The correlation between tectonics, topographic processes and climate of the Greater Caucasus. *An Approach by Remote Sensing*

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1. An introduction

The Greater Caucasus (GC) lies to the northwest of the South Caspian Basin (SCB). The NW-SE trending range extends for approximately 1000 km and connects the Caspian Sea with the Black Sea (fig. 1).

Although plate margin type and spatial setting are the main factors to determine the presence of mountain ranges and tectonic processes are the main reason for their formation and evolution, climate plays an important role in the mountains development. The effects of air and water may cause significant erosion of outcrops causing deformation and distortions which in turn affects the morphology and geological structures of the mountain belts.

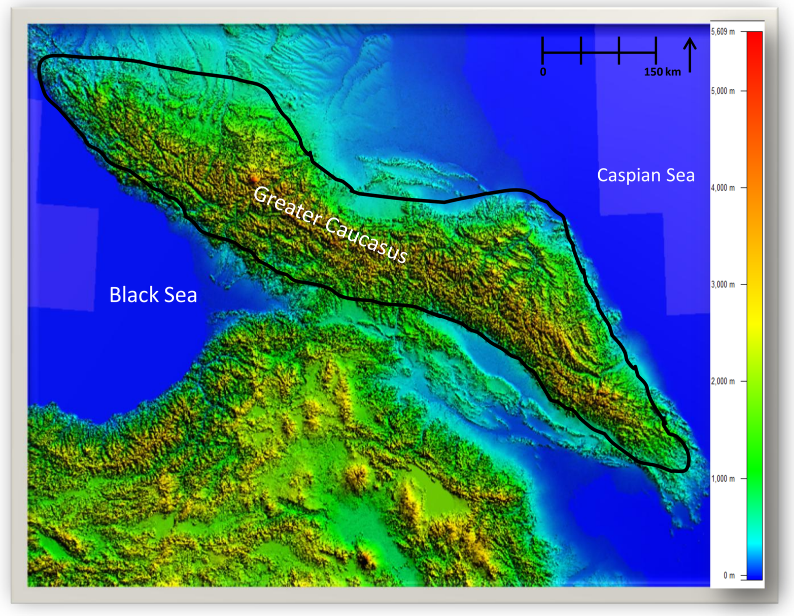


Fig. 1: SRTM digital elevation model of the GC, showing the location and topographic characteristics of the belt that have been quantified in this study.

2. Rationale

The surface processes resulting from climate are able to configure extreme relief and rugged topography by accelerating the tectonic processes as a result of reducing the lithospheric mass (Bishop et al., 2002). However, to what extent the climate and erosion processes are controlling the topography and geodynamics is still not well understood.

Understanding in how tectonics and climate impact on the topography is still complicated and unclear, due to the interactions among the tectonics and climate and because of the various processes that may affect erosion rate.

The interplay between tectonics and geomorphic processes and climate controls the expression of collisional orogenic belts e.g.:

Himalayan uplift controlled the onset of the Asian Monsoon.

Climate plays a part in the preservation of the Tibetan plateau.

The aim of the present study is to determine or better understand the role of climate in topographic development in the Greater Caucasus mountain range.

3. Methodology and data used

Using ArcMap, GOCAD and RiScan software and the SRTM data for the area, 926 profiles for elevation and slope have been constructed across the Greater Caucasus, with a distance of 1 kilometre between neighbouring sections (fig. 2).

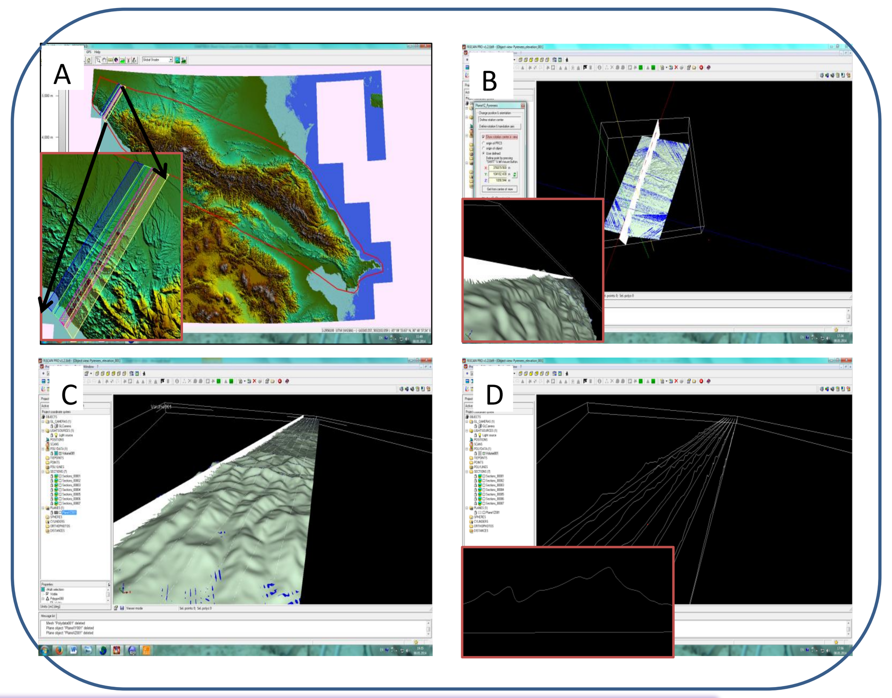
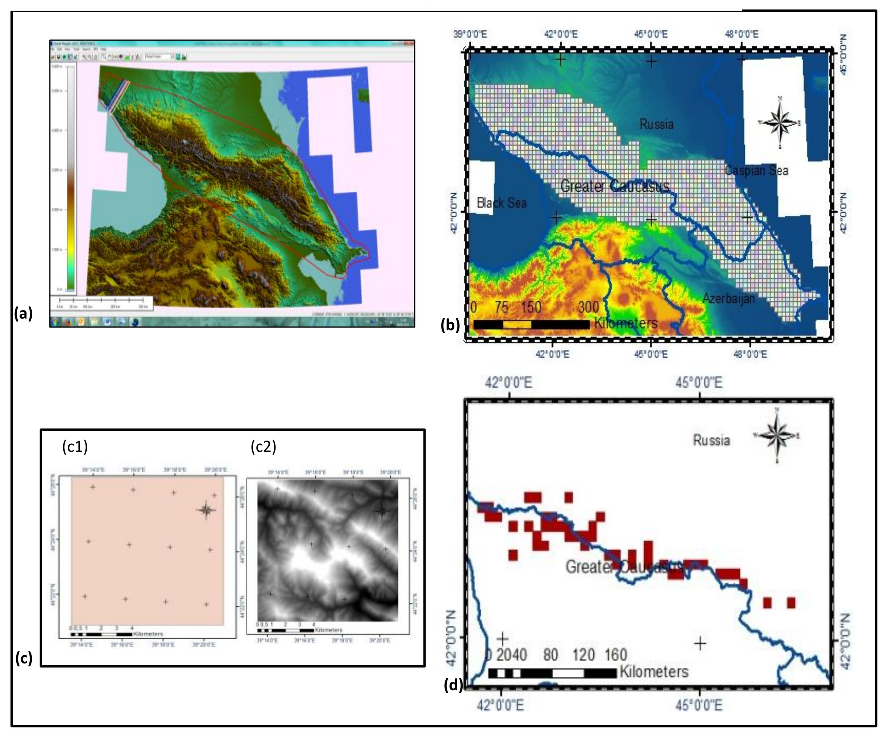


Figure.2: The steps to create slope and elevation profiles, where; (A) is SRTM data showing the division of the belt under study into small rectangles, (B) the data in RiScan software were the plane for the profile created and modified to the required direction and position, (C) the data after creating the profiles, and (D) showing the sections or profiles with a fixed distance between every two neighbouring sections,

Local Relief map generation:



By using Arc Map the area was divided into squares with an area of 10km2, the boxes are projected onto the SRTM data used for clipping the raster to calculate the local relief value of each particular window which is the highest and lowest elevation difference in each selected square (Fig.3).

Figure.3: showing the processes of local relief generation (a) is SRTM data showing the dividing of the belt under study into small boxes, (b) Showing all squares that cover the entire area, (c) Showing the squares (with an area of 10km2) in small scale before and after relief calculation, and(d) an example of one of relief groups (high relief group).

4. Results and discussion:

4.1. The correlation between the tectonics, topography and the climate of the GC:

A. local relief vs the tectonics of the belt.

The relief of each square has been derived to form a mosaic map that shows the relief of the entire belt (Fig,4). The first thing to note from this map is that the local relief of the belt is extremely high and complex, as more than 50% of the belt has relief between (2000 - 4000 m) which can be considered as high relief.

There is a strong association between the main Caucasus thrusts and the high relief regions, where almost all of large thrusts in the region are spatially distributed within the areas of high relief at the large scale.

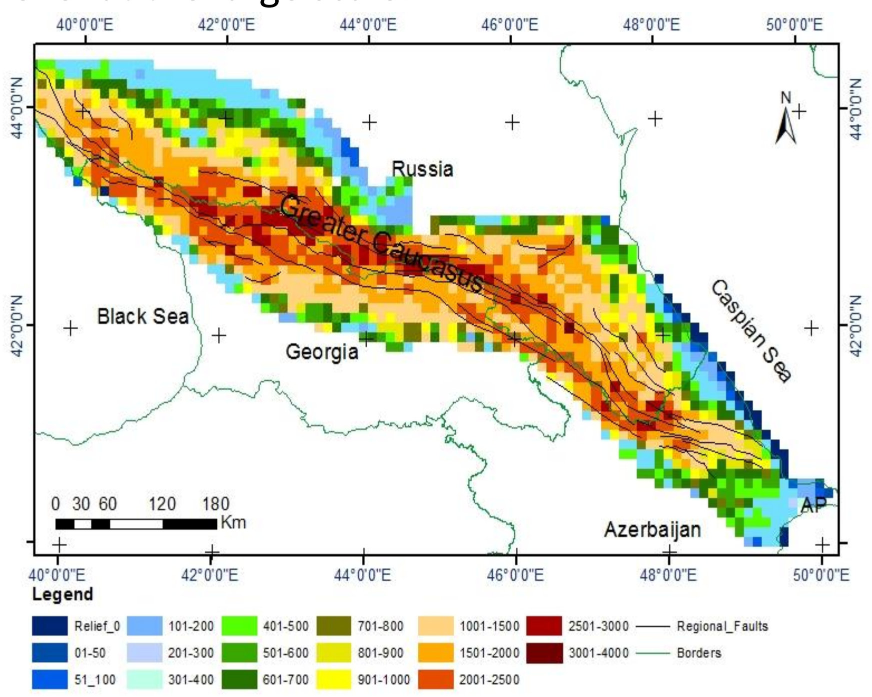


Figure 4. Local relief map of the Greater Caucasus belt, showing the relationship between the main faults and high relief areas in the belt. Regional faults were adapted from the Caucasus geologic map

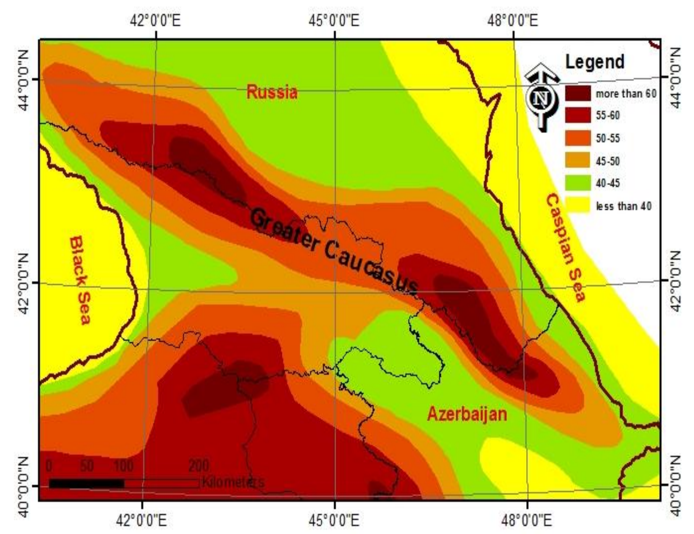


Fig. 5. The Moho depth map underneath the Greater Caucasus belt modified after.

A high correlation between elevation and Moho depths underneath the Caucasus region can be seen in Figure 5, where the high Moho depths occur beneath the higher local relief of the belt. Furthermore, the Moho depths reduce sharply to the east and gradually to the west, mirroring the mean elevation changes.

B. local relief vs the elevation changes.

The plots in figure 6 (a-d) were produced to elucidate the relationship between those factors (local relief, elevation changes and slope) along the belt, where they show that there is a strong positive relationship between slope and elevation so that whenever the mean elevation increases, the mean slope increase. The relationship between the elevation changes and the local relief is more variable, however a positive relationship is still expected because whenever the elevation is very low the relief cannot be high, due to the reduction in the probability of deep valleys forming in such areas.

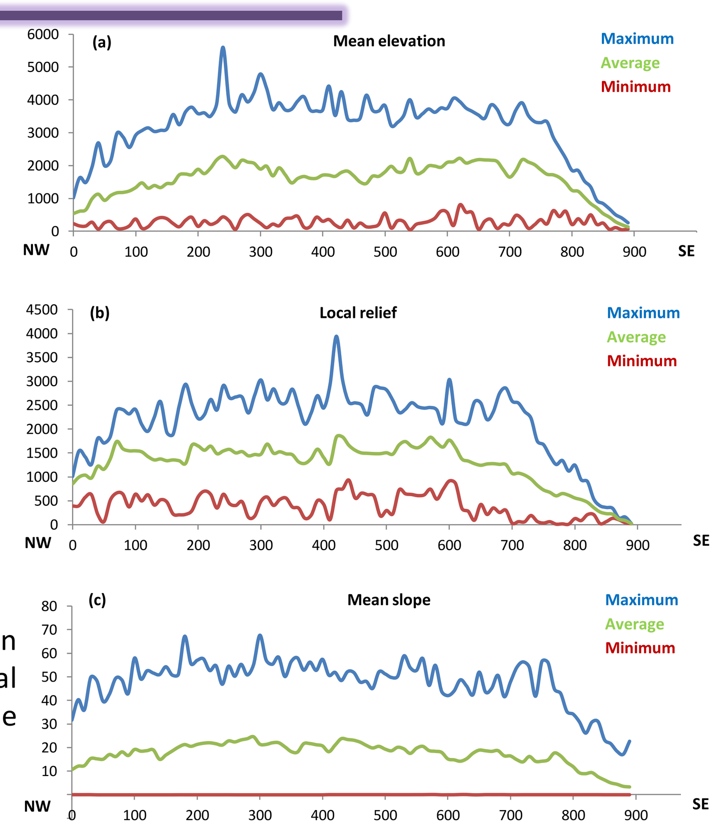


Figure. 6.; showing plots of maximum, minimum and the mean of the elevation changes and slope of 900 sections along the GC and about 90 sections of local relief. (a); is the mean elevations, (b); local relief, and (c); mean slope of the region,

C. The topography vs climate.

The relationship between climate and the elevation changes of the belt can be examined from Figures (7 and 8), where the gradual reduction of the mean altitude which characterise the western region of the belt, has a close relationship with the region of wetter climate. Whereas the sharp reduction of the mean altitude in the eastern part of the belt is recognize the dryer area.

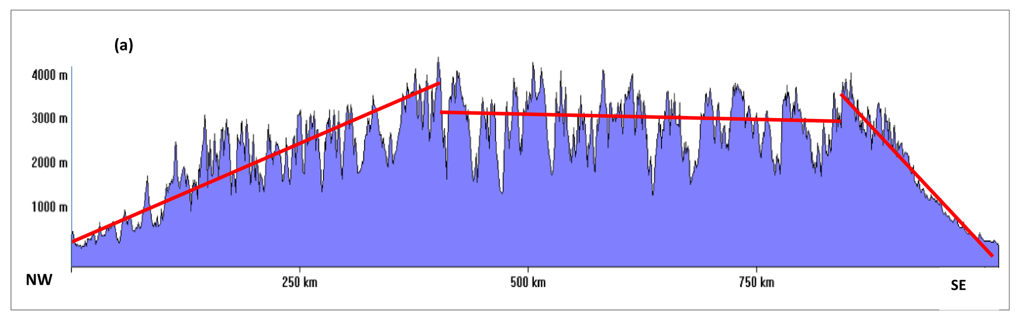


Figure. 8; showing a (NW-SE) plot of the elevation changes along the GC, the red lines indicate to the elevation changes angles in east and west of the belt.

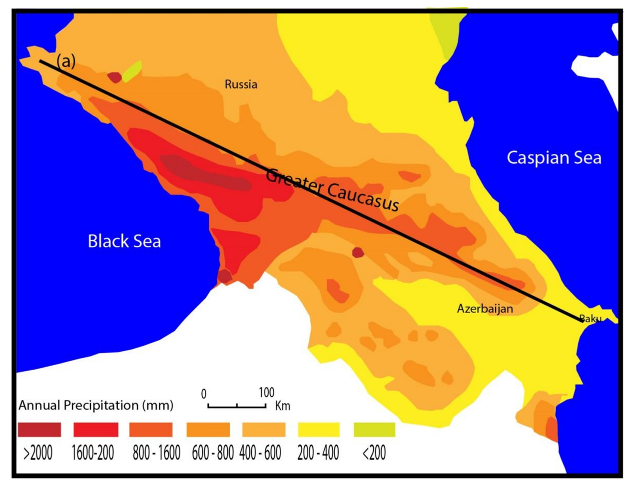


Figure. 7; Annual precipitation map of the Greater Caucasus (line a shows the location of the section in fig.8.

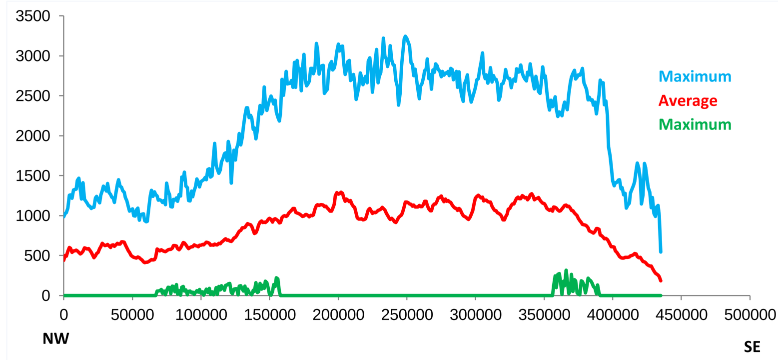
4.2. Topographic comparisons between GC belt and other mountain belts of the world:

A. Pyrenees Mountains (along the border between Spain and France).

From the elevation plot (figure 9), we can note that elevation in the western part changes gradually while in the eastern it changes steeply, which shows a high degree of similarity with the Greater Caucasus topographic changes. The climate is quite analogous to that in the Greater Caucasus where it is wet in the west and drier to the east fig.10.

Consequently, this result can be used as evidence to support the idea that the cause of the steep or gradual gradient of the elevation in a mountain belt could be the climate.

Figure. 9. Showing the plots of the maximum, average and minimum elevation of 440 sections along Pyrenees Mountains.



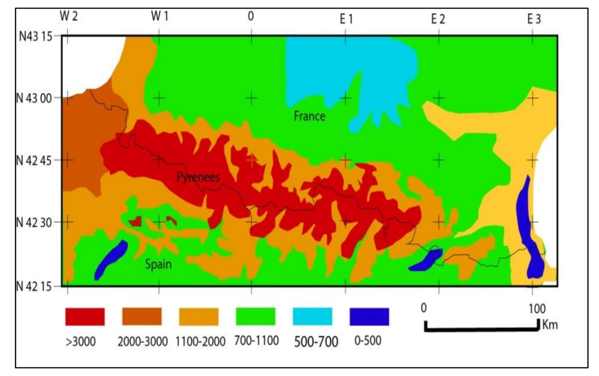


Figure. 10. Figure. 10. Annual precipitation map of the **Pyrenees** for the period of (1957-1973), modified after(Frederic G et al., 2008).

B. Southern Tibetan Plateau (Himalayas).

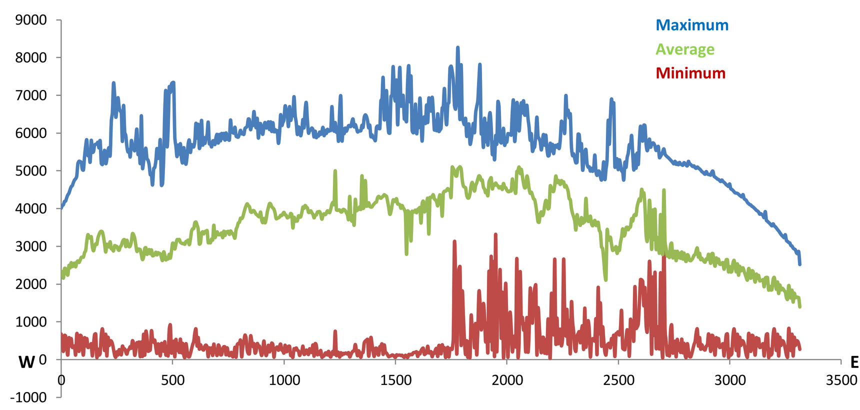


Figure 11. Showing the plots of the maximum, average and the minimum of the Himalayas elevation.

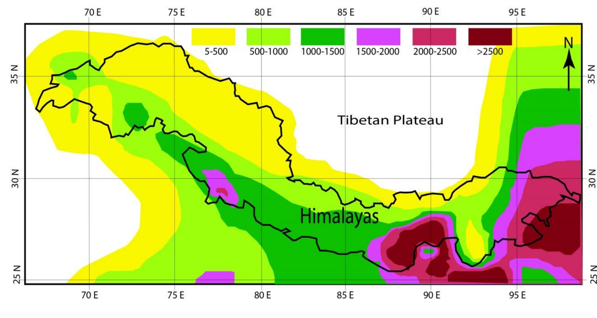


Figure 12. Annual precipitation map of the Himalayas modified after (Finlayson et al., 2002).

From figures 11 and 12, a correlation between lower gradients and wetter climate is apparent. Thus the Himalyan evidence can be used as further evidence for to support a hypothesis that says that the cause of a steep or gradual reduction of the elevation could be the climate so that whenever the area is wet the erosion rate will increase which lead to gradual elevation decrease and vice versa.

5. Conclusions

- The Greater Caucasus can be divided into three parts depending on its elevation (west, centre and east), and erosion in the western part is greater than in the eastern part because it is wet in the west and dry in the east.
- Topographically, the similarity between the GC and the Pyrenees, has led us to think about the relationship between tectonics and climate/erosion effects in both.
- There is a correlation between elevation changes and climate between the east and west ends of the belt, where the gradual reduction of the mean altitude which characterises the western area of the belt, has a close relationship with a wetter climate in this part, and the sharp altitude decrease characterises the eastern part with a drier climate.

6. References

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