Detection of Change in Snow Cover on Mount Hood Using Principal Component Analysis

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Tufts

Mountain glaciers in the Pacific Northwest, specifically in the Cascade Range, have undergone significant melting since the 1980s.

Using LANDSAT images obtained from the USGS Earth Explorer web site and utilizing ENVI image processing and analysis software, principal component analysis (PCA) was applied to two separate images – one from 1986 and one from 2003 – to determine the shift in snow and ice cover on top of Mount Hood.

Applying PCA to these images can help to show the change in snow and ice cover, while analyzing the methods necessary for it can give a better understanding of the principles behind unsupervised image classification.

Overview

As the planet undergoes warming due to rises in greenhouse gas levels, scientists are finding that because of their sensitivity to shifts in temperature, glaciers, important sources of drinking and irrigation water, are undergoing a dramatic reduction in size. One study of small mountain glaciers found that from 1961 to 2005 they lost a total of nearly 9,000 total cubic kilometers of water globally. A 2006 study by Portland State University revealed that since 1982 Mount Hood glaciers had lost a total of 34% of their volume, with some glaciers even reaching a 61% loss.[1]

In addition to indicating the degree to which we are altering the climate, the differences in the melting of glaciers can also spell dire effects for those who depend on regular meltwaters. In the Pacific Northwest, glacial meltwater from the Cascade Mountains provides drinking water and crop irrigation for millions of people.[2] It is estimated that by 2057, the areas of the major irrigating glaciers on Mount Hood will reduce by an additional 50%.[3] This will have an effect of limiting the main irrigation diversions from the glacial meltwaters by up to 44%.

Image 2 - Taken 5 October 1986

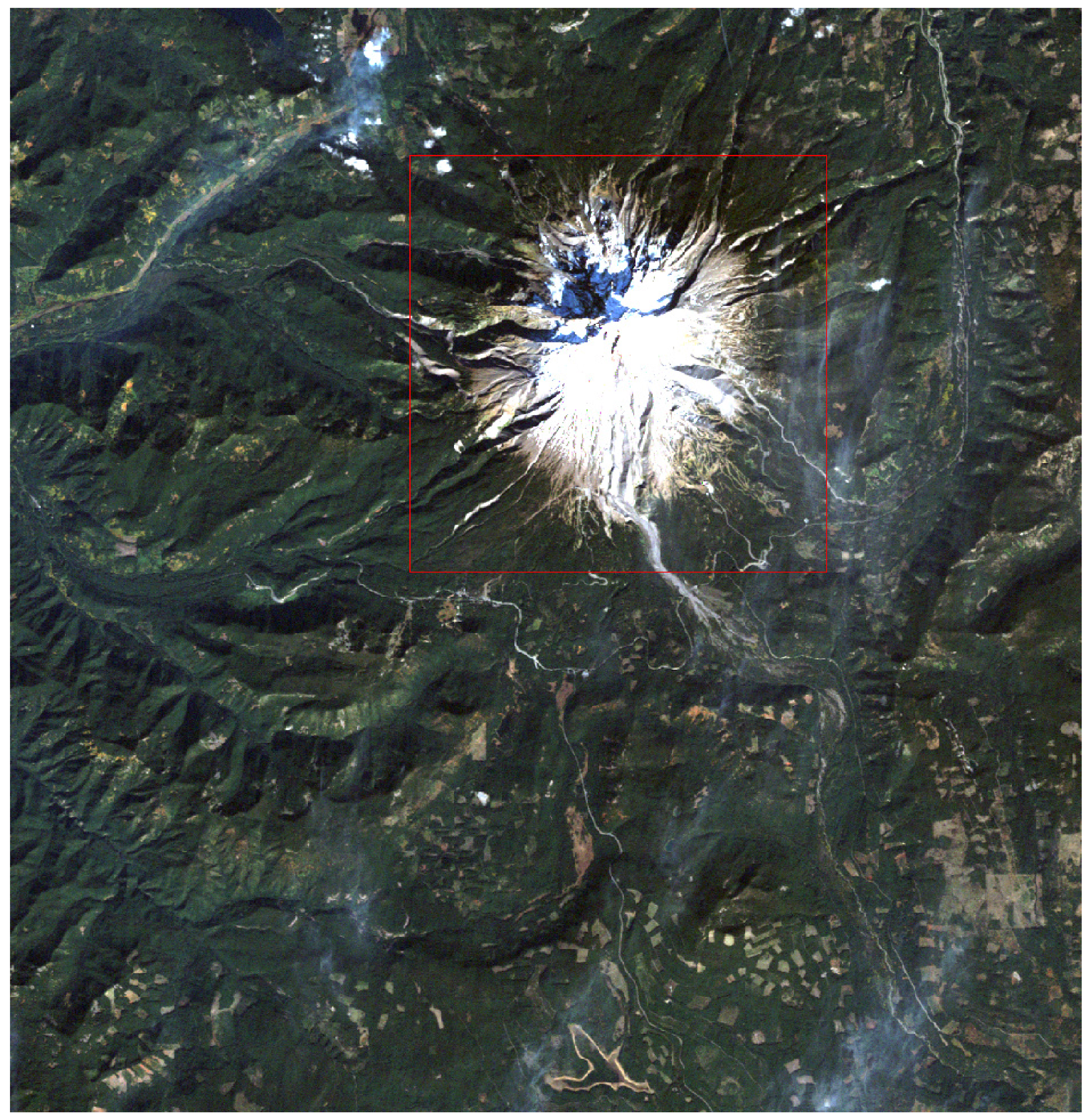
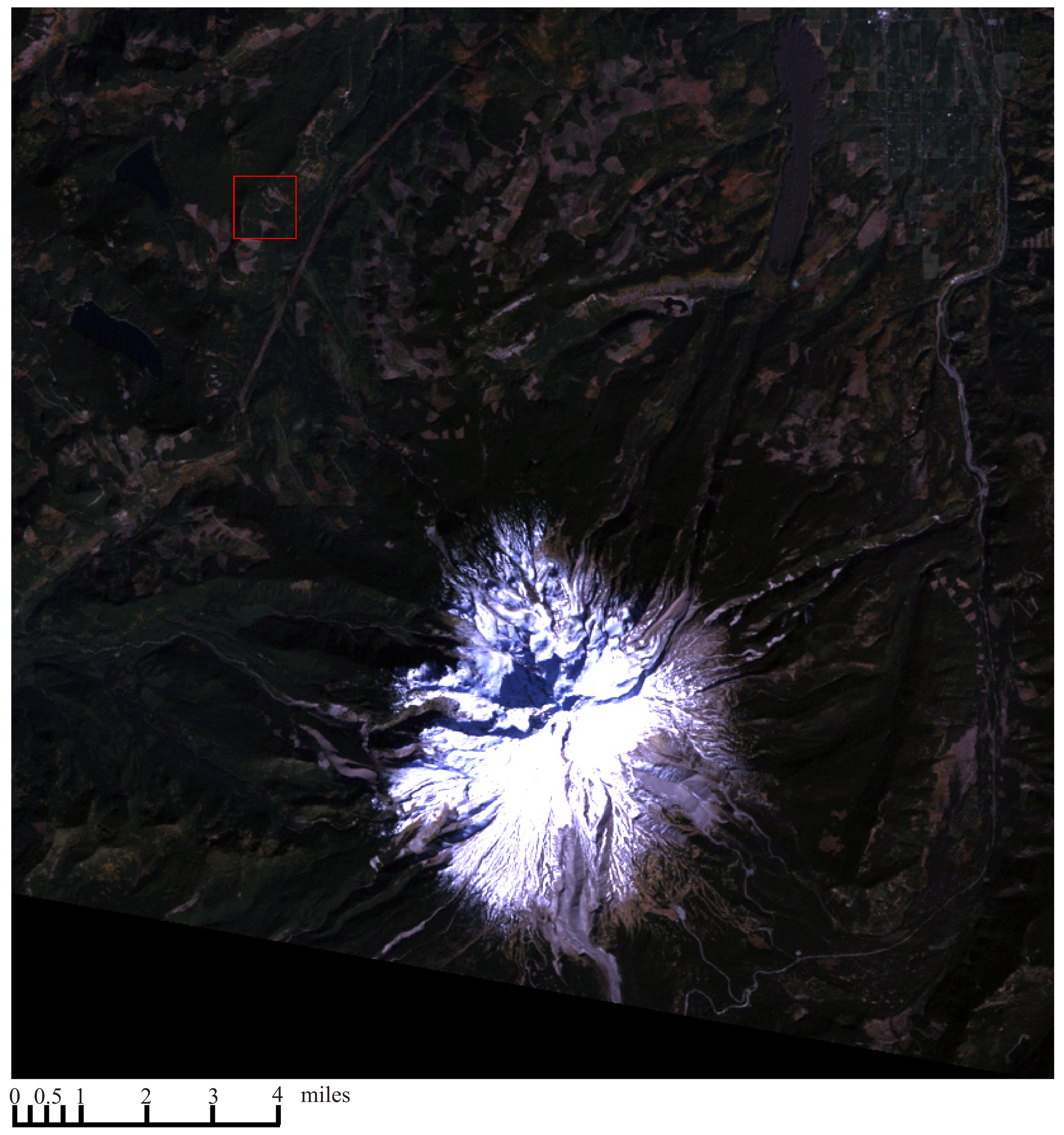


Image 2 - Taken 21 October 2003



Methodology and Results

Step 1: Band stacking – Combine bands from original LANDSAT images obtained from USGS Earth Explorer web site to form one image[4]

Step 2: Clipping – Reduce size of image

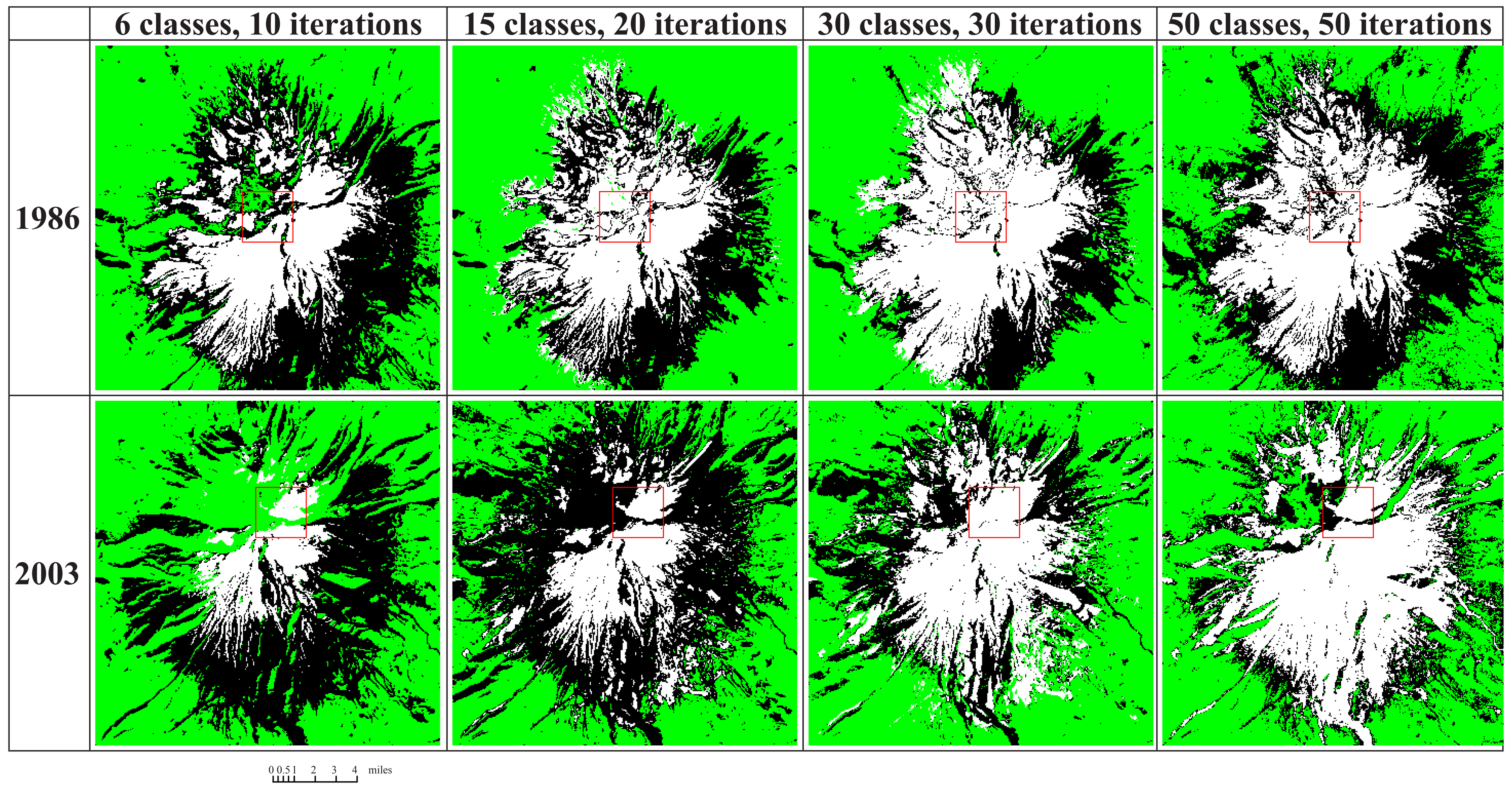
Step 3: MNF Rotation – Reduce band redundancy, condensing data into three bands

Step 4: K-means Classification – Generate classes for land cover for both images

Step 5: Combine classes – Merge similar land covers. The first time K-means classification was attempted on the two images, 6 classifications and 10 iterations were selected through the unsupervised classification menu. However, the classifications were found to be poor, with regions obvious as snow and rock under normal visual identification classed as forest. Thus, three more K-means classifications were performed for both the 1986 image and the 2003 image to improve accuracy:

- 15 classes and 20 iterations
- 30 classes and 30 iterations
- 50 classes and 50 iterations

Step 6: Change detection statistics – Produce statistics showing land cover change



	6 classes, 10 iterations	15 classes, 20 iterations	30 classes, 30 iterations	50 classes, 50 iterations
Area of snow, 1986 (m²)	18.896	23.118	30.935	26.665
Snow area lost to Rock (m²)	7.055	10.662	8.695	6.066
Snow area lost to Forest (m²)	3.941	2.245	4.996	3.361
Area of snow, 2003 (m²)	7.899	10.211	17.244	17.239
Difference in Snow area (m²)	-10.996	-12.907	-13.691	-9.427

Conclusions

While the change in snow and ice cover on Mount Hood is important, the real value in this exercise has laid in looking at the differences that can result depending on the constraints input during principal component analysis. One of the most interesting results of this study is the decrease in snow and ice-covered area of both the 1986 and the 2003 images when the 50 class, 50 iteration K-means classification is applied, contrary to the trend of the other iterations.

One possible explanation of this lies in the K-means classification. With such a large number of classes and iterations, the resolution of the classes was very high. It is possible that at such a high resolution, ENVI put pixels in separate classes when it shouldn't have. With lower numbers of classes, ENVI might be able to better classify these pixels into the same class, rather than separating them out to different classes.

This change in trend could have also been caused because of issues with the class color mapping stage. When combining classes, it was observed that many classes consisted of very few pixels that were difficult to distinguish whether they were rock or snow and were perhaps assigned to the wrong class. If this error were propagated across the image, a change from the desired classification would be noticeable.

If this study were re-attempted, a number of things could be done differently. First, less emphasis on classes and more emphasis on iterations would be recommended. With fewer classes, there is less of a chance of pixels that should be grouped together split apart and less of a chance they will be incorrectly combined. Additionally, it would be helpful to perform change detection on thermal data from both time periods. While change detection of the visual bands is helpful in determining the change in land cover, a comparison of the thermal bands could help to determine the areas that are cold enough to retain snow and could help predict future retreats of glaciers.

1 Hess, Susan. "Mt. Hood's Glaciers Melting Away, Say PSU Glaciologists". Climate and the Gorge. 2006. New West. 22 Apr. 2009. <http://www.newwest.net/index.php/topic/article/6796/C147/L38>.

2 Campana, Michael E. "Mt. Hood Glaciers and Summer Streamflow: Going, Going…Gone?" WaterWired. 2008. WaterWired. 22 Apr. 2009. <http://aquadoc.typepad.com/waterwired/2008/02/mt-hood-glacier.html>.

3 Nolin, Anne et al. "Glacier Melt Makes a Significant Contribution to Summertime Upper Hood River Streamflow". Oregon State University. 2008. Oregon State University. 22 Apr. 2009. <http://www.fs.fed.us/psw/mtnclim/talks/pdf/Nolin_Poster2008_Glaciers.pdf>.

4 USGS. "EarthExplorer". USGS. 2009. United States Geological Survey. Apr. 22, 2009. < http://edcsns17.cr.usgs.gov/EarthExplorer/>.