

Analyzing The Alpine Fault of New Zealand

Testing a Proposed Geodynamic Theory That Aims to Explain the Varying Uplift Rates Along The Length of The Alpine Fault

Carlos Camacho

GEO 371C

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I. Introduction

A) Purpose: The main purpose of this project is to use GIS tools and methods to test the proposed geodynamic theory by Little and others (2005) which suggests that the varying uplift rates along the length of the Alpine Fault of New Zealand are due to high local rates of precipitation in the central section of the fault resulting in fast uplift rates.

B) Problem Formulation:

a. Are high local rates of precipitation (which are directly proportional to the amount of erosion) responsible for the anomalous fast uplift rates found in the central section of the Alpine Fault of New Zealand?

b. Do low precipitation values correlate with slow uplift rates and vice versa?

To answer this question one must:

i. Represent the graph of Thermochronometric and Fission Track ages plotted against the distance along the Alpine fault from the Fiordland coast as data points (Batt et al., 1999).

ii. Calculate an average raster layer out of these data points.

iii. Compare this raster layer to a raster of the areas average precipitation.

iv. Calculate a final raster between these two raster layers that represents how the two types of data overlap.

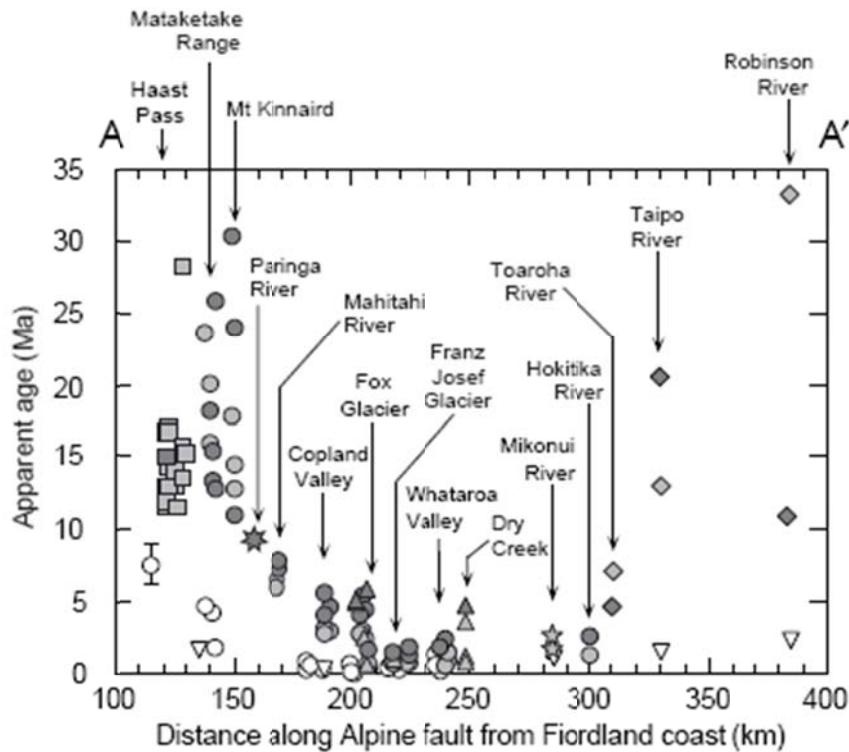
c. Discuss the results of the project and what that means with respect to the proposed geodynamic theory.

II. Data Collection

- 250m Resolution Digital Elevation Model of New Zealand
 - <http://www.geographx.co.nz/downloads.html>
File: nztm250m.asc
- 100m Resolution Land Cover of New Zealand
 - <http://www.geographx.co.nz/downloads.html>
File: landcover100m.jpg
- Outline of the New Zealand Coast
 - <http://koordinates.com/layers/global/oceania/new-zealand/>
File: nzcoast_nztm.shp
- Average Precipitation of New Zealand from 1971-2000
 - <http://www.niwa.co.nz/our-science/climate/our-services/mapping>
File: mean_rain.asc

(This piece of GIS data was not free and was kindly provided by Dr. Andrew Tait)

- Thermochronometric and Fission Track Ages Plot (Uplift Rates)
 Thermochronological analysis of the dynamics of the Southern Alps, New Zealand (Batt et al., 1999).



LEGEND

Data Source

- - This study
- ☆ - Chamberlain et al., 1995
- ▽ - Tippett and Kamp, 1993
- - Adams and Gabites, 1985
- △ - Adams, 1981
- ☆ - Hawkes, 1981
- ◇ - Terry Spell, unpublished data

Chronometer

- - Zircon fission tracks
- - Biotite K-Ar
- - Muscovite K-Ar



III) Data Processing

1) Preparing Base Map

A work folder must be created for the project and the online GIS data mentioned above must be downloaded into this folder.

The first step in this project was to create an aesthetically pleasing base map of New Zealand to which any later calculated rasters or digitized data could be projected onto. To do this, the downloaded files were first previewed in ArcCatalog.

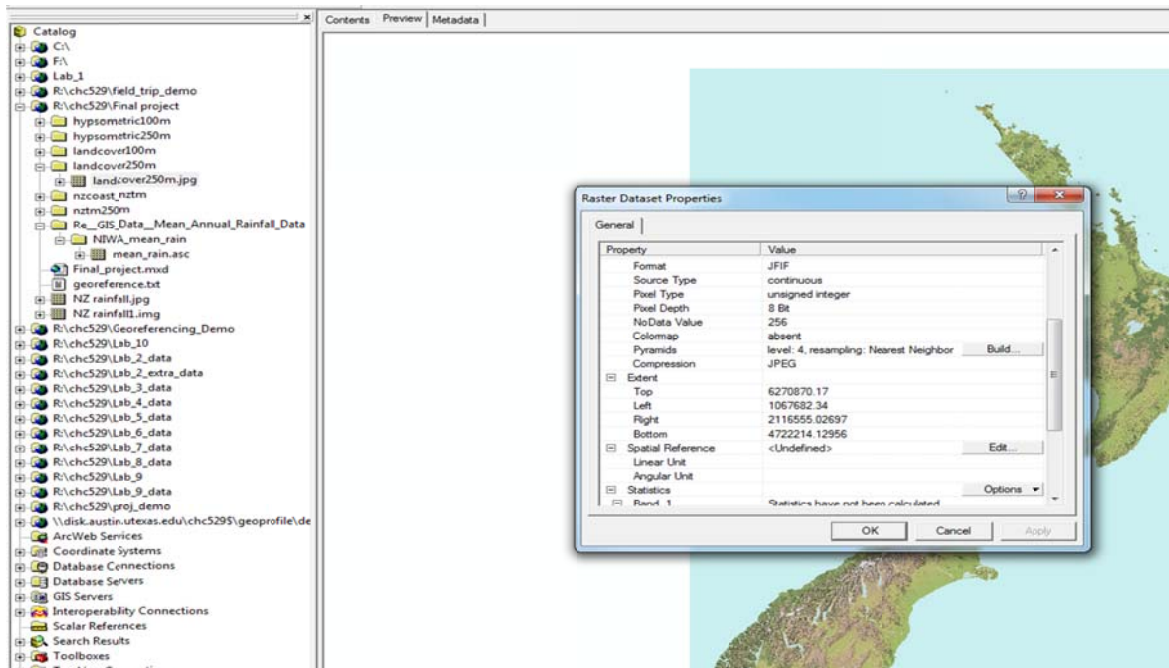
i. So that the files can be projected correctly into an ArcMap document, the spatial reference of each file must be defined. This was checked by:

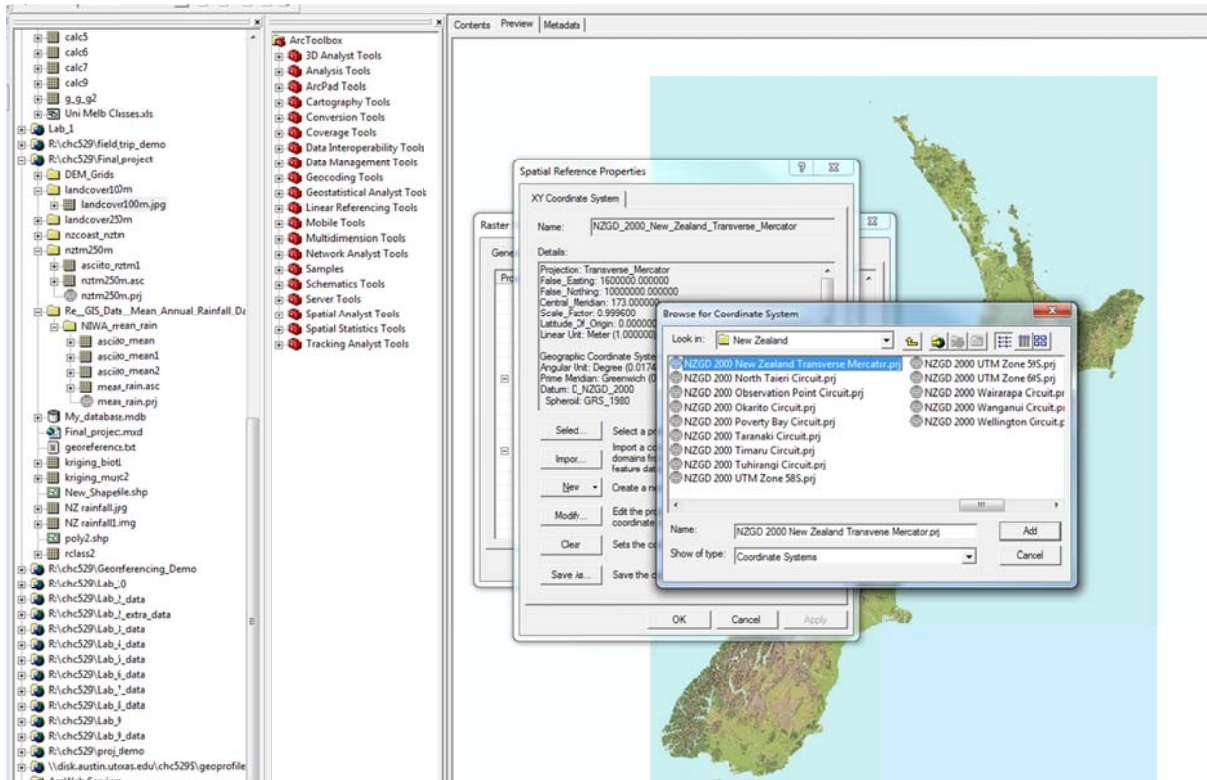
- Right clicking on the layer in the table of contents
- Selecting the properties options

If the “properties” dialog box displayed “undefined”, then a coordinate system was selected clicking the “edit” option.

All of these files had an undefined coordinate system. The correct coordinate system for the individual data can be found in the respective websites.

Ex: Assigning the correct coordinate system to 100m Resolution Land Cover of New Zealand in ArcCatalog:





(Assigning a defined coordinate system to a downloaded GIS file in ArcCatalog by selecting “Properties” and editing the “Spatial Reference”).

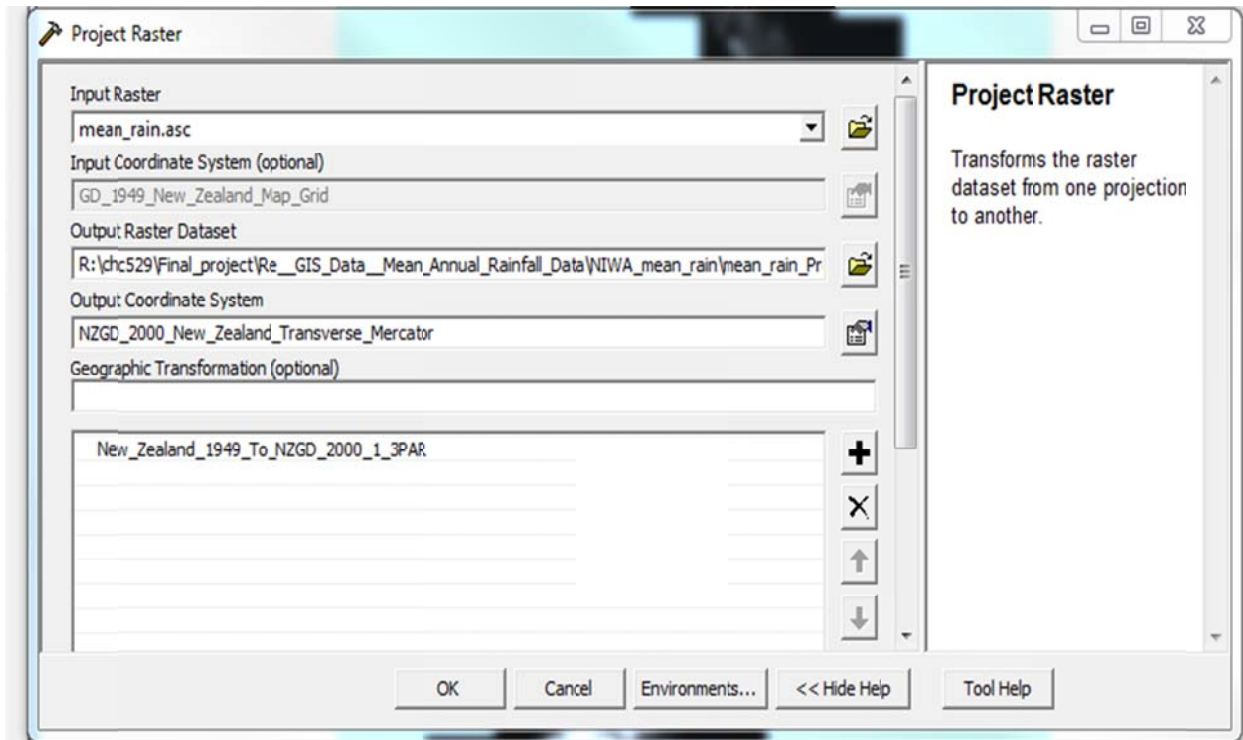
Once all of the files have their appropriate coordinate system defined they can be uploaded into an ArcMap document and projected correctly (on the fly) by using the “add data” button or dragging and dropping them into the Table of Contents.

- ii. The Digital Elevation Model, the 100m Resolution Land Cover, the Outline of the Coast, and the Average Precipitation files can be manipulated to create the necessary base map for this project. These files were assigned the following coordinate systems respectively: New Zealand Transverse Mercator, New Zealand Transverse Mercator, New Zealand Transverse Mercator, and New Zealand Map Grid.

Even though one of these files has a different coordinate system it is still being projected correctly and is in synchronization with the others because ArcMap can convert the coordinates of the file “on the fly” into the coordinate system of the first file that was uploaded into the ArcMap document. While simply defining the correct coordinate systems is enough to properly project the files into an ArcMap document, it is not sufficient if we later want to make calculations using this layer such as “raster calculation”. For this reason, the coordinates of the Average Precipitation file need to be

permanently transformed into the coordinate system of the other files (NZTM). To do this, the “project raster” tool from ArcToolbox must be used because this is a raster file.

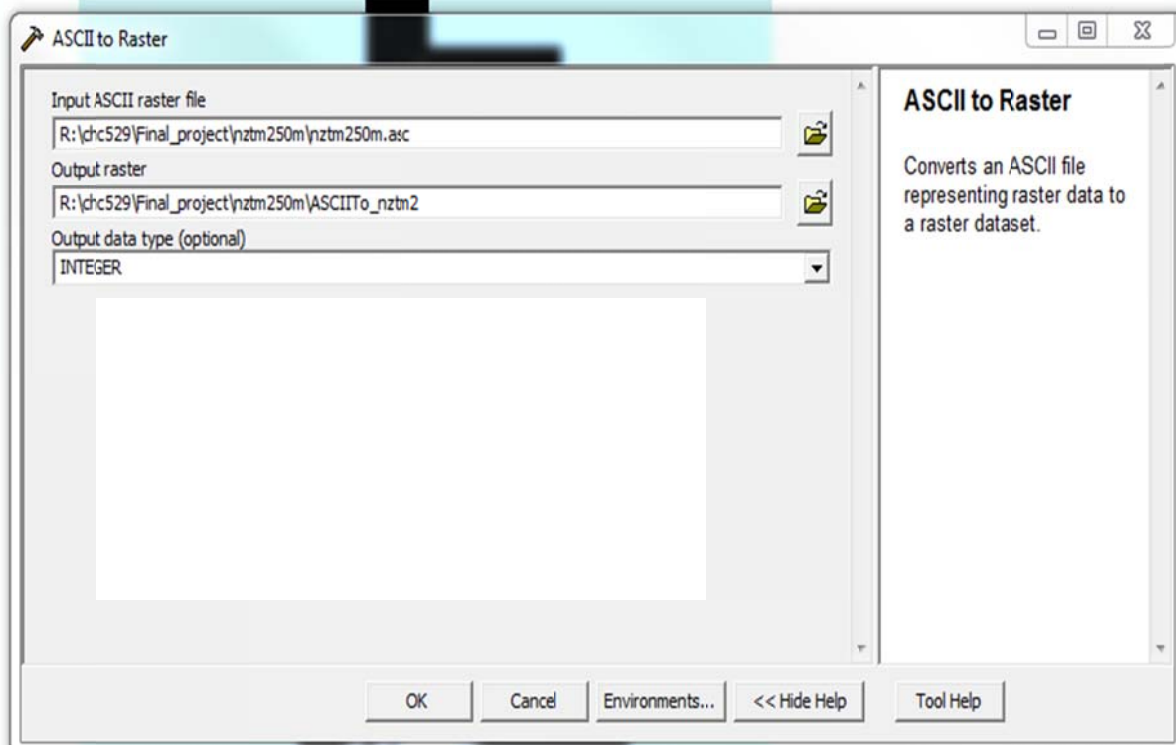
Ex: Permanently converting the coordinates of the Average Precipitation file into NZTM coordinates.



Now that this is done, the data can be manipulated to create the base map for the project.

- iii. The DEM raster layer has extra “no data” cells that do not portray any useful information and need to be removed. Similarly, the Average Precipitation raster layer has a few cells that protrude beyond the New Zealand coastline and create a blurry outline. These issues can be resolved by using the “Raster Calculator” to clip the raster layers to the New Zealand Coastline layer. However, The DEM and the Average Precipitation raster layers are ASCII file types. The “Raster Calculator” can only carry out calculations if the raster is in grid format. Additionally, both layers used in the calculation must also have coordinates in the same coordinate system. This was taken care of in the last step.

So before we clip the rasters to the New Zealand coastline we must first convert them from ASCII file type to Grid format. To convert the raster ASCII files into Grid format, the “ASCII to Raster” tool from ArcToolbox must be used.

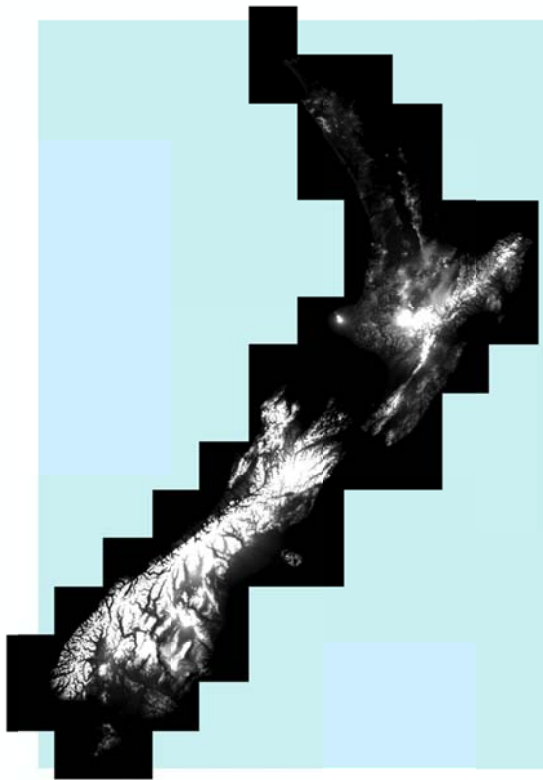
Ex: Converting the DEM raster layer from ASCII files type into Grid format.

Using this tool for both layers creates new raster layers and they are added to the Table of Contents. The former ASCII raster layers can be removed.

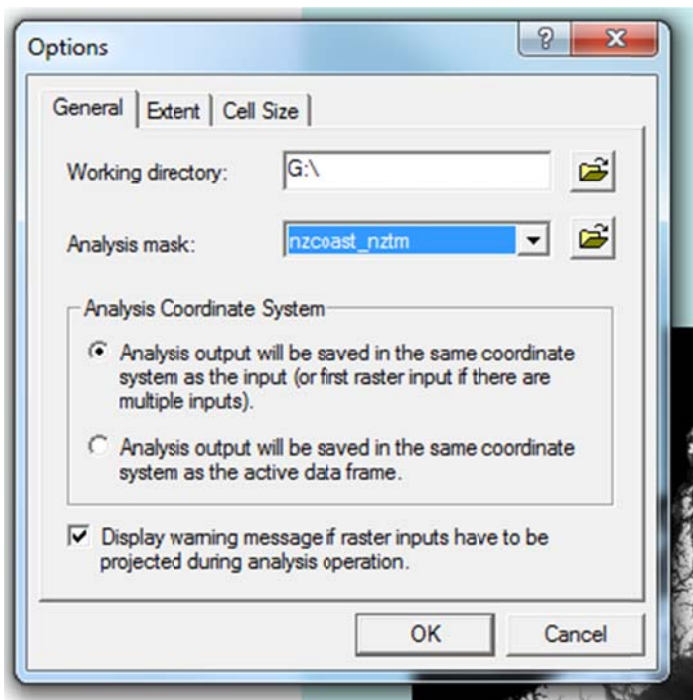
Now that the DEM and Average Precipitation raster layers are in Grid format, the “Raster Calculator” can be used to clip the layers to the New Zealand coastline layer. To do so, the “spatial analyst” toolbar is used:

- First the analysis mask must be selected in the “options” dialog box found in the drop down menu of “Spatial Analyst” toolbar.
- In this case the analysis mask will be the Outline of the Coast layer since this is what we want to clip the raster layers to.
- Once this has been set up, the “raster calculator” can be used which is also found in the drop down menu of “Spatial Analyst” toolbar.
- Once the “raster calculator” dialog box is opened, simply double click on the raster layer that needs to be modified and select “evaluate”.

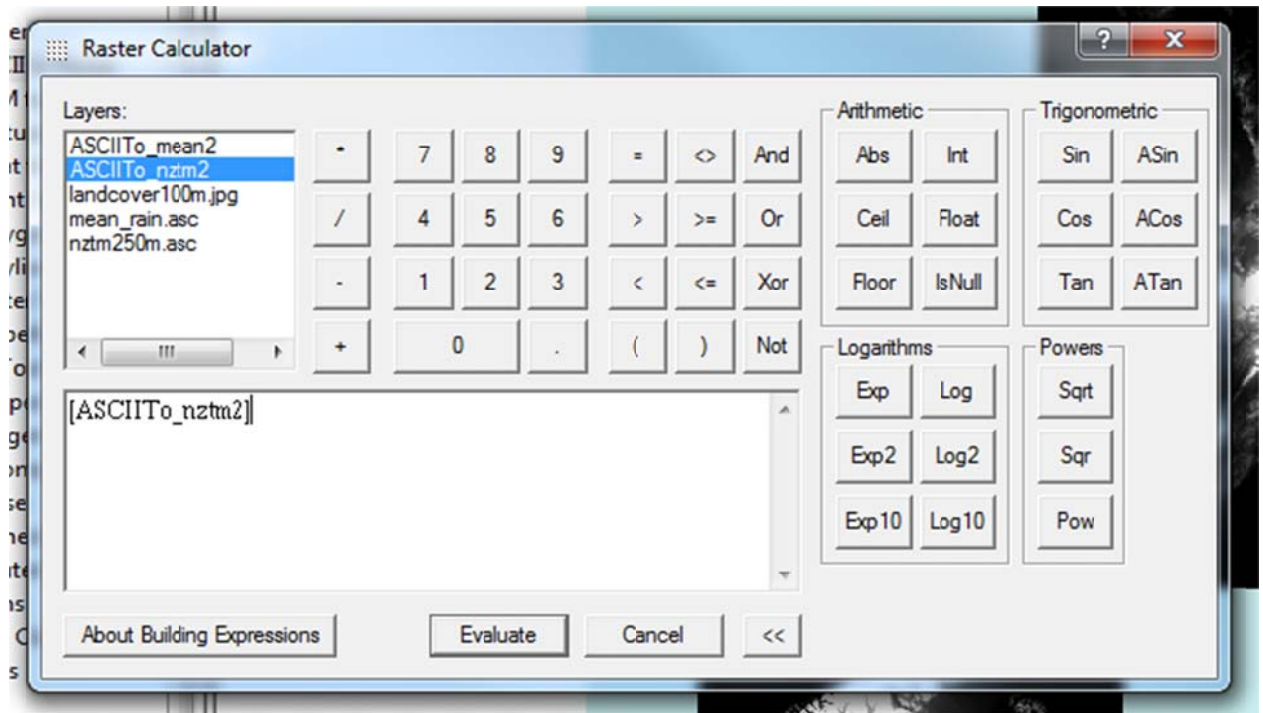
Ex: Clipping the DEM raster layer to the New Zealand Coast using the “Raster Calculator”



DEM Raster layer before clipping.



Setting the New Zealand coast layers as the Analysis Mask.



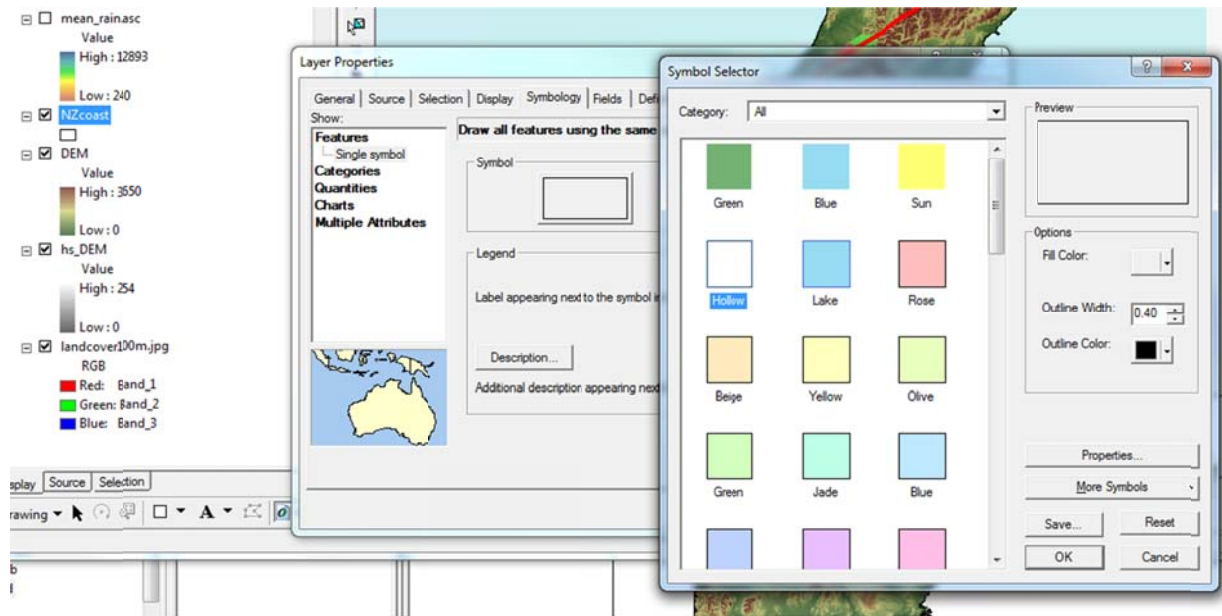
Using the Raster Calculator to clip DEM to Coastline



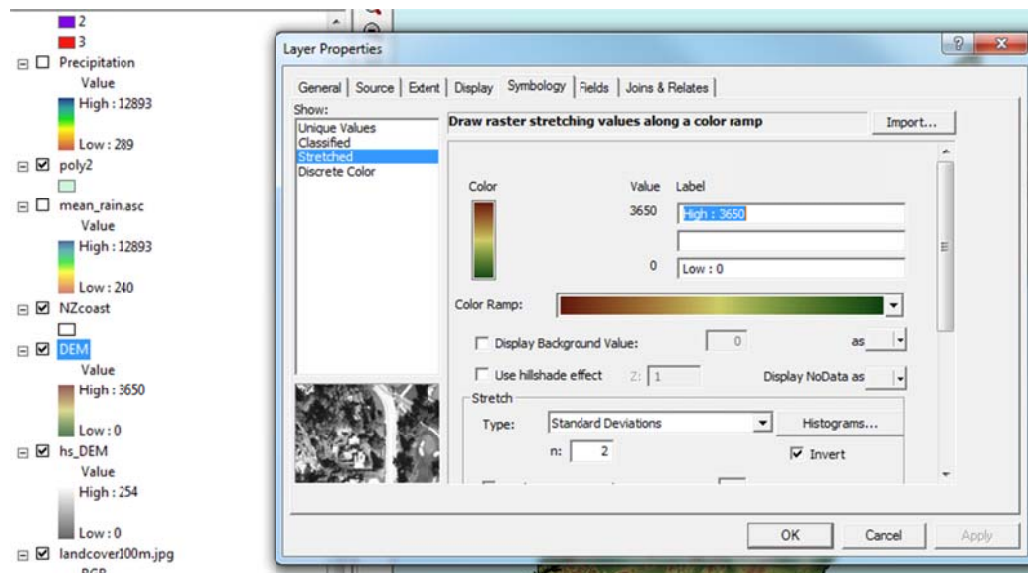
Result of the DEM raster layer after using the “Raster Calculator”

Once this has been done for both the DEM and the Average Precipitation raster layers new raster layers are created and added to the table of contents. The old raster layers can be removed.

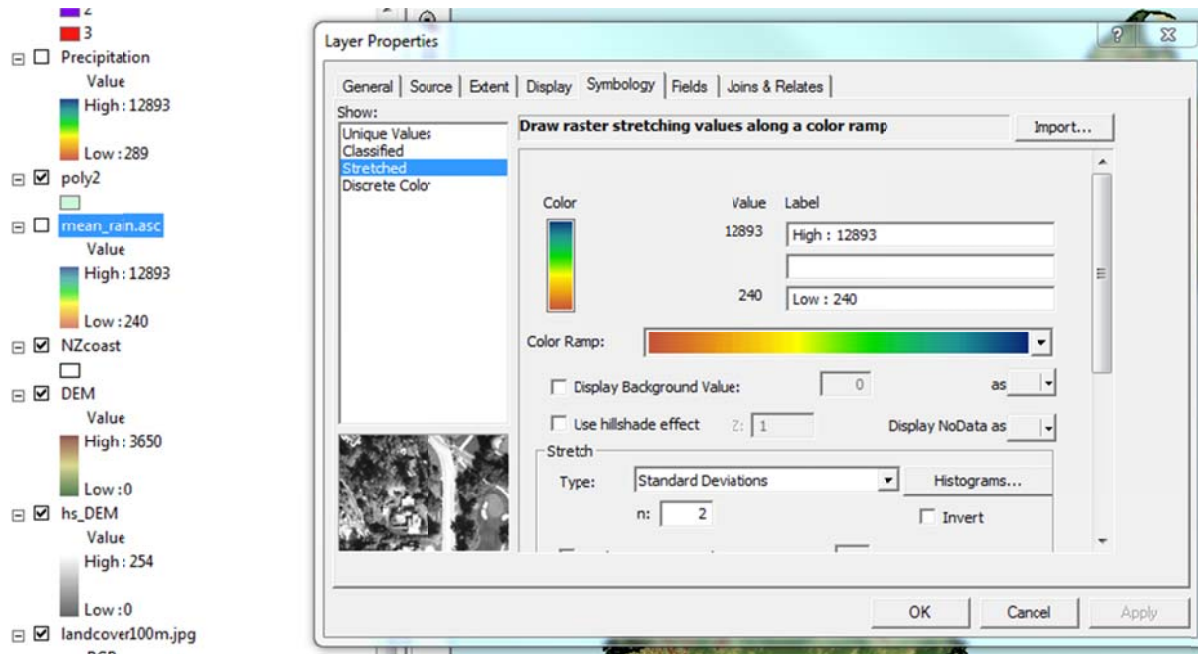
- iv. The “symbology” for the New Zealand Coast layer and the two raster layers should be modified. The color of the New Zealand Coast layer should be made hollow and the layer should be dragged above the other three layers.



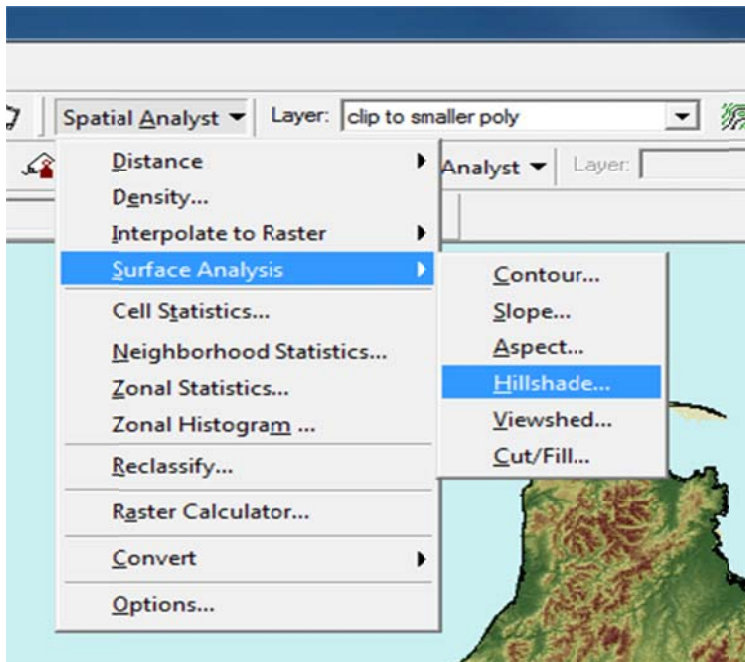
The “symbology” for the newly calculated DEM and Average Precipitation layers should be “stretched” and have “standard deviations” selected as “stretch type”. The color ramp for the DEM can be “red to green diverging, dark” and inverted.

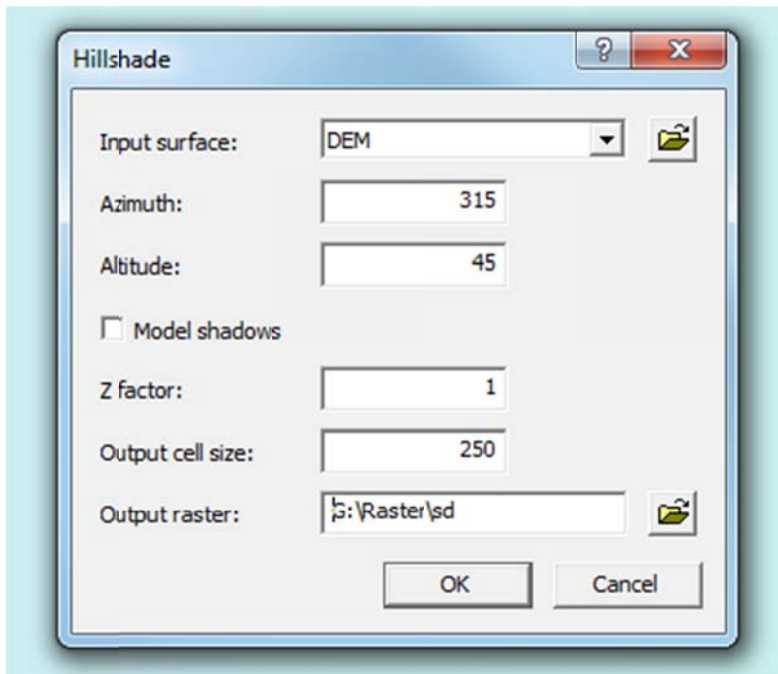


The color ramp for the Average Precipitation can be “precipitation” with no inversion.



A hillshade can be calculated for the DEM raster layer using the “hillshade” option under “surface analysis” dialog box found in the drop down menu of the “Spatial Analysis” toolbar.





Resulting Hillshade from using “Surface Analysis”

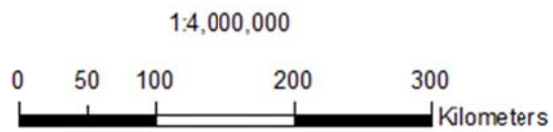
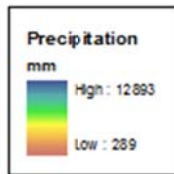
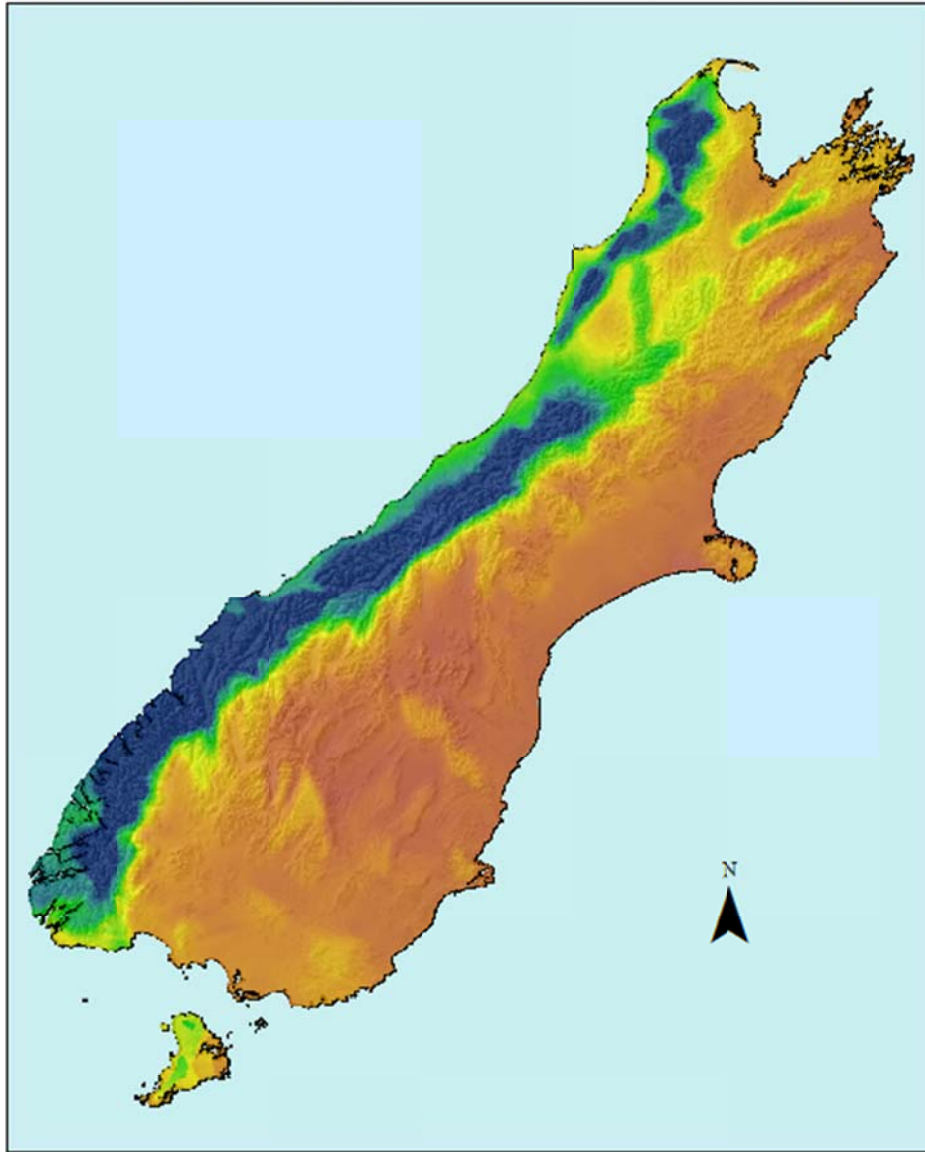
- v. All of these modifications will result in the following base maps:



Average Precipitation from 1971-2000 of New Zealand's South Island

New Zealand Transverse Mercator System

Carlos Camacho



2) Digitizing Data

Now that a base map has been created, any digitized or calculated information can be projected on a meaningful surface.

This project aims to display the correlation between the precipitation and uplift rates. The clipped Average Precipitation raster layer will provide the necessary precipitation data. The uplift rates data will come from the Thermochronometric and Fission Track Ages Plot displayed in the beginning of the report. This data can be represented as digitized points along the Alpine Fault. To plot them accurately, the Alpine Fault will also have to be digitized.

- i. To digitize any data, a personal geodatabase must first be created. This database will hold Feature dataset and can be done by:
 - right clicking on the project folder in ArcCatalog
 - searching under the “New” drop down menu
 - And selecting the “personal geodatabase” option.

A feature dataset will hold feature classes and can be created in the geodatabase by:

- Right clicking on the geodatabase
- searching under the “New” drop down menu
- And selecting the “feature dataset” option.

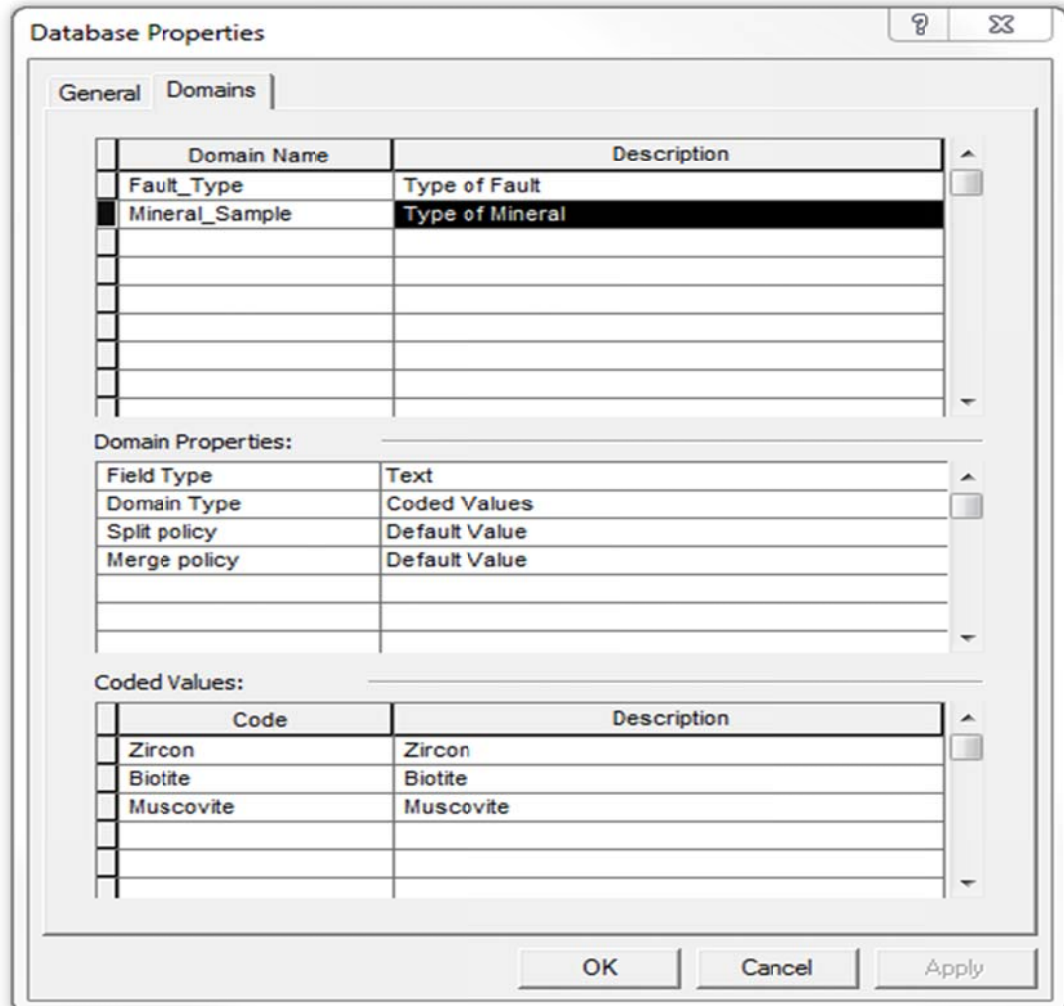
A feature class will hold the digitized elements and can be created by:

- By right clicking on the feature dataset
- searching under the “New” drop down menu
- And selecting the “feature class” option.

For this project, three feature classes will be required. A line feature class for the Alpine Fault, a polygon feature class to create a polygon around the Alpine fault to which later calculated rasters will be clipped to, and 3 point feature classes to digitize the uplift rate data point from the Thermochronometric and Fission Track Ages Plot.

The Thermochronometric and Fission Track Ages Plot contain uplift rate values gathered from zircon, muscovite, and biotite grains. Each of these minerals has different closing temperatures—the temperature at which no more degenerate isotopes can leave the grain. This means that whether an uplift rate is classified as fast or slow depends on what mineral the data was gathered. For example, an uplift rate value of 5Ma is considered high for a zircon grain but low for a muscovite grain. For this reason, there will be 3 point feature classes.

The point feature classes will require a domain with the following characteristics:

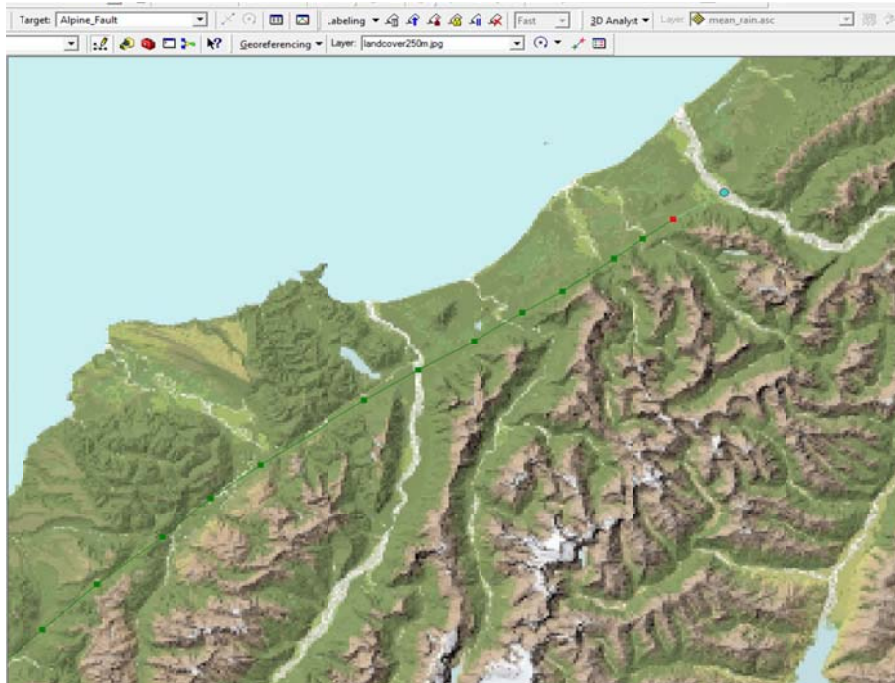


After creating the domain it must be linked to the appropriate feature class so that the data points can be attributed as they are created.

- ii. Digitizing is done by:
- using the “editing toolbar”
 - selecting “start editing”
 - choosing the correct “task” and “target”
 - and selecting the “sketch tool”

To digitize the Alpine fault the Land Cover of New Zealand layer should be used as a base because it provides the best resolution. The alpine fault is a significantly linear feature and is distinguishable on the map.

Ex: Digitizing the Alpine Fault.



Digitized Alpine fault

To digitize the uplift rate values from the Thermochronometric and Fission Track Ages Plot, it is important to figure out at what length of the fault each data point lays. The apparent age (uplift rate) is plotted against the distance along the alpine fault from the Fiordland coast. To figure out the corresponding length on the map of each point, I printed out a map at a known scale and figured out the relative scale knowing that the length of the fault was 625km. At a scale of 1:4,000 1in is equal to ~50km. With this information I was able to digitize the data points from the plot.

Ex: Digitizing and attributing the uplift rates



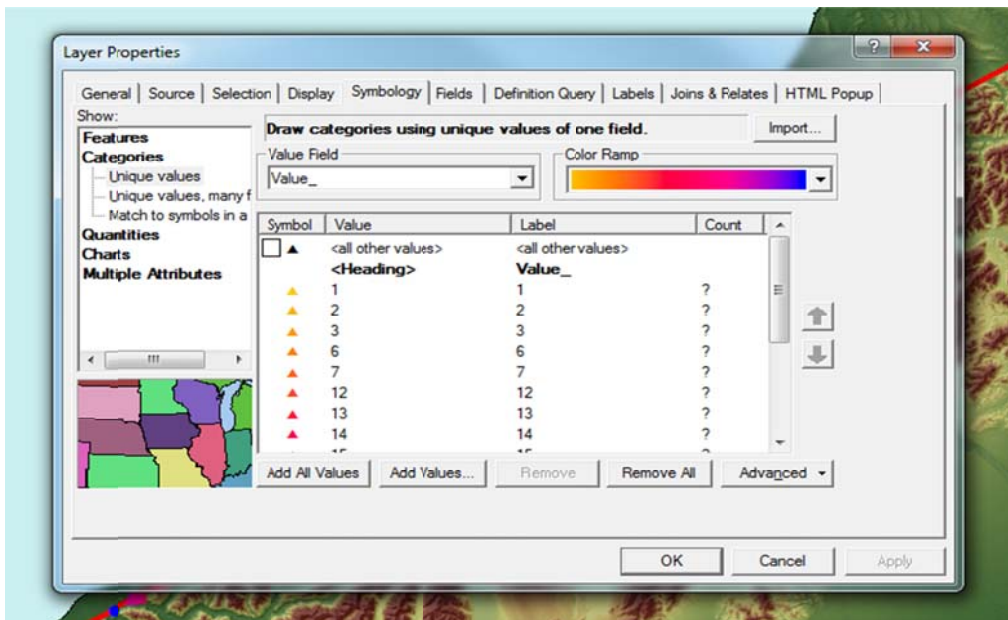
Property	Value
OBJECTID	19
Value_1	1
Type	Zircon
	<Null>
	Biotite
	Muscovite

1 features

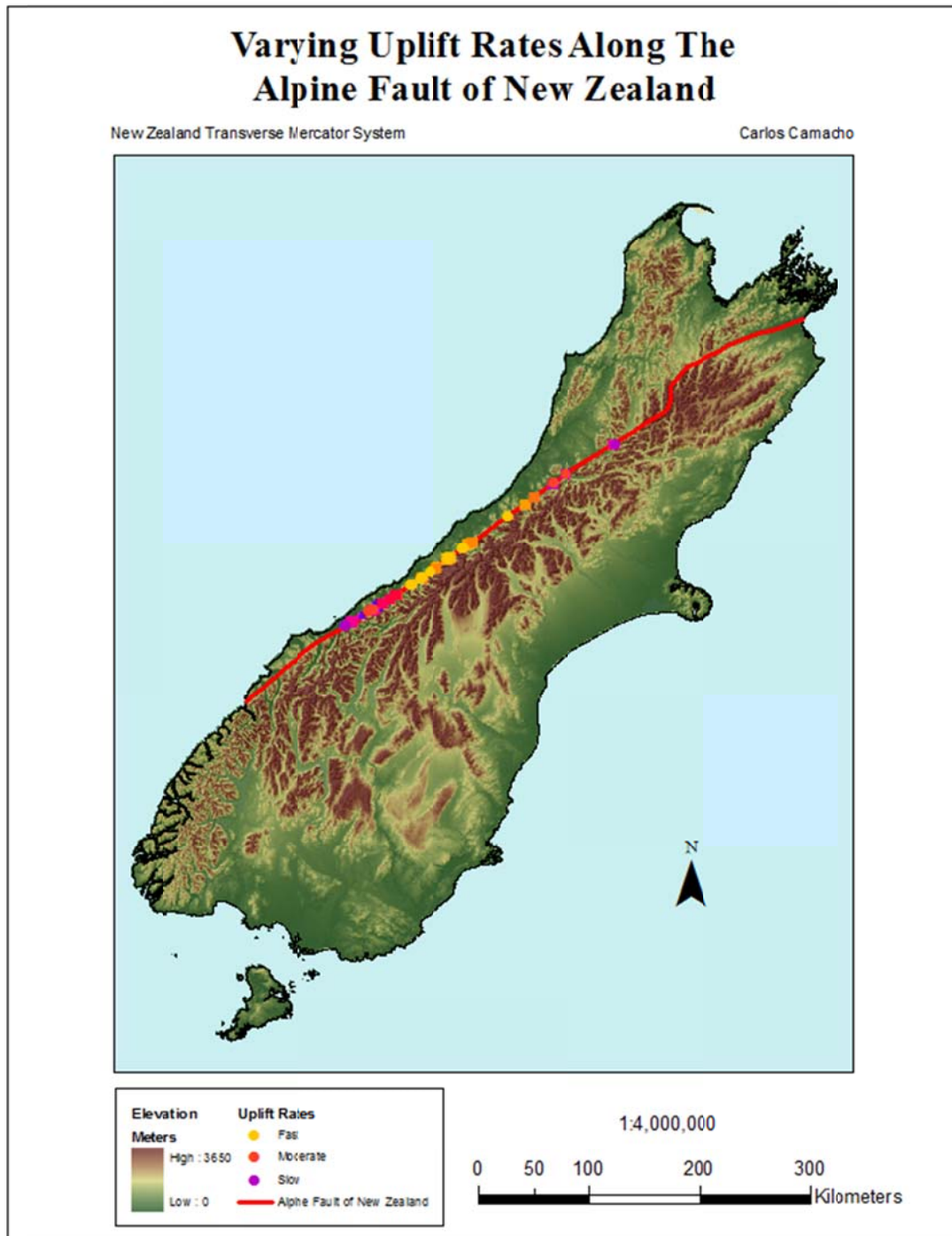


Digitized uplift rates along the Alpine Fault.

The symbology of each point feature class was then modified by “unique values” under categories with “value” as the value field to be represented as above.



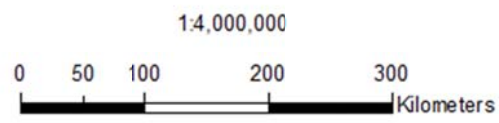
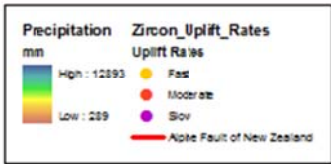
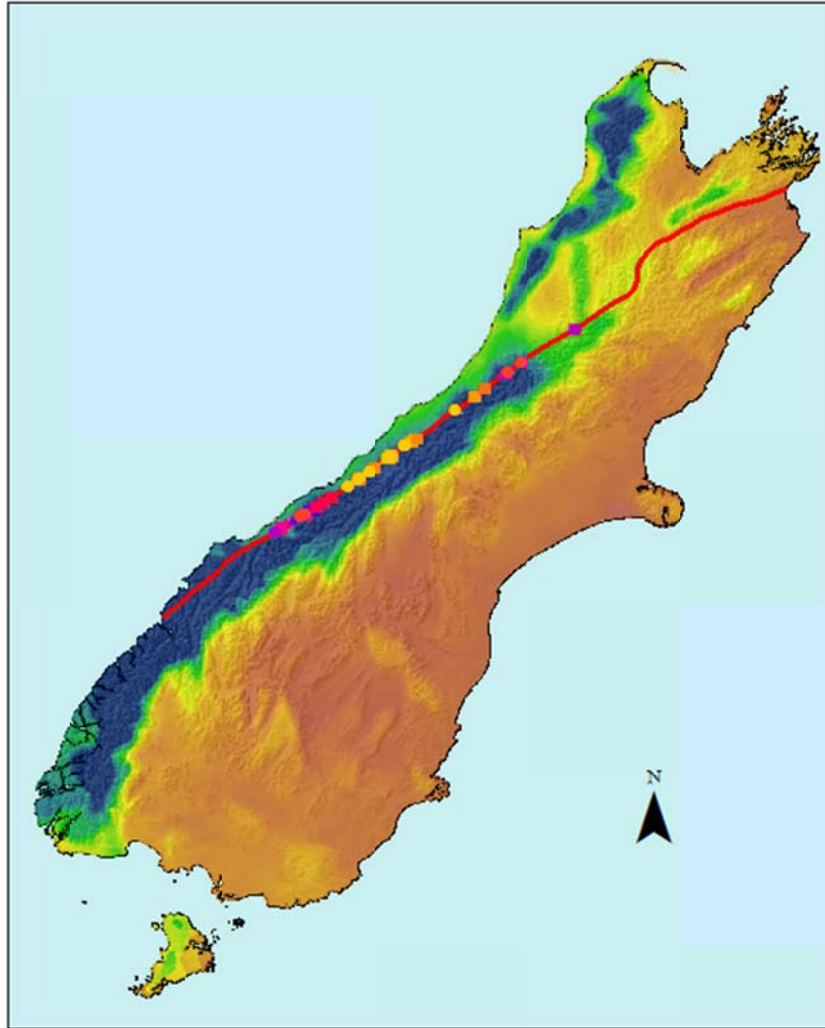
While this information does not yet show the correlation between precipitation and uplift rates in a single raster, it can still however produce an interesting map depicting the varying uplift rates along the alpine fault and also a map showing these data points superimposed on the precipitation raster.



Correlation Between Precipitation and Uplift Rates Along The Alpine Fault of New Zealand

New Zealand Transverse Mercator System

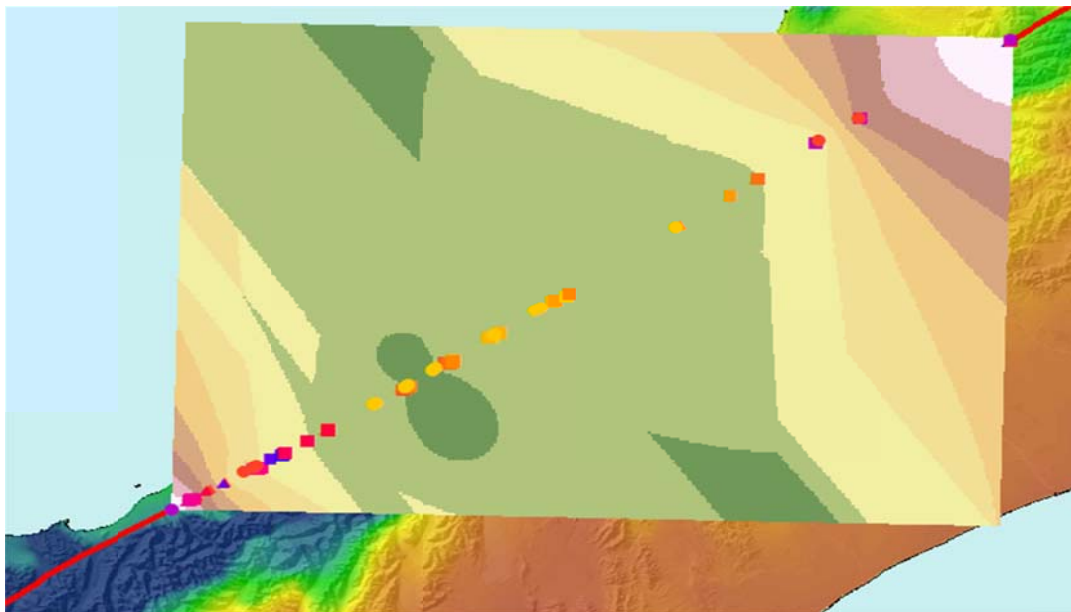
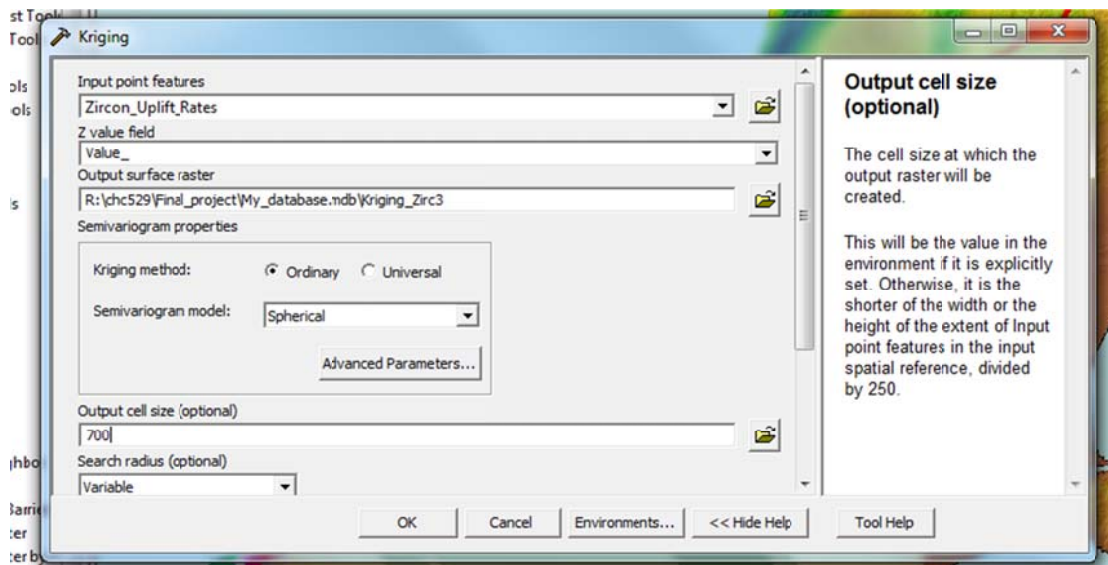
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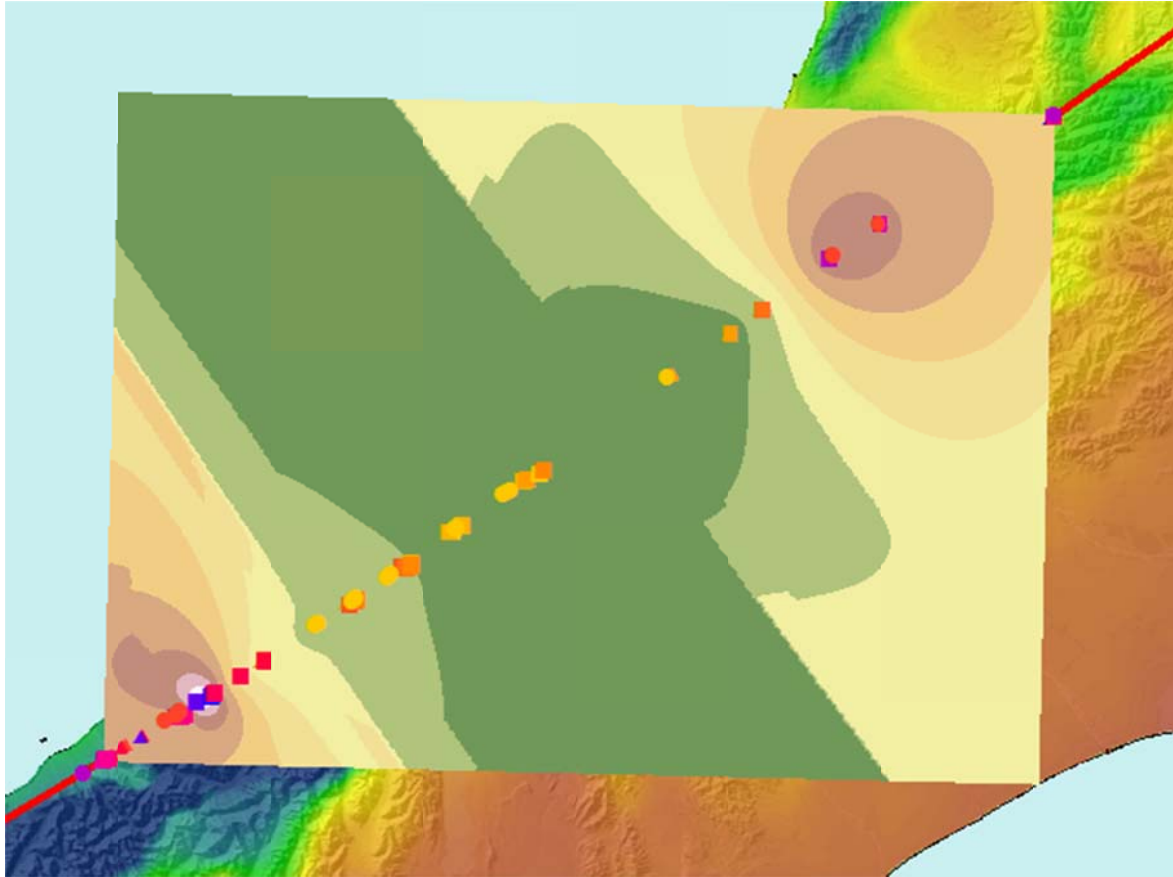
3) Calculating Rasters

Now that all the necessary data has been digitized, the desired rasters can be calculated. In order to calculate a single raster that represents the correlation of precipitation and uplift rates we must first convert the uplift rate data points into rasters.

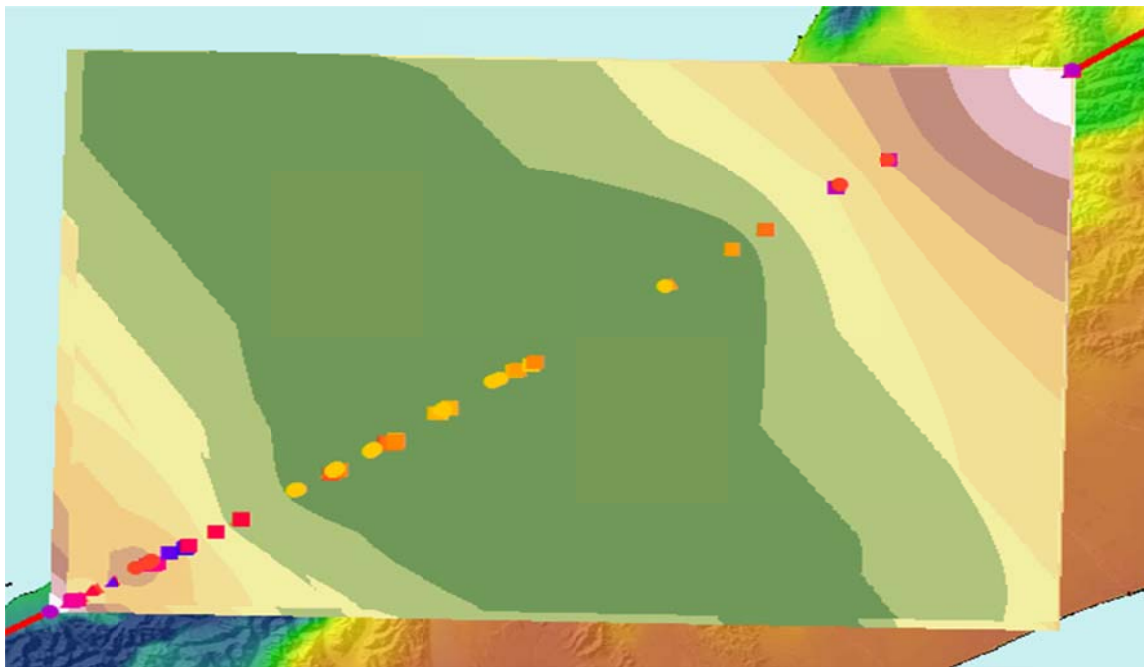
- i. The uplift rate data points can be converted into rasters using the “Kriging” tool from ArcToolbox. Because there are 3 separate point feature classes, the tool will have to be used 3 times and 3 rasters will be calculated.



Raster produced from zircon data points by using the “kriging” tool.



Raster produced from muscovite data points by using the “kriging” tool.

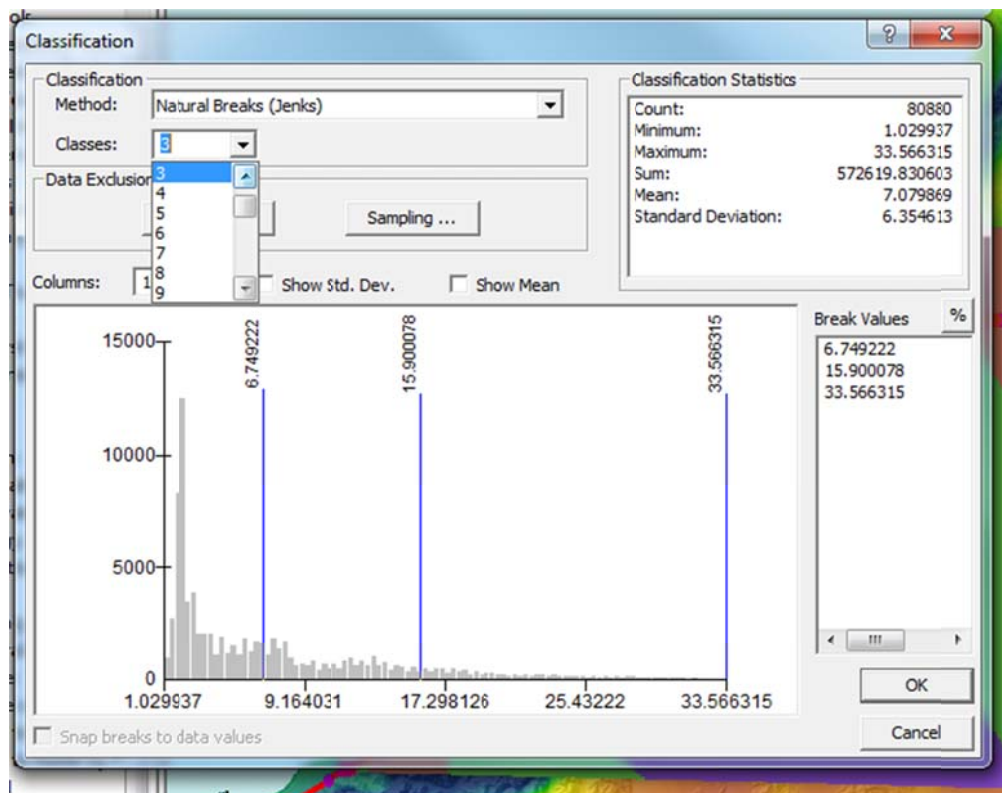


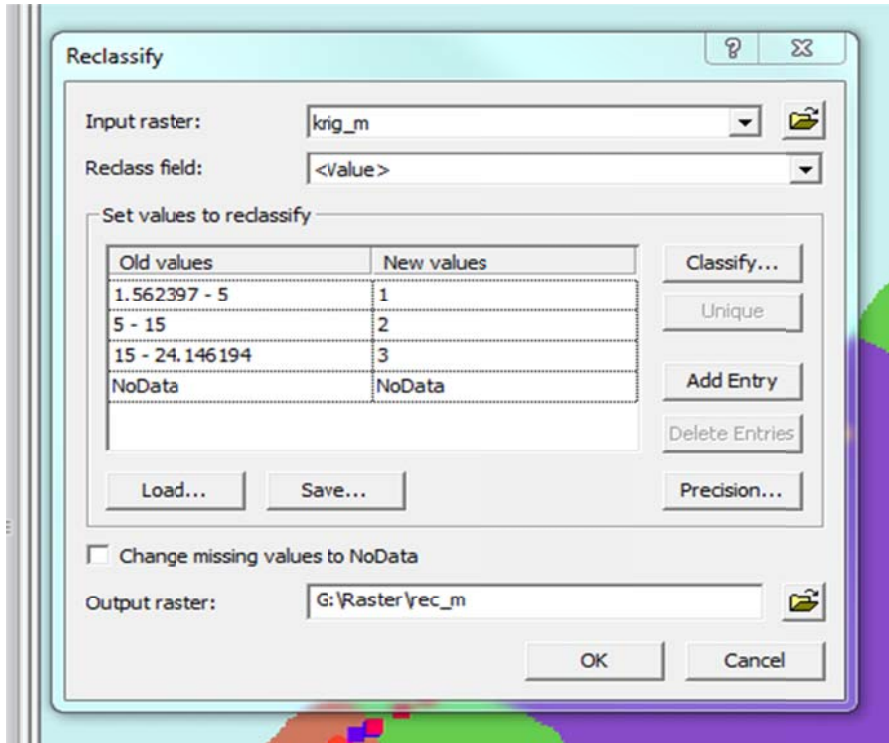
Raster produced from biotite data points by using the “kriging” tool.

- ii. The uplift rate data points are now represented in Raster layers. By using the raster calculator we could take the average of the three rasters to create one raster which would then allow us to calculate a final raster between the average raster and the precipitation raster.

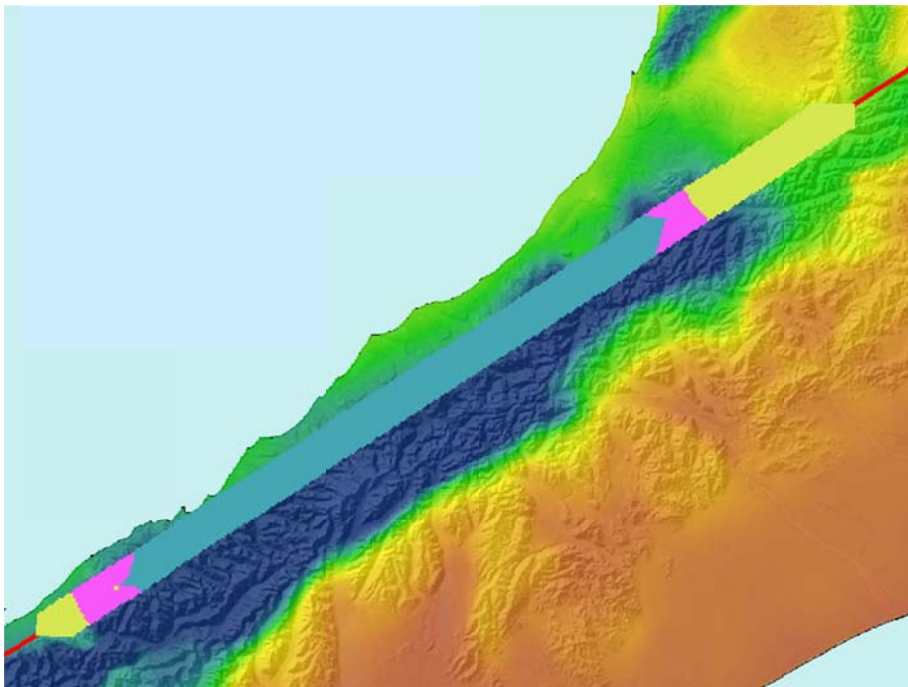
However, as mentioned earlier, because the different minerals have different closing temperatures and different ranges for fast and slow uplift rates, these rasters cannot be averaged as they are. Doing so would create an inaccurate raster because the raster calculator does not recognize there are different ranges for fast and slow uplift rates between the minerals.

To solve this problem the “reclassify” option in the “spatial analyst” toolbar can be used. This tool basically assigns the categories of fast, moderate, and slow to the uplift rate values of each mineral type according to the characteristics of the mineral. In this case, for biotite and muscovite grains, the “fast” range was 0-5, “moderate” was 5-15, and “slow” was higher than 15. For zircon grains the “fast” range was 0-2, “moderate” was 2-4, and “slow” was 4-7. Making these changes allows the data between the three rasters to match up correctly and will produce an accurate average raster between the three when the “raster calculator” is used.

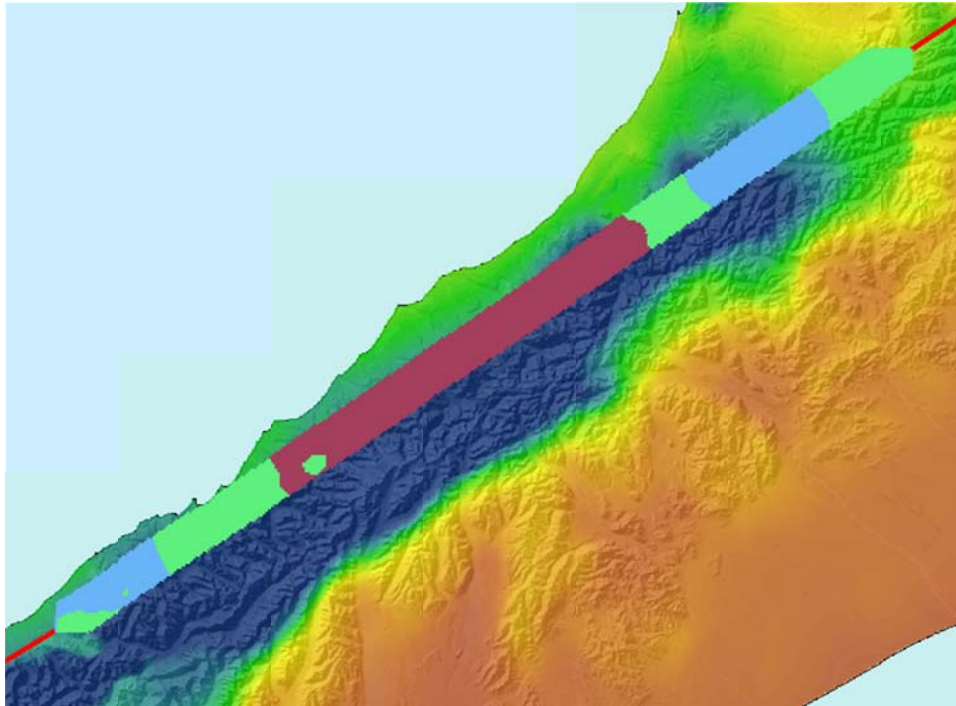




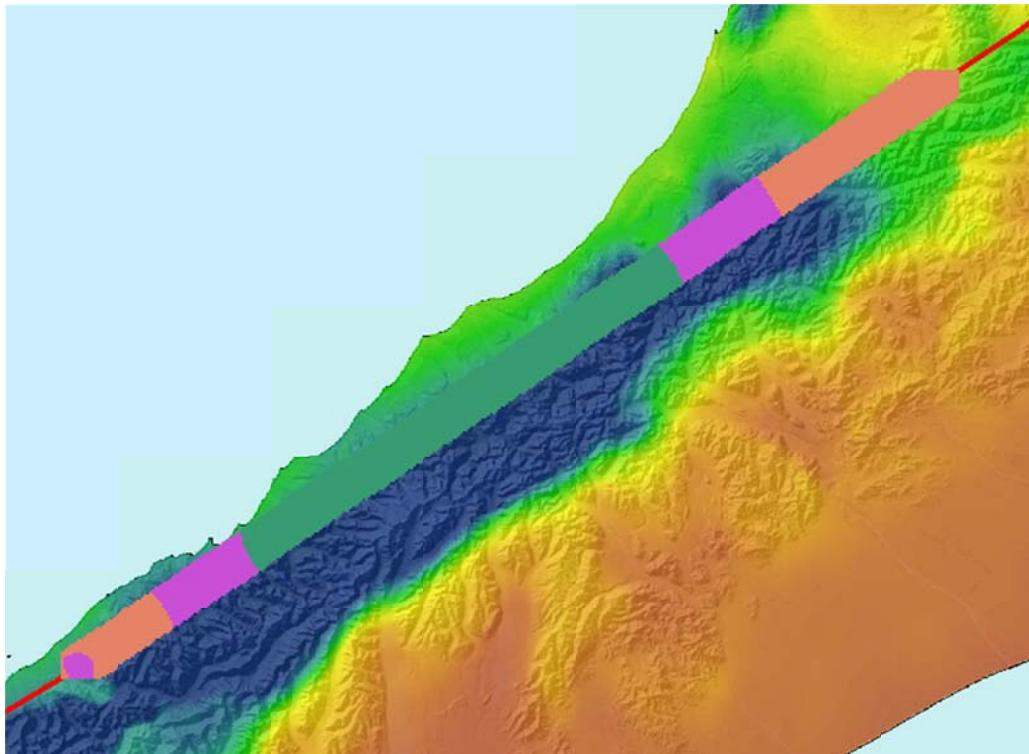
The “reclassify” option not only reclassifies the values but also clips the rasters at the same time. For this project we are only interested in the information along the Alpine Fault so the “Analysis Mask” should be set to the polygon that was digitized around the Alpine Fault in the Polygon feature class.



Raster produced from zircon data after reclassifying and clipping to polygon.

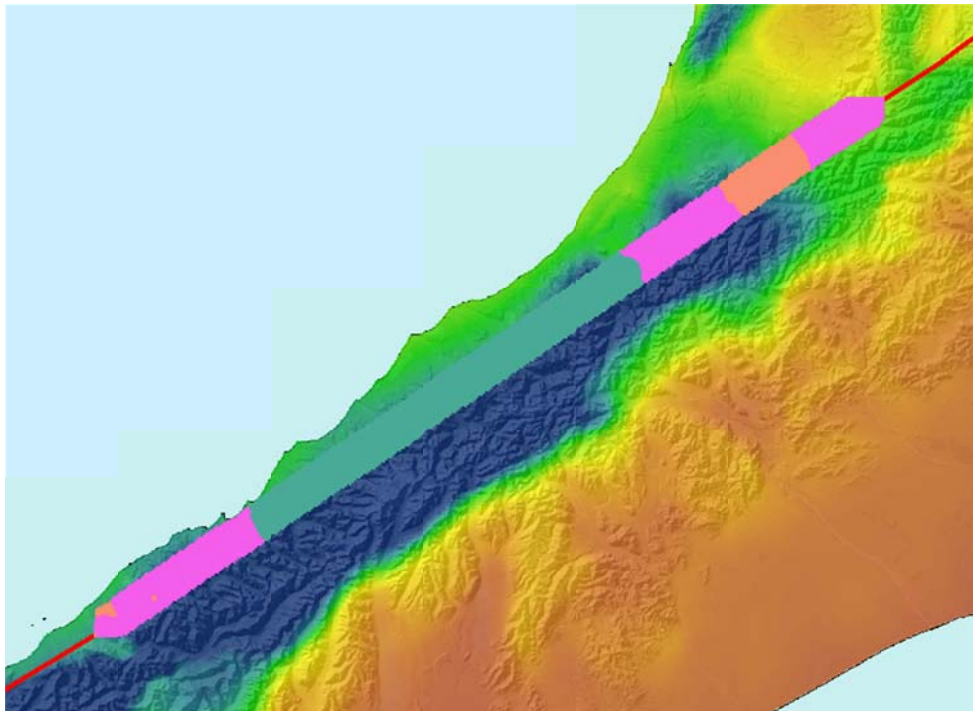
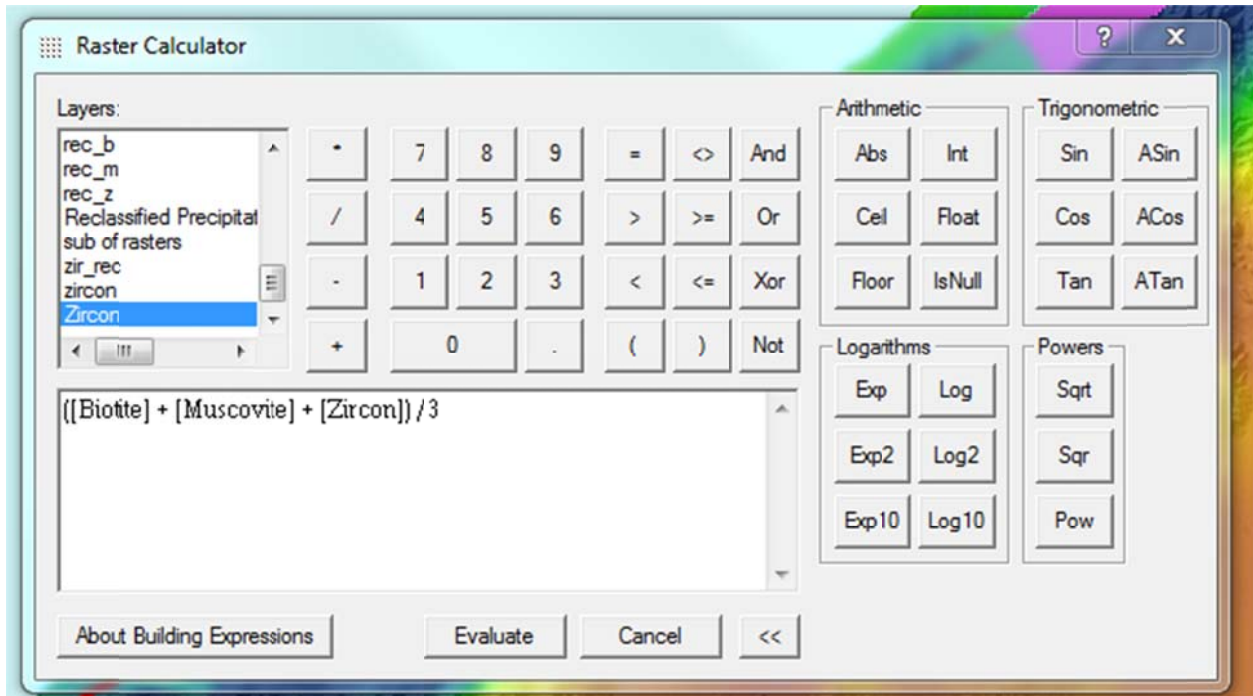


Raster produced from muscovite data after reclassifying and clipping to polygon.



Raster produced from biotite data after reclassifying and clipping to polygon.

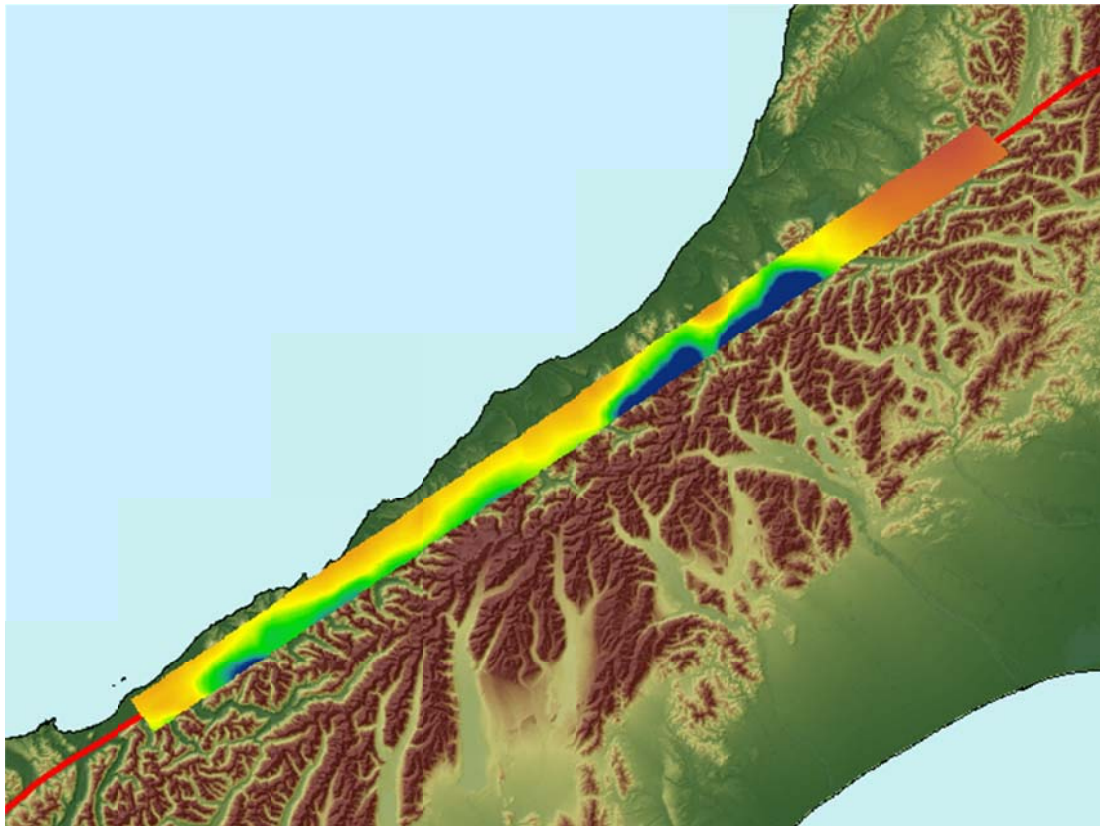
- iii. Now that the uplift rate data points have been turned into raster data and reclassified, the “raster calculator” can finally be used to take an average of the three rasters by using the mathematical operators. The polygon should remain as the “analysis mask”.



Raster produced by the average of the three reclassified rasters.

- iv. Now that an average raster layer has been calculated for the uplift rates, all that is left to do is calculate a raster between the average uplift rate raster layer and the precipitation raster layer to somehow represent the correlation between the precipitation and uplift rates along the Alpine Fault of New Zealand.

To do this, the precipitation raster needs to be slightly modified first. The layer should be clipped to the digitized polygon using the “raster calculator” and then that new raster should be reclassified into a low, medium, and high precipitation ranges using the “reclassify” tool as was done with the other rasters.

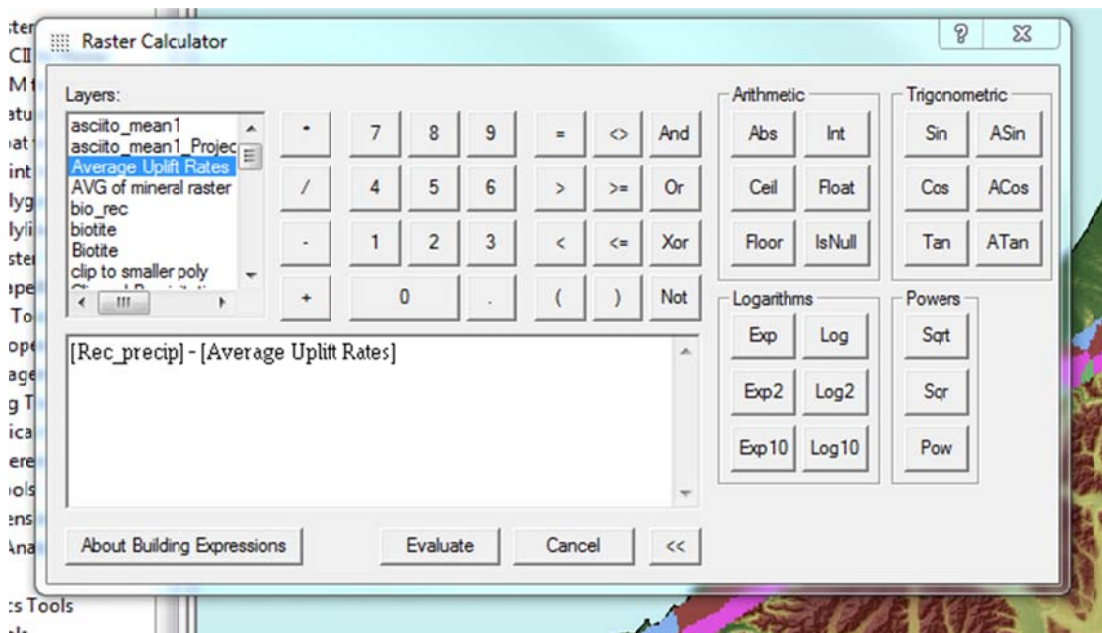


Raster calculated by clipping the precipitation raster to the digitized polygon using the raster calculator.



Raster produced after reclassifying the clipped precipitation raster using the “reclassify” tool.

Now a new raster can be calculated between the reclassified precipitation raster and the average uplift rates. The two rasters should be subtracted in the “raster calculator”. Both of these layers have been reclassified and only have values of 1, 2, and 3. Therefore, if we subtract the two rasters, the resulting values of the new raster can tell us how well the two types of data correlate or match up.





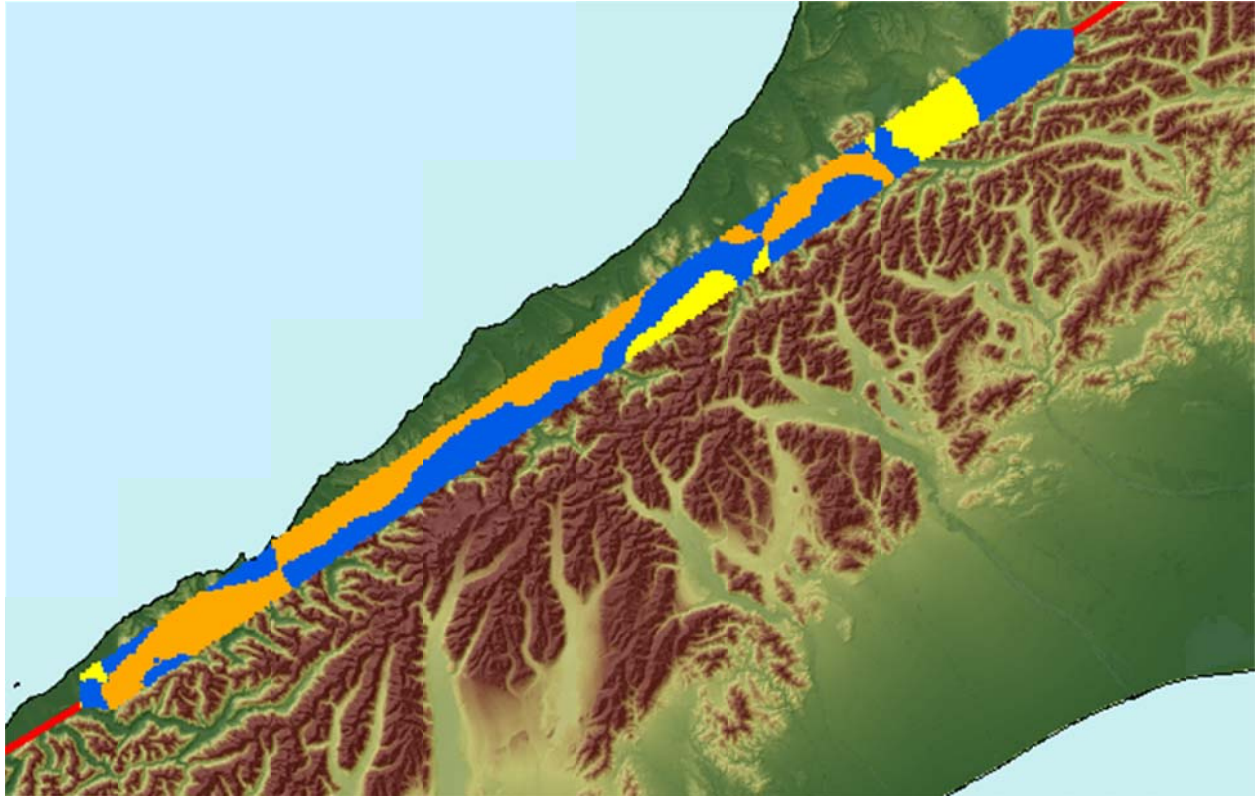
Raster calculated from subtracting the reclassified precipitation raster layer from the average uplift rate raster layer.

The calculation only produced values of: -2,-1,0,1, 2. We can group values -2, 2 and -1, 1 because these represent the same quality of correlation. Making these changes and changing the colors of the values gives us:

Symbol	<VALUE>	Label	Count
<input type="checkbox"/>	<all other values>	<all other values>	
<Heading>			
<input checked="" type="checkbox"/>	-2	-2	353
<input checked="" type="checkbox"/>	-1	-1	2162
<input checked="" type="checkbox"/>	0	0	2678
<input checked="" type="checkbox"/>	1	1	1242
<input checked="" type="checkbox"/>	2	2	554

Context menu options:

- Group Values
- Ungroup Values
- Reverse Sorting
- Remove Values
- Flip Colors
- Properties for selected Colors...
- Properties for all Colors...
- Apply Color Scheme
- Edit Description...
- Move to Heading



Results after grouping values and changing color of values.

These values represent how well the precipitation data correlates with the uplift rate data. 0 represents a perfect correlation, $-1/1$ a moderate correlation, and $-2/2$ a poor correlation.

To try and better represent the results we can create a smaller polygon the exact width of the fault and clip this final correlation raster to that polygon so that only the raster's cells along the fault can be seen. However, at the same time it is hard to see in a large scale. This gives:

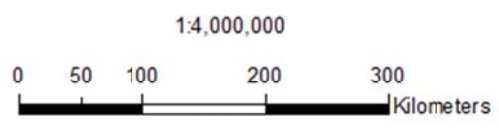
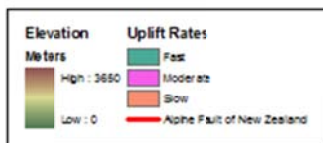
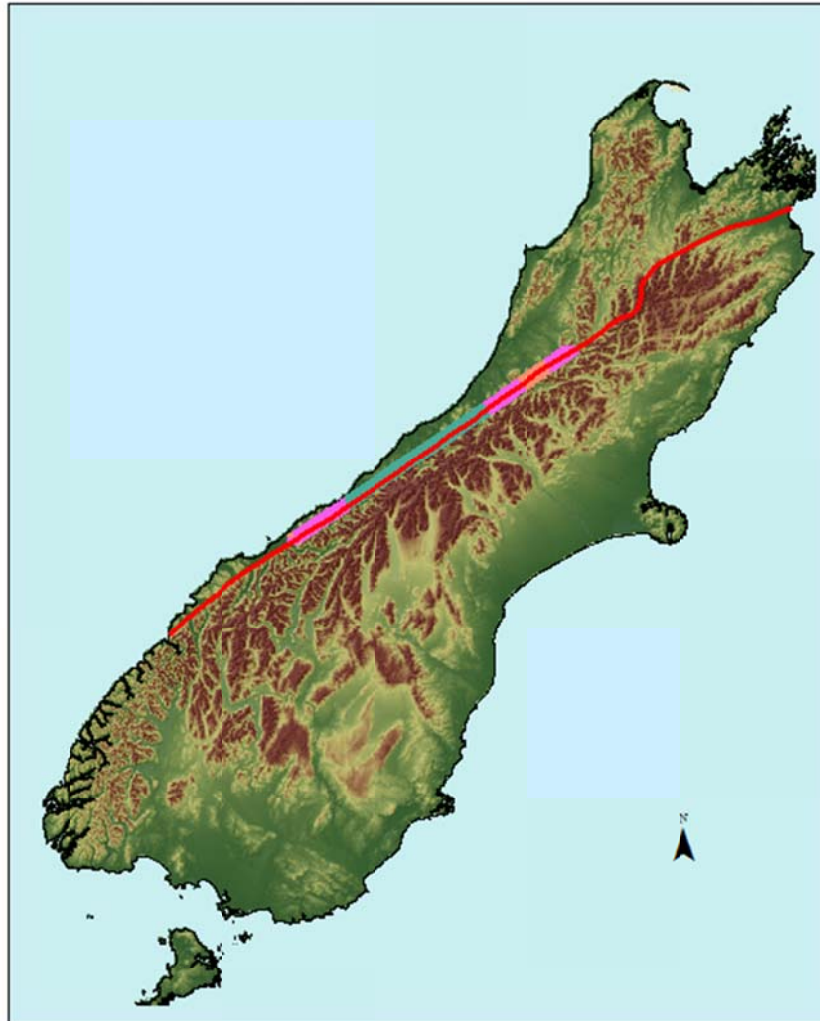


Correlation between precipitation and uplift rate data clipped within and along the alpine fault.

Varying Uplift Rates Along The Alpine Fault of New Zealand

New Zealand Transverse Mercator System

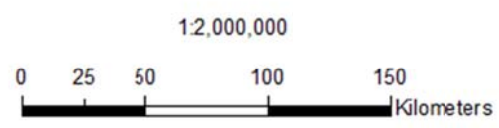
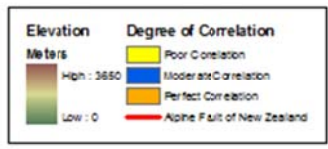
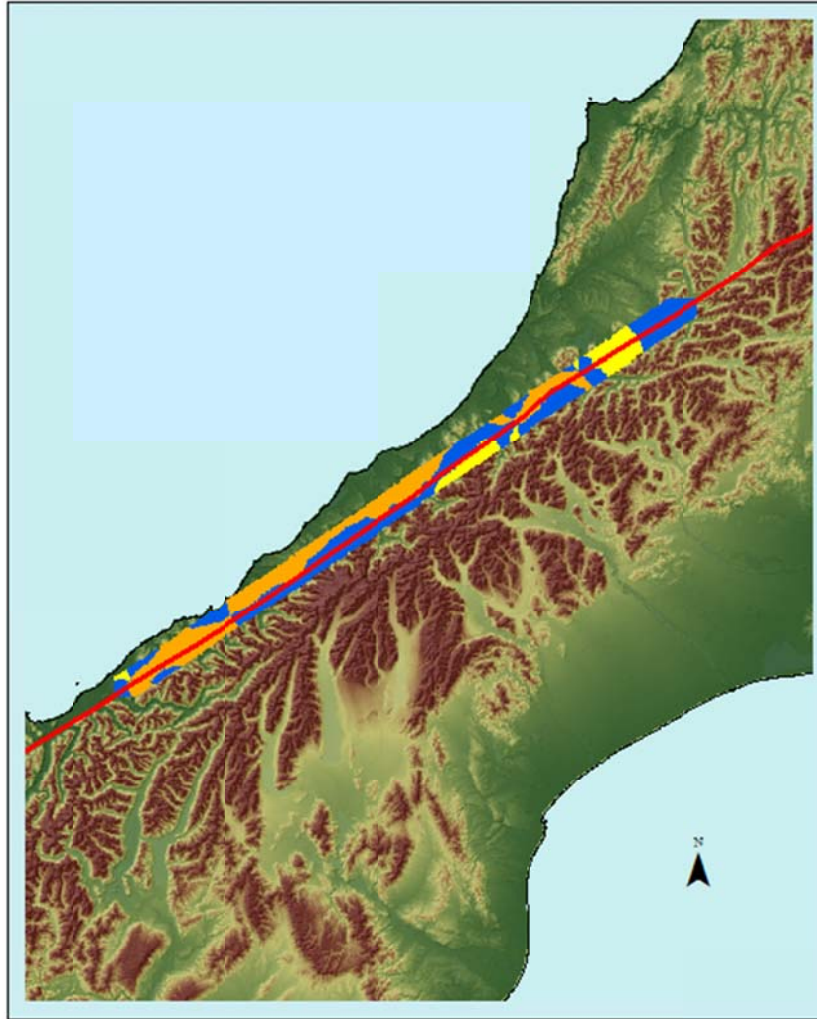
Carlos Camacho



Correlation Between Precipitation and Uplift Rates Along The Alpine Fault of New Zealand

New Zealand Transverse Mercator System

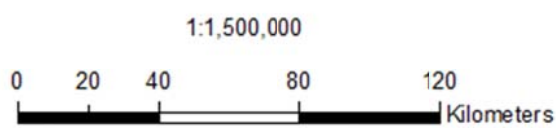
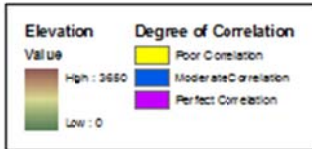
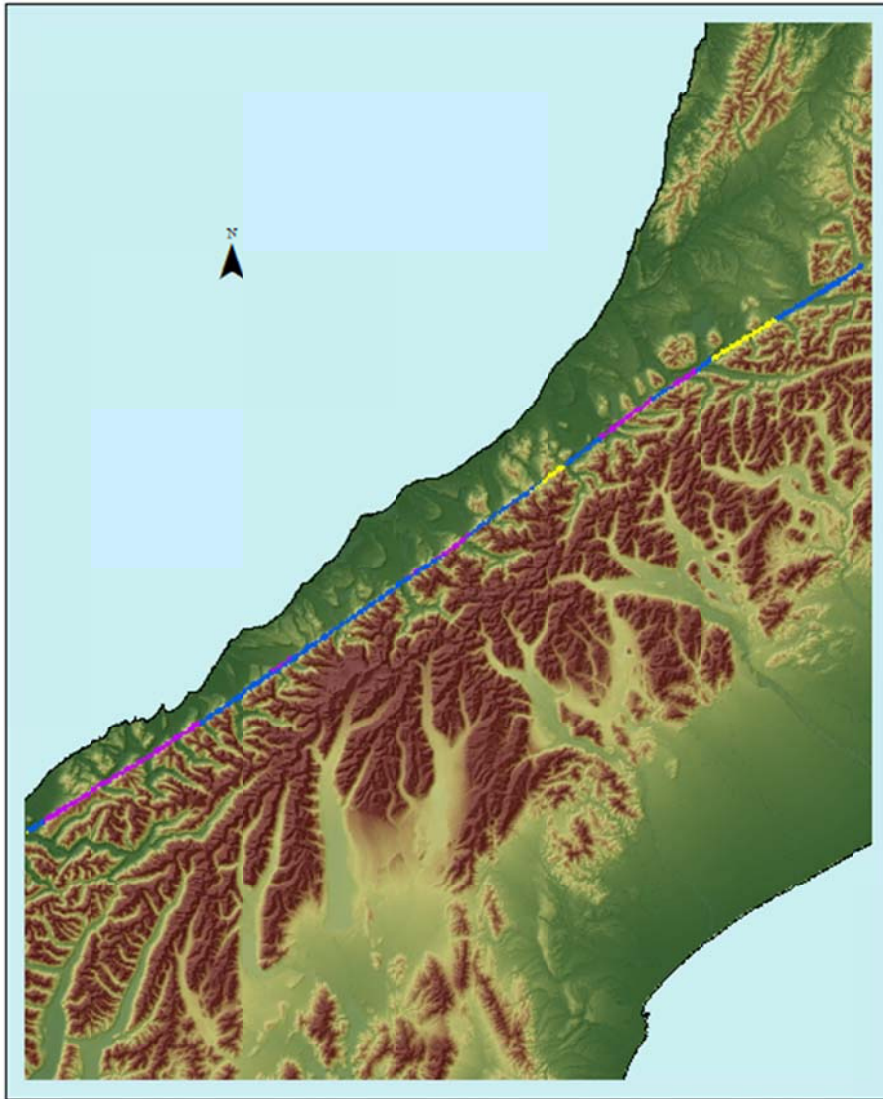
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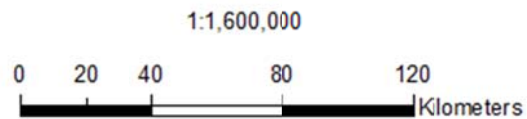
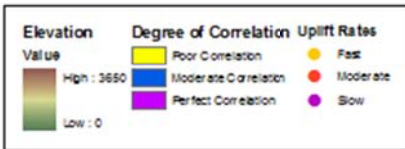
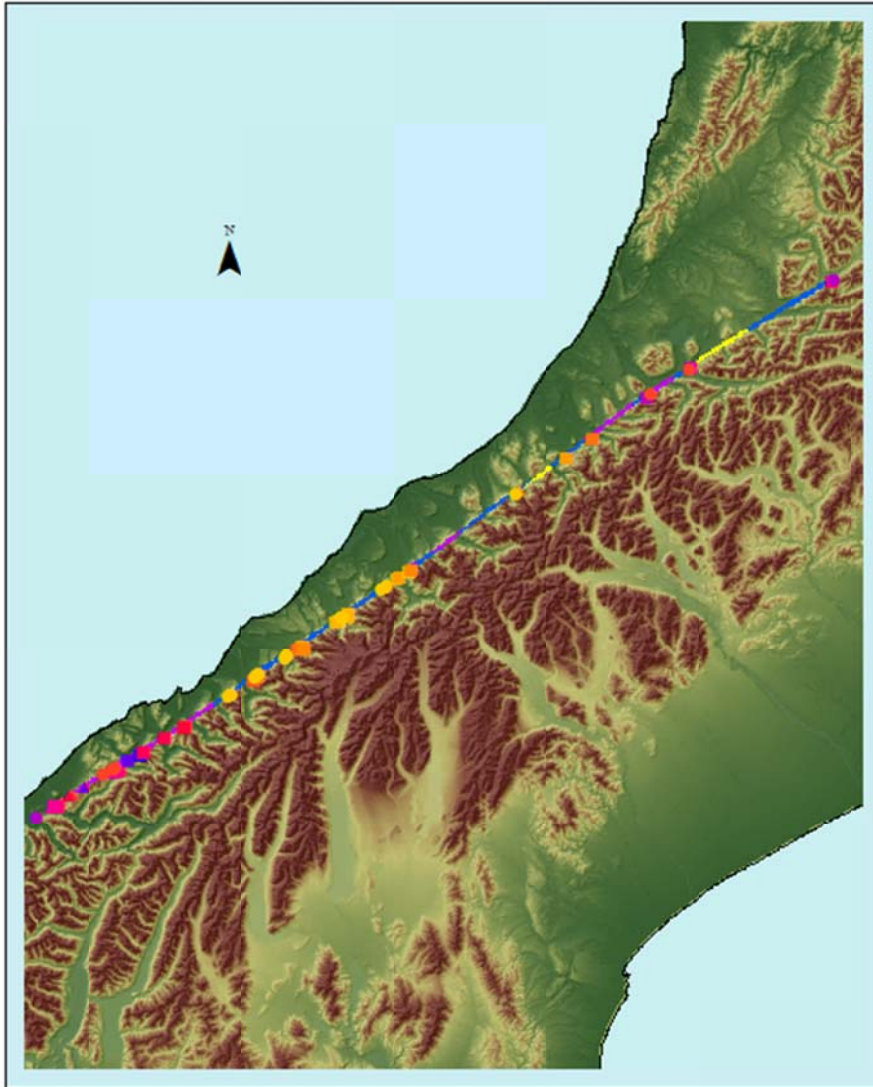
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IV) Conclusion

The results of this project show that low precipitation rates do more or less overlap with the slow uplift rates and vice versa. The most prominent degree of correlation is moderate correlation; however, the second most prominent degree of correlation is perfect correlation and it is significantly more abundant than poor correlation.

If the correlation between the two data types is analyzed from the southwest end of the fault towards the northeast end, one can notice that in the southern section of the Alpine Fault the two types of data have perfect correlation. When the original uplift rate data points are superimposed (ex: last map) on the correlation raster, it is apparent that the slow uplift rates lie on top of the perfect correlation area. This means that the south section of the fault does have slow uplift rates along with low precipitation rates. The central section of the alpine fault is characterized mainly by moderate correlation. Fast uplift rate data points lie over this stretch of the fault; however, the moderate correlation between the data makes it unclear as to whether the area experiences high precipitation rates as it would be expected. Little can be said about the results of the northern section of the fault. Heading northeast, the correlation in the northern section of the fault switches back and forward from poor to perfect, perfect to poor, and poor to moderate. The values of the original uplift rate data points generally increase in the north east direction. However, few data points have been gathered for this area and the poor correlation areas lie in sections where no uplift rates have been gathered at all. The lack of data could be compromising the results.

From the results I would conclude that it is possible that high local rates of precipitation are responsible for the anomalous fast uplift rates found in the central section. The results from the southern section of the fault strike curiosity and the theory should therefore not be completely discarded yet. Additional uplift rates need to be gathered and analyzed if this theory is ever to be put to rest. Even if the high local rates of precipitation don't turn out to be the main reason responsible for the fast uplift rates, they will most likely at least play a minor role in causing the fast uplift rates.