Glacial Shrinkage in the Austrian Alps from 1986 to 2009

By: Aaron Caldwell

Department of Geography & Geology

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Dr. Eman Ghoneim

Abstract

Landsat TM 5 images of the Austrian Alps from July 1986 and July 2009 were compared using bands 1, 4, 6 and 7. ENVI imaging software was used to asses image changes. Glacial cover losses in the region amounted to over 62% over the 24 year period accompanied by gains 0f 24.65% in forest cover for the region. The dramatic change observed in this region is indicative of a larger global warming issue that continues to reshape the environment around us.

Introduction

On June 3, 2002 the US government acknowledged for the first time that man-made pollution is largely to blame for Global Warming. Indications of the effects of global warming have been most evident in global temperature rise and the consequential effects of this increase. Observations of ice/glacial melting in the polar regions often fail to have a great deal of impact given their distance from the majority of the world's population. Nevertheless, changes can be observed in areas much closer to populated areas such as the melting of glaciers in the Austrian Alps.

Methods & Materials

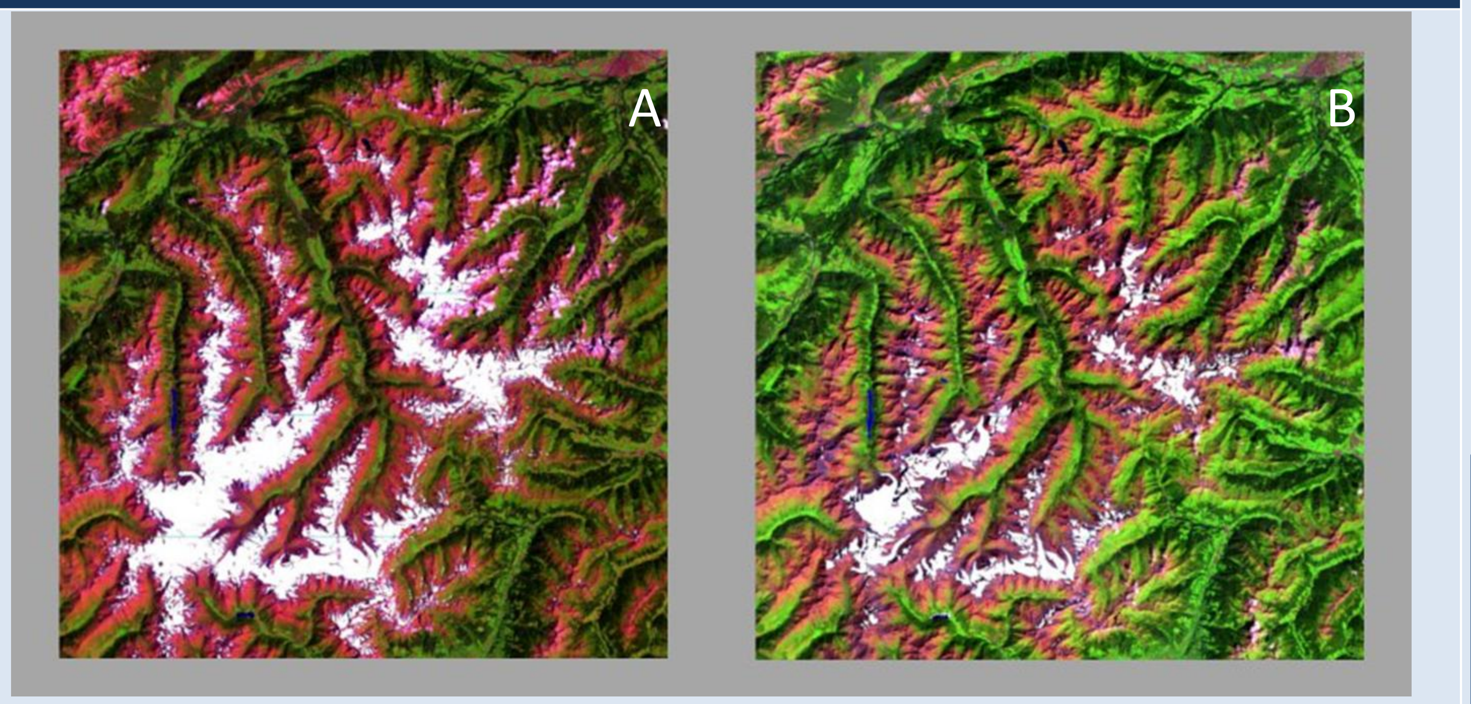


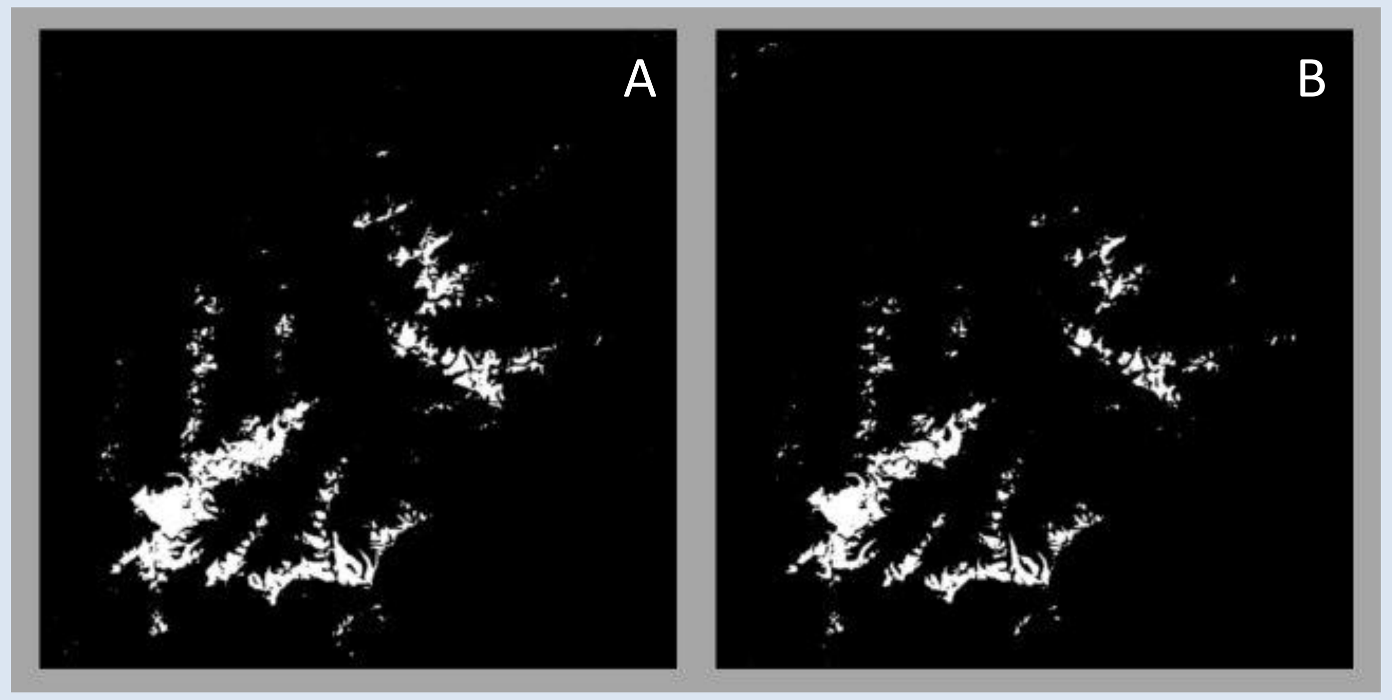
Figure 1: Image A shows glacial cover in July, 1986. Image B shows the same region in July, 2009. Glacial cover for each image was enhanced by use of a vector overlay.

Projection: UTM, Zone 32 North
Map: 648435.00E,5208855.00N
Meters
LL : 47°0'59.60"N, 10°57'11.03"E

To assess change in glacial cover for the Austrian Alps, two Landsat TM 5 images were used for image analysis, one from July, 1986 and another from July, 2009 (Figure 1). Bands 7, 4, and 1 were used to differentiate between Red, Green and Blue hues respectively. Band 6 (the thermal band) was used for both images to confirm glacial vs. non-glacial surfaces. Classification of each image was heavily aided by referencing Landsat 7 ETM images obtained in August, 1999 and August, 2009. Bands 7, 4, 1 and the thermal band 61 were used. Google earth images proved useful as well for its high level of detail in differentiating between cover types. Landsat 7 images obtained in 2009 were unfortunately heavily impacted by the effects of SLC-off and therefore weren't useful for comparison of changes in cover.

Image enhancement, analysis and comparison were performed using ENVI software. Some post classification image enhancements were performed using the GNU Image Manipulation Program (GIMP).

Figure 2: Image A shows glacial coverage in the Austrian Alps in 1986 using thermal band 6. Figure B depicts glacial coverage for the same region in 2009.



Differentiation between glacial surfaces was attempted using four different approaches. Image classification proved effective using bands 7, 4 and 1 as previously mentioned. The following classes and their colors using these bands were readily identified: Bare Rock (Pink-Orange), Glacial Snow/Ice (Light-Dark Blue), Grassland (Light Green), Forest (Dark Green), and Water (Medium- Dark Blue).

Both the Normalized Difference Snow Index (NDSI) and Glacier Index (NDGI) were used to aide classification however the complete results were mixed for each (Figure 3). The following equations were used:

Figure 3: Band Math formula for Normalized Snow and Glacier Index respecteively. MIR = mid-infrared

$$NDSI = \frac{Green - MIR}{Green + MIR} \qquad NDGI = \frac{Green - Red}{Green + Red}$$

Results

The greatest amount of change was observed in glacial cover which lost 62.28% of its total surface area from 1986 to 1989. Bare Rock made the only other observable loss during this time with a -6.96% change. Forest, grassland and water each made gains of 24.76%, 11.14%, and 7.16% respectively (Figure 4).

Figure 4: Classes gains and losses were compared for the image captured in 1986 vs. 2009. Changes in cover types are represented in the chart below. Figures are calculated in km^2 followed by percentage change .

Cover Type (1984)	Cover Type (2009): Glacier	Water	BareRock	Forest	Grassland	Row Total	Class Total
Glacier	161.81 (37.49)	0.42 (10.77)	0.43 (.03)	0 (0)	0.03 (0)	162.70 (99.92)	162.83 (100.00)
Water	0.28 (.06)	3.44 (87.13)	0.51 (.03)	0 (0)	0 (0)	4.23 (100.00)	4.23 (100.00)
BareRock	267.93 (62.07)	0.08 (2.1)	1274.05 (74.35)	11.87 (1.00)	26.77 (2.61)	1580.70 (99.14)	1594.49 (100.00)
Forest	0.49 (.11)	0 (0)	109.34 (6.38)	1150.83 (96.7)	223.19 (21.73)	1483.85 (99.94)	1484.76 (100.00)
Grassland	1.15 (.27)	0 (0)	329.34 (19.22)	27.44 (2.31)	777.02 (75.66)	1134.95 (99.43)	1141.43 (100.00)
Class Total	431.66 (100.00)	3.94 (100.00)	1713.68 (100.00)	1190.14 (100.00)	1027.00 (100.00)	0 (0)	0 (0)
Class Changes	269.85 (62.51)	0.51 (12.87)	439.63 (25.65)	56.55 (3.3)	249.98 (24.34)	0 (0)	0 (0)
Image Difference	-268.83 (-62.28)	0.28 (7.16)	-119.19 (-6.96)	294.62 (24.76)	114.43 (11.14)	0 (0)	0 (0)

Changes were relatively evident when observing thermal images obtained from band 6 (Figure 2) and even more so in a vector overlay of 1986 glacial cover vs. glacial cover in 2009 (Figure 5). Several significant changes in cover type were observed as well including Glacier to BareRock (62%), BareRock to Grassland (19.22%) and Grassland to Forest (21.73%).

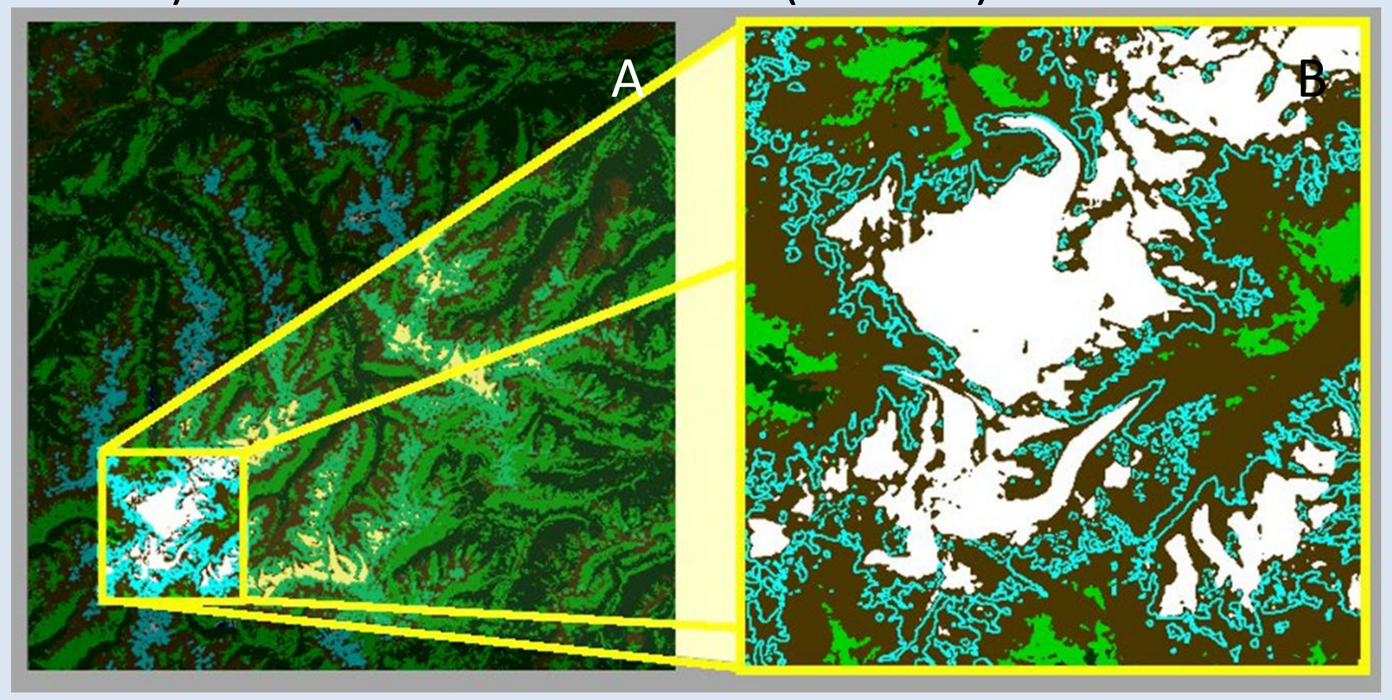


Figure 5: A portion of image A has been increased. Image B shows glacial cover 2009 classified here in white. A vector overlay was used to outline the glacier's boundary in 1986 in light blue.

Conclusions

There is clear evidence of the impact of warming annual temperatures. Current estimates indicate there will be no glaciers in the Alps by the year 2050. This estimate seems realistic (if not generous) given the rate of glacial melting observed in this study.

References

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B. Frank Paul, Andreas Kaab, Wilfried Haeberli, Recent glacier changes in the Alps observed by satellite: Consequences for future monitoring strategies, Global and Planetary Change, Volume 56, Issues 1-2, Climate Change Impacts on Mountain Glaciers and Permafrost, March 2007, Pages 111-122

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Glaciers in the Alps have long served as a source of water, a natural boundary and an asset to tourism.

There is evidence that glaciers both in the Alps and in other regions of the world are rapidly shrinking dramatically altering local eco-systems and affecting global sea levels. Several glaciers worldwide face imminent extinction in this century with many more facing severe depletion.