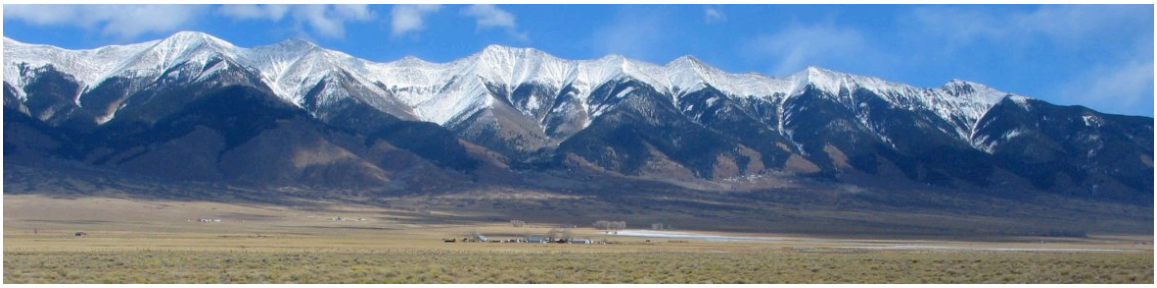
GY 320 Surface Processes and Geomorphology
Block 1, 2009

Topographic Analysis of Sangre De Cristo Range
GIS Project



Sangre De Cristo Range from the San Luis Valley

This lab is a DEM-based GIS project using ArcMap. You are going to look closely at DEMs to try to understand the factors controlling the topographic development of a Colorado mountain range – the Sangre de Cristos. There are some real differences in surface morphology between the west and east sides of the Sangres. These differences may relate to climate, to tectonics, to rock type, to differences in geomorphic processes, or to combinations of these factors (or to something else I'm overlooking).

Your lab assignment is to try to *document* and to *explain* these morphological differences. What you will turn in at the end is a summary of your observations and a discussion of likely causes of what you have observed. The write-up should be amply illustrated/supported with maps, graphs, and data tables. Write-ups should have no more than 4-5 pages of text plus lots of figures. **Your write-ups are due Thursday at 9 am.**

I will suggest some new types of analysis and should definitely draw on what you learned in the Intro GIS lab last week. I will also introduce you to few additional things you should try to get a bit more information on the Sangres. Don't, however, limit your horizons to these suggestions – try other analyses.

Everyone will complete this project ***individually***. Because there are only 18 computers in the GIS Lab (Palmer Hall 1), you cannot all work at once. The GIS lab is ours on Tuesday and Wednesday afternoons this week.

File Setup
This time I recommend doing your work on hard drive of the computer you are working on, not on the server. IMPORTANT: when you are done for the day though, copy the files back into your folder within S:/GY260_Students. Subsequent times working on the lab should begin by copying your server files back onto whichever computer you are using.

- Use Windows Explorer to Navigate to Y:\GY320_2009
    - (Drive Y:/ is mapped to GISDataserv/Classes)
- Copy the folder "Sangre_de_Cristo"
- Paste the "Sangre_de_Cristo" folder onto the hard drive of the computer your working on – use C:/GIS_Temp
    - Save all your new files within this local directory "C:/GIS_Temp/Sangre_de_Cristo"
    - **Be sure to save often!
- When you done for the day, copy your "Sangre_de_Cristo" folder back to the server – use you folder on S:/GY320_Students (**Created during the intro lab)
- Keep all your files organized and be sure that you save your projects frequently as you go and that your new "layers", if you make any, are being saved to the correct place.

Data
The "Sangre_de_Cristo" folder contains all the *starting* data you will need. If you'd like, you can begin by exploring these file in ArcCatalog to orient yourself.

- An overview DEM (filename '*sangres_dem*').
    - This DEM covers the central portion of the Sangre de Cristo Range of south central Colorado. It is a composite of twelve 30m DEMs (each the size of a 1:24,000 topo map). It covers about 42 x 42 km.

- Two smaller DEMs of the Northeast and Northwest sides of the Sangre de Cristo Mts., which you'll be focusing on to make your main comparison between the two sides of the range - (filenames '*ne_dem*' and '*nw_dem*').

- Three polygon shapefiles indicating the extent of the three main rock types – Precambrian crystalline rock, Paleozoic sediment and young Tertiary/Quaternary sediment (filenames '*geology_precambrian.shp*', '*geology_paleozoic.shp*', and '*geology_tertiary_quaternary.shp*')

- Two stream shapefiles for the streams within the northeast and northwest DEMs (filenames '*ne_streams_grt1sqkm.shp*' and '*nw_streams_grt1sqkm.shp*') – I used a 1 km^2 drainage area cut-off to make these stream files, hence the filename.
    - Each of these stream shapefiles has one additional shapefile associated with it that contains imbedding information about DEM values at each point along the stream - I will explain these during lab.
        - *ne_streams_dem_values.shp*; *nw_streams_dem_values.shp*

Begin by Orienting Yourself!

Start a new ArcMap Project…open all these files!

Now before you do anything else go to *"File:Document Properties:Data Source Options" and make sure "Store relative path names" is selected*. Once this is done you should be able to move the project folder (with all its associated files) around with (relative) impunity.

Save your project file in "C:/GIS_Temp/Sangre_de_Cristo

Now you're good to go!

--Turn off all layers except '*sangres_dem*'

The light-colored, high-altitude, area, trending NNW-SSE across the center of data frame is the Sangre de Cristo Range. The dark area in the southwest is the San Luis Valley, a segment of the Rio Grande Rift. The dark area in the northeast is the Wet Mountain Valley. The west side of the Sangres is defined by a fault which offsets features as young as 8000 years. There are large faults on the east side of the range as well, but there is no evidence that they have been active during the Quaternary (last 2,000,000 years).

Bedrock in the Sangres consists of Precambrian crystalline rock, primarily in southern and western areas and Pennsylvanian/Permian clastic sediments (and a few later intrusive rocks) in northern and eastern areas. The valley floors on both sides are underlain by Cenozoic (Tertiary and Quaternary) sediments (including the Great Sand Dunes which appear at the west base of the range at the south edge of the DEM).

Okay, let's GO!!!

Make hillshade and slope maps for the Sangres DEM and the two focus areas. Keep you naming schemes simple:

'*sangres_hs*' and '*sangres_slp'*
'*ne_hs*' and '*ne_slp*'
'*nw_hs*' and '*nw_slp*'

Once you've made your hillshade maps, choose your favorite color scheme for topography (i.e., play with the symbology). Then display the DEM at 40% transparency with the hillshade map underneath.

1) Begin by examining the whole range (Sangres DEM, Hillshade and Slope Map).

Take a look at the west and east margins of the range. **What do you notice?** Take a look at the valleys penetrating the range from the two sides. **What do you notice?** The northwest and northeast DEM focus areas also show the differences in the valleys and drainage patterns pretty dramatically.

Take a minute to list some initial observations about the two range fronts and the valleys of the streams draining the two sides of the range from the DEM and the hillshade map. **How does the east side range front differ from the west side? How do the east side valleys differ from the west side valleys?** *Describe* what you see of topographic/ geometric differences, *don't get into genesis* of the range front or valleys yet. Take this initial examination seriously, since the differences are what you will be trying to explain in this lab.

A first thing you might want to check is whether the differences are related to bedrock geology. Try opening the bedrock geology layers. Once you've opened them, choose distinct colors and make them 50% transparent. **Study the map and make what observations you can about lithological control on the topographic differences between the two sides of the range.**

Slope maps are very powerful tools for analyzing topography. Take at look at the slope map. Zoom back out to the entire slope layer. **Where are slopes steep? How do steepness patterns differ between the two sides of the range?** You may want to change how things are displayed to see a little more. Change the slope map color ramp in symbology to the 'red to blue' one (low slopes blue, red high) - I think this color ramp does a good job highlighting the really steep terrain. Make the slope map semi-transparent with the hillshade layer below. **Where are the very steepest slopes? Where are they in the valleys? Which way do they face?** Zoom in a bit on the center of the range to answer this. **What (geomorphically) would you call these steepest slopes and what process formed them?**

Do you see any glacial moraines? Where? Moraines may be a little harder to see on the west side of the range than on the east. There is a nice well-preserved lateral/terminal moraine complex at around 442800/4204300 (units are meters) and another in the next valley to the north at around 442900/4206000 m. **How extensive were the glaciers on the two sides of the range?** Turning the slope overlay back on may help you answer this question. It is pretty easy to answer this question for the east side of the range, but I don't find it so easy for the west side. **Why is that?**

Okay, now you should feel well oriented and have made some great observations about the differences in surface morphology between the west and east sides of the Sangres. Time to learn some new tools for quantifying topography, some of which follow directly from the above questions, other of which are new ideas.

Now for some new Quantitative Analysis Tools:

- Raster Calculator
- Making Relief Maps
- Topographic Profiles
- Elevation and Slope Map Histograms
- Making Stream Profiles in ArcMap

Raster Calculator

You may find yourself asking:

- Where exactly are slopes at least 30 degrees?
- Where is elevation less than 3000 m?

To perform a calculation like this, use *Spatial Analyst* and choose Raster Calculator

- *Build your expression, for example, for the questions above:*
  - [ne_slp] >= 30
  - [ne_dem] > 3000
- *Hit Evaluate*
- *The result will be a new grid exactly the size of the original grid but with 1 values where the statement was true, and 0 values where it is false*
- *To save a calculated grid like this, right click the layer, choose Data, then 'Make Permanent'*

For both the east and west sides, where are slopes at least 30 degrees? Make the layer you calculate semi-transparent, and then look closely at the distribution of steep slopes on the two sides of the range.

Making Relief Maps

Topographic relief is simply the difference in elevation (maximum - minimum) for the length scale you choose. For example, if we were to calculate relief over a 30 km window for most locations within the Sangres, we would basically get the difference in elevation between the highest peak and valleys (in that case about 2000 m). If we use a smaller window, say 1 km, then relief is measuring the difference between local high and low elevations.

To make relief maps in ArcMap, use *Spatial Analyst*, choose Neighborhood Statistics

- *Input data: sangres_dem*
- *Field: VALUE*
- *Statistic Type: Range (**note the other ways you can use Neighborhood Statistics) Neighborhood: Circle*
- *Radius: 17*
- *Units: Cell*
- *Leave Output Cell Size as is…change it to 300 to make the calculation go a lot faster*
- *Save the output raster to your folder; 'sg_relief1' or something*

This will take a while. Change the color ramp (maybe to orange to blue) to see if there are any differences in patterns of local relief across the range, again paying close attention to the two range fronts. **In what parts of the range does the greatest relief occur?**

Now redo the relief calculations – with all the same parameters except for the '*ne_dem*' and '*nw_dem*' DEMs.

Right click on the new relief layer - properties - source tab – scroll down to check out the statistics of that grid and note the Min and Max values. (**Note that this is one way to make a

quick check of statistics on any grid). **How do mean and maximum relief compare between the two sides of the range?**

Topographic Profiles

Making Topographic profiles in ArcMap:

1. *Use 3D Analyst*
2. *Make sure the DEM you want to pull a topographic profile on is active.*
3. *Choose the "Interpolate Line button"*
4. *Once you've made your line, use the "Create Profile Graph"*
5. *After you've made a topographic profile, you can right click the plot to get access to a number of options: export the data, change axes, etc..*

1) Make some topographic profiles across individual major valleys on each side of the range. **What do the cross-valley profiles look like? How about valley-floor width? Are there side-to-side differences? Do higher elevation sections of the valleys differ from lower-elevations sections on the two sides of the range?**

2) General cross range profiles SW to NE across the entire range (perpendicular to the trend of the range. **Is the range symmetrical/asymmetrical? How so?**

3) Specific cross range profiles following ridge: find a place where you can start in the San Luis valley, run up a ridge on the west side of the range, cross the range crest, and then run down a ridge on the east side of the range, and then out on to the floor of the Wet Mountain Valley. **Are the ridge gradients constant? Do they have steps? Are they different on different sides of the range? What happens to ridges gradients near the mountain front on the two sides of the range?** Try a couple more of these specific ridge profiles going short distances up other ridges at each range front – asking the same question.

Elevation and Slope Map Histograms

1. *Spatial Analysis*
2. *Make sure the DEM or Slope Map you want to make a histogram of is active.*
3. *Click to "Histogram" Button…*
    a. *Unfortunately ArcMap doesn't make the best plots in this regard (e.g., they don't label the axis)…I suggest quickly exporting the data to Excel for easy viewing and manipulation.*
        i. *After you've made a histogram, you can right click and choose 'Export…', then the hit the 'Data' tab, then choose Excel as the format and click save. Open the '.xls' file you just created and you'll see the bins and number.*

In addition to making histograms for an entire DEM or Slope map, you can also analyze any particular part of the DEM or slope map by drawing a polygon and then while the polygon is highlighted, hitting the Histogram button…as long as the polygon you draw intersects with the active grid in the Spatial Analyst bar, that's the grid you'll be pulling values from for the histogram.

- To draw a polygon…use the Drawing Toolbar, hit the small black triangle next to the Rectangle, choose polygon…draw your polygon.

Can you see any differences between the two sides in terms of their elevation histograms? (the west side DEM goes to a lower minimum altitude).

How about the two sides' slope histograms? Which side has a higher mean slope? Which side has the maximum slope values?

Draw some polygons in specific elevation ranges for both the east and west sides, then look at the slope histograms for those polygons.

On the east side is there any correlation between elevation and slope? How about the west side? Do the two sides of the range differ?

I've gone a bit further here to help you answer these questions. Using another program (MicroDEM) I have found the mean slope at different elevations on the two sides of the range. A plot of this altitude vs. slope relationship for the two sides of the range (along with MicroDEM plots of area/altitude distribution and slope/area distribution for the two sides) is on the tackboard at the back of the classroom and is saved in the folder "MicroDEM_output" in the "Sangre de Cristo" folder.

Making Stream Profiles in ArcMap

Same as with other topographic profiles…Use 3D Analyst…

1. *This time you are going to use the select button to highlight one of the streams in the files "ne_streams_dem_values.shp" or nw_streams_dem_values.shp". These shapefiles have been specifically prepared to extract a very particular topographic profile…right down the stream!*
2. *Once a stream is highlighted, then use the "Create Profile Graph" button.*
3. *The plot on the graph is depicting a stream profile.*

Take a look at a bunch of stream profiles from both sides of the range. **Are there lots of knickpoints on these profiles? Which side generally has smoother looking profiles?**

Printing Maps/Figures/Plots

If you want key, labels, etc, you need to change from the view you've been working in called the "data view" to another view called the "layout view". To do this, when you are ready to print a map on the toolbar bar selects "View: Layout View". In this view you can relocate and rescale you map, insert a title, text, legend, scale, north arrow, etc. Be warned, though, that it is time consuming and somewhat frustrating to do this. For a thesis you'd need to do it, for a class project like this it may be more time consuming than it is worth. I'll accept (neatly) hand-labeled figures at no cost to your grade, although you are certainly welcome to fool around with printing from the layout view if you want.