right-click on the colored square that represents the countries and select 'No Color'.



17. ArcGIS displays the files as layers and the one on top is the first on your TOC. If you want to visualize the files at the bottom of the TOC you must uncheck the files that are on top.

18. Question: I zoomed in to a cell off the coast of Gabon, Africa and found that the value stored in the cell was 3247. How many **liters** of rain fell in that cell? To answer this question, you must know the following: a) one mm of rain is equal to one liter per m^2; b) each raster cell is 0.25 x 0.25 degrees wide; c) WGS 84 datum establishes that the Earth's radius at the Equator is 6,378,137 meters; d) $2\pi R = 360$ degrees. Show your work for full credit. Don't be surprised if the number is big!
19. Let's use the raster calculator and calculate the average (normal) precipitation using this 10-year series. Remember though that 'climate normals' typically require longer series (30 years or more).
20. First, let's set up our raster working environment. Click on the menu Spatial Analyst → Options → General tab. Set the Working directory to your Z:\...\TRMM folder. Click on the 'Extent' tab and select one of your `totYEAR.tif` files. Click on the 'Cell Size' tab and select again one of your `totYEAR.tif` files. Click OK (see figure below).
21. Click on the menu Spatial Analyst → Raster Calculator. In the white box below the list of files, type and/or click on the icons and files until you have something like:

```
average = ([tot2000.tif] + [tot2001.tif] + [tot2002.tif] + [tot2003.tif] +
[tot2004.tif] + [tot2005.tif] + [tot2006.tif] + [tot2007.tif] +
[tot2008.tif] + [tot2009.tif]) /10
```



22. This command is creating a new raster file called 'average', which is the sum of all 10 years divided by 10. Notice the ( ) at the beginning and end of the summation.
23. Assign symbology following (13). Make sure your 'average' file is on top of the other yearly files.
24. Question: Describe the basic statistics (min, max, st. dev., mean) of the file 'average'. Right-click on the file → Properties → Source tab and scroll down until you find a field Statistics.
25. Add the file `world_grids30.shp` and make it hollow just like in (16). Take a moment to identify the equator and the zero meridian.
26. Describe the major precipitation patterns. What are the regions with high/low precipitation? Write approximate lat./long ranges for those regions. Notice that if you

rest your mouse pointer in any place on the map, you can read the coordinates at the lower right corner. Negative latitudes/longitudes mean south/west.

27. Make a map to illustrate your answer and include in your report.
28. Question: What is the name of this zone of high precipitation along the tropics that spans around the world?
29. Question: Why is there more rainfall in that zone?
30. Question: In general, in what latitudinal range are most deserts on earth found? Why? Is your map in agreement?
31. Add the file `srtmperu.tif`, which is the digital elevation model of Peru. Right-click on the file →Zoom to layer.
32. Change the symbology of this file following instructions in (11) but pick the color ramp called Elevation #2.
33. Question: Do a quick research in the internet and answer the following questions. What is the major vegetation type to the east of the Andes? And to the west (i.e. coastal area of Peru)?
34. We will try to visually determine if there is any change in precipitation among those three regions. We will use a cool tool called 'Swipe.' Click on the menu View → Toolbars and select Effects, just like in (7).
35. Set the file `srtmperu.tif` as your layer on Effects, click on the inverted triangle icon on the right. Place your cursor to the right of the DEM. Click and drag your mouse back and forth.
36. Question: describe the rainfall gradient in Peru as you move from east to west. Explain why rainfall is different in those three regions.
37. Question: can you think of a region in the US where you would observe similar rainfall trend?
38. Question: Suppose the trade winds are reversed or weakened and the Pacific waters off the Peruvian coast become warmer. What would you expect to occur in the Peruvian coastal areas? Why?
39. Question: Go to http://www.elnino.noaa.gov/index.html , and answer to the following questions. What is the El Ninõ phenomenon? What is the weather like in Peru during El Niño years?
40. Zoom in to Bangladesh. Rainfall levels are relatively high in that country.
41. Question: In which season would you expect most of the rain to fall in Bangladesh? Explain the land/water circulation driving such process.
42. Calculate a raster called `anmly2009` using the raster calculator. This raster should be equal to the precipitation in 2009 minus the average precipitation raster. Write below exactly what you typed in the raster calculator box.

43. Change the symbology of your new raster, just like you did in (13 & 14) but select the layer called '`anmly2009.lyr`'.
44. Question: what do positive and negative numbers mean?
45. Question: Did you analyzing climate or weather data? Explain.

46. Question: Go back to the **Background** section (first paragraph). Read the questions over again and provide an answer for each question based on what you have learned in this assignment.

[i] Although not correct, I use the terms rainfall and precipitation interchangeably here.
[ii] File prepared by ESRI®. Make sure you have proper authorization to use this data.