Vatnajökull Glacier, Skeidhararjokull Outlet changes through Remote Sensing

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ABSTRACT:

Vatnajökull, is the largest glacier in Iceland. Vatnajökull has been the focus of an array of glaciological studies by scientists from different part of the world, including many remote-sensing investigations. Satellite images can be used to show precisely glacier margin changes on a time series basis.
Various types of image data are available by the Landsat Multispectral Scanner (MSS) that can be assessed for their value to glaciological studies of the glacier. Two multi-spectral digital enhancements from Skeidhararjokull outlet were applied for this study, one image for February 2014 and one image for May 2024. A good angle MSS Landsat image of Skeidhararjokull Outlet provides information about the distribution and size of ice and snow, and the probable position of surface ice decreased. The 2014 image is used to show the location of the principal surface and considered as the base image for this study that will be considered as as No Change. The second image from 2024 provides information about the same study areas after 10 years that will provide the changes on ice since February 2014.

1. INTRODUCTION

This document summarizes the main findings and insights from studying Vatnajökull-Skeidhararjokull glacier outlet changes in Iceland using historical stellite imagery from 2014 and 2024. The study focuses on the Vatnajökull-Skeidhararjokull outlet ice and snow coverage, analyzing ice fluctuations, above and below Equilibrium Line Altitude (ELA), to understand past trends changes. The research seeks to determine if freely available satellite images can lead to comparable results as studies using cost-intensive height models. the images for this study are exported from USGS.

2. BACKGROUND

Vatnajökull, is the largest glacier in Iceland (Björnsson, 1980b). It represents a classical glaciological field work for many years. For the past century, Vatnajökull has been the focus of a vast array of glaciological studies by scientists from many nations, and much of the research has been published in *Geografiska Annaler*.

2. STUDY AREA

Vatnajökull is a large glacier with 38 outles. And it does not function as a unified mass of ice. Each of its outlet has its own hydrological basin each has different situation based on its topographic configuration and mass of ice. In addition, many of Vatnajökull's outlet glaciers affected by volcanic activity.

A good angle of MSS Landsat 8 image of Skeidhararjokull Outlet provided information about the differences of Ice, water, land, and delineation of the probable position of surface ice divides. The 2014 image (Figure 1) is used to show the location of the principal surface and consider it as base image.

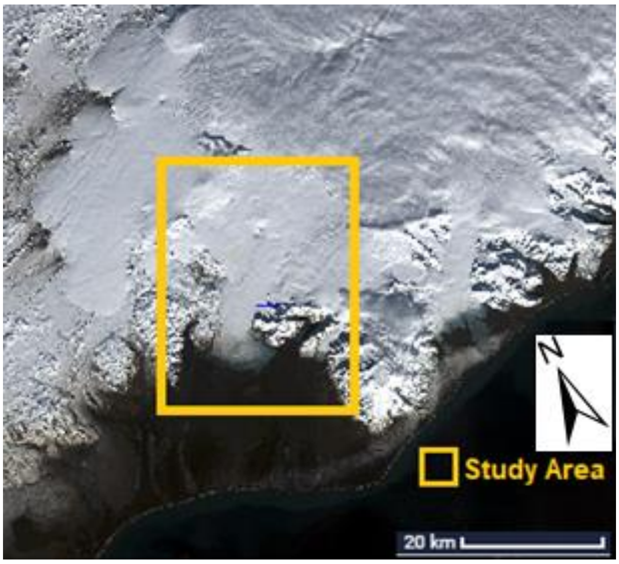

Figure 1: The Vatnajökull-Skeidhararjokull Outlet (Landsat 8 image – February 26, 2014)

3. DATA

After specifying the study area, two imagery product bundles were download from USGS Earthexplorer for Landsat 8. One for February 26, 2014 (Path 217, Row 15) and the second one for April 26, 2024 (Path 217, Row 15). MTL file for each bundle has been merged and the pix files created. The study area were clipped from the images and two sub pix files created **2014-Sub** (Figure 2), and **2024-Sub** (Figure 3).

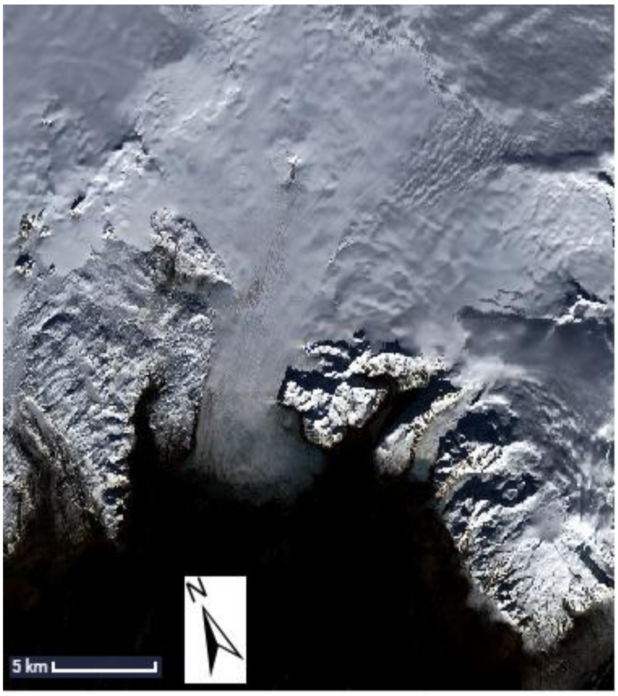

Figure 2: Landsat 8 subset image - February 26, 2014 (Path 217, Row 15)

Figure 3: Landsat 8 subset image - April 26, 2024 (Path 217, Row 15)

4. METHODS AND ANALYSIS

This study is completed in different phases.

By using **ARI** (Image Channel Arithmetic) algorithm in Geomatic application, the image that shows the changes of study area from **2014-sub** and **2024-sub** was created (Figure 4). Unsupervised classification implemented on Band 2,3,4,5,6, and 7 (Blue, Green, Red, NIR, SWIR 1, and SWIR 2) on the new difference image, and aggregate classification for creating ChangeNoChange image conducted.

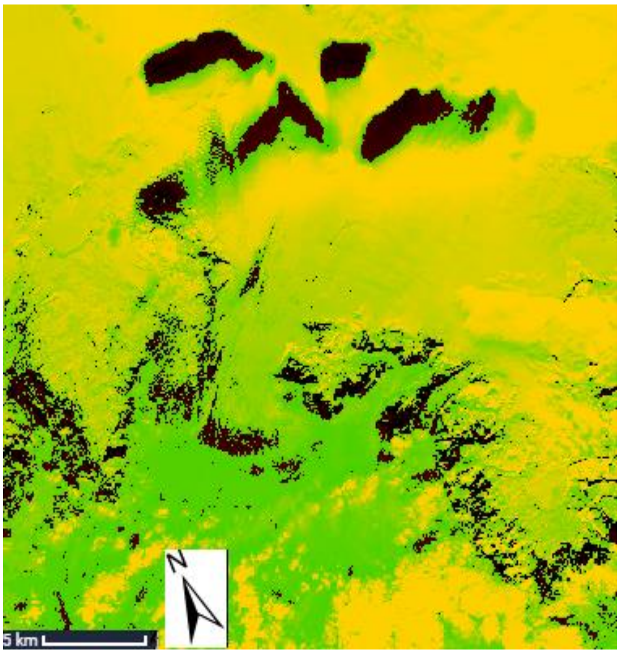

Figure 4: Band4 (2024-Sub) minus Band4 (2014-Sub)

From this point three different classifications are implemented on **2024-Sub** image.

1- Running an Unsupervised Classification on Band 2,3,4,5,6, and 7 (Blue, Green, Red, NIR, SWIR 1, and SWIR 2) on **2024-Sub** image **with no algorithm.** Aggregate classification and create an image based on three classes (**Land, Ice, and Water**), and running the **Accuracy Assessment**

2- **PCA** (Principal Component Analysis) algorithm is **appended** to **2024-Sub** image. Run an Unsupervised Classification on Band 2,3,4,5,6,7 (Blue, Green, Red, NIR, SWIR 1, and SWIR 2) and PCA on 2024-Sub image. Aggregate classification and create an image based on three classes (**Land, Ice, and Water**), and running the **Accuracy Assessment**

3- **Texture Analysis** algorithm is **appended** to the image **2024-Sub** with PCA algorithm from the previous phase. Run an Unsupervised Classification on Band 2,3,4,5,6,7,(Blue, Green, Red, NIR, SWIR 1, and SWIR 2), **PCA**, **Homogeneity and Contrast** on 2024-Sub image. Aggregate classification and create an image based on three classes (**Land, Ice, and Water**), and running the **Accuracy Assessment**

Unsupervised classification shows the ice changes in the study area of the glacier in different times. PCA and Texture Analysis algorithms were implanted in this study. Principal components analysis (PCA) is a method to estimate the variations in intensity of images around the usual Euclidean mean. PCA retains the highest possible variance with lowest possible correlation (measured as covariance) by rotating the object around different axes to find the best orientation. The extension of the axes are eigenvalues (Figure 5).

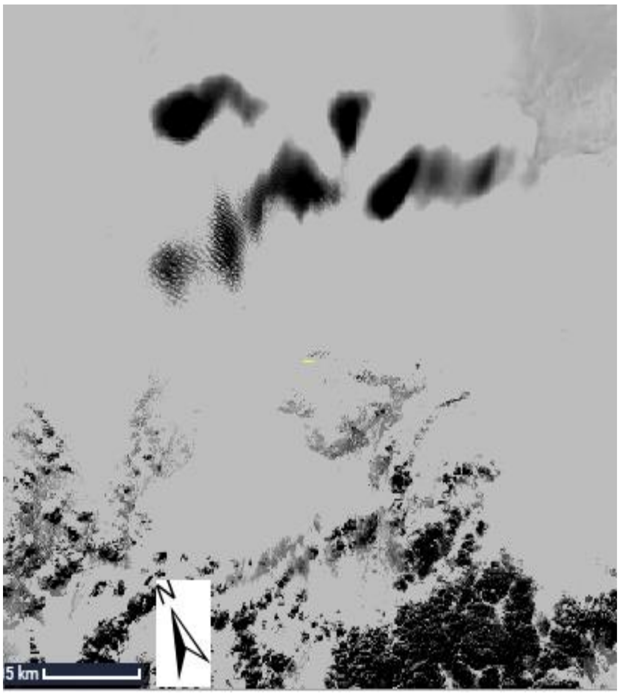

Figure 5: PCA1 (2024-Sub)

Texture analysis was used for with homogeneity (Figure 6) and contrast parameters. Contrast (Figure 7) could show the amount of local variation while homogeneity distinguished ice changes noticeably.

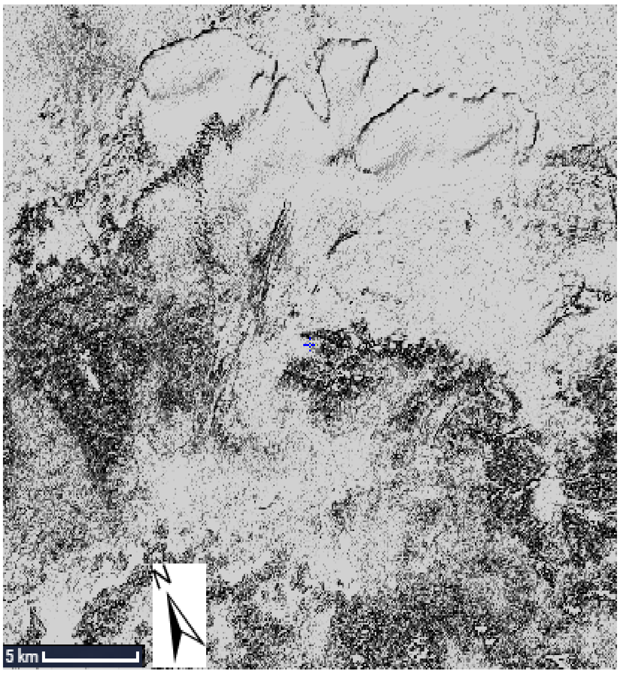

Figure 6: Texture Analysis Homogeneity Parameter– 2024-Sub

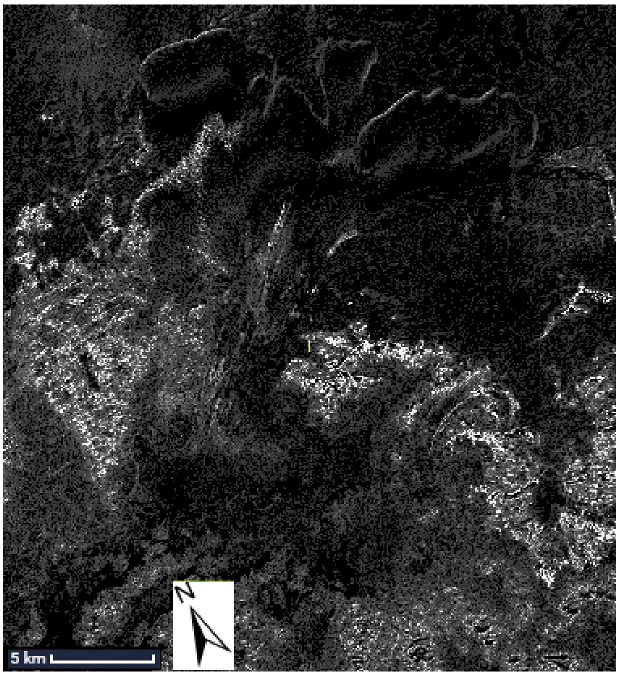

Figure 7: Texture Analysis Contrast Parameter– 2024-Sub

Accuracy Assessments Analysis shows a better overall accuracy on aggregation result with **PCA** algorithm appended to **2024-Sub** (Figure 8) than 2024-Sub with no algorithm appended and 2024-Sub with PCA + Texture Analysis algorithm appended.

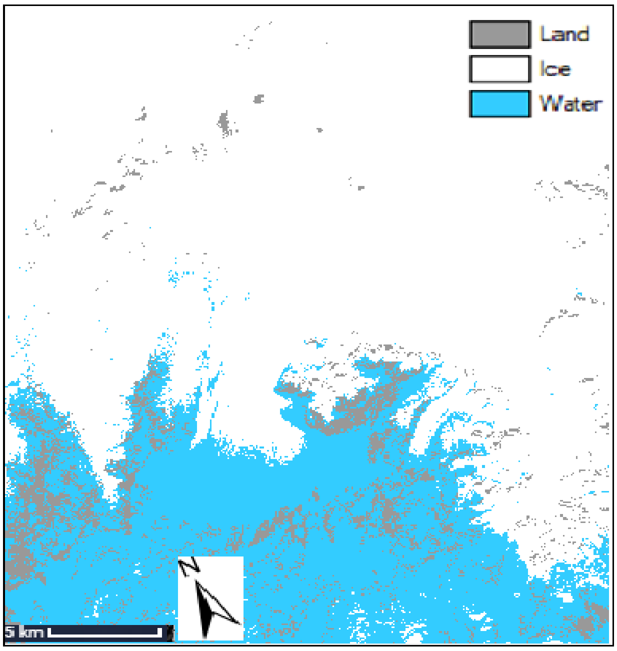

Figure 8: Aggregation result with **PCA** algorithm – **2024-Sub-Aggregation.img**

Tables 1a to 3a show Accuracy Statistics for the classification without and with algorithm(s) appended and **Tables 1b to 3b** shows Accuracy Statistics - Error (Confusion) Matrix for the classification without and with algorithm(s) appended. As we see from Tab 2a, Accuracy Statistics for Classification with **PCA Algorithm** has the highest overall accuracy (88%). Tab2 b shows very good accuracy in separating Land, Ice and Water compared with other two approaches.

Tab 1a: Accuracy Statistics for Classification with **No Algorithm appended**.
Overall Accuracy: 87.000% - 95% Confidence Interval (79.908% 94.092%)
Overall Kappa Statistic:0.770-Overall Kappa Variance : -0.004

Class Name	Producer's Accuracy	95% Confidence Interval	User's Accuracy	95% Confidence Interval	Kappa Statistic
Land	64.29%	(35.614% 92.957%)	56.25%	28.817% 83.683%)	0.4913
Ice	91.53%	(83.571% 99.479%)	93.10%	(85.720% 100.487%)	0.8318
Water	88.89%	(75.183% 102.595%)	92.31%	(80.142% 104.474%)	0.8946

Tab 1b: Accuracy Statistics - Error (Confusion) Matrix.

Classified Data	Reference Data			
	Land	Ice	Water	Totals
Land	9	4	3	16
Ice	4	54	0	58
Water	1	1	24	26
Totals	14	59	27	100

Tab 2a: Accuracy Statistics for Classification with **PCA Algorithm**.
Overall Accuracy: **88.000%** - 95% Confidence Interval (81.131% 94.869%)
Overall Kappa Statistic: 0.784-Overall Kappa Variance : -0.019

Class Name	Producer's Accuracy	95% Confidence Interval	User's Accuracy	95% Confidence Interval	Kappa Statistic
Land	28.57%	(1.336% 55.807%)	66.67%	(20.613% 112.720%)	0.6124
Ice	100.00%	(99.091% 100.909%)	91.67%	(83.840% 99.494%)	0.8148
Water	93.55%	(83.287% 103.810%)	85.29%	(71.919% 98.669%)	0.7869

Tab 2b: Accuracy Statistics - Error (Confusion) Matrix.

Classified Data	Reference Data			
	Land	Ice	Water	Totals
Land	4	0	2	6
Ice	5	55	0	60
Water	5	0	29	34
Totals	14	55	31	100

Tab 3a: Accuracy Statistics for classification with **PCA and Texture Analysis Algorithms**.
Overall Accuracy: 81.000% - 95% Confidence Interval (72.811% 89.189%)
Overall Kappa Statistic: 0.686 -Overall Kappa Variance : -0.000

Class Name	Producer's Accuracy	95% Confidence Interval	User's Accuracy	95% Confidence Interval	Kappa Statistic
Land	60.87%	(38.750% 82.989%)	63.64%	(41.262% 86.011%)	0.5277
Ice	96.15%	(89.965% 102.342%)	90.91%	(82.402% 99.416%)	0.8106
Water	68.00%	(47.714% 88.286%)	73.91%	(53.793% 94.033%)	0.6522

Tab 3b: Accuracy Statistics - Error (Confusion) Matrix.

Classified Data	Reference Data			
	Land	Ice	Water	Totals
Land	14	0	8	22
Ice	5	50	0	55
Water	4	2	17	23
Totals	23	52	25	100

As Classification with **PCA Algorithm** has the best overall accuracy,the pix image resulted of aggregation with **PCA** algorithm was converted to img file and imported to ArcGIS along with ChangeNoChange pix image (Figure 9).

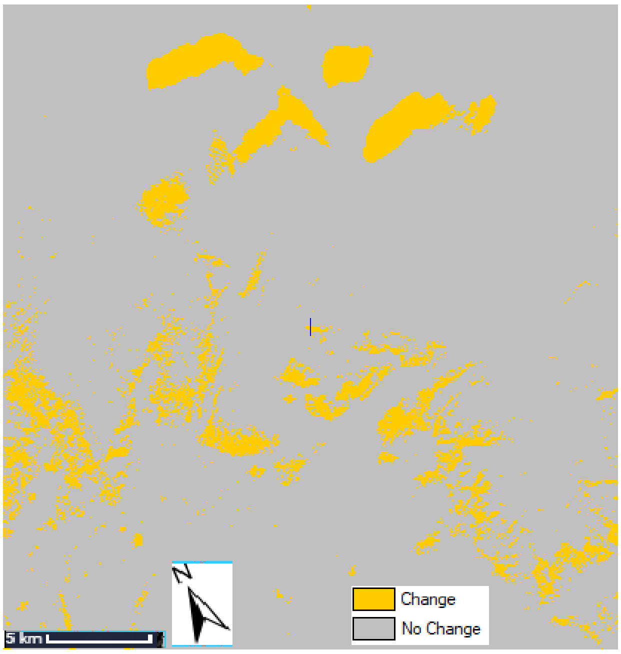

Figure 9: ChangeNoChange image resulted from Unsupervised Classification on 2024-Sub Minus 2014-Sub (**ChangeNoChange.pix**)

In ArcGIS the Rasters for both images (**ChangeNoChange.pix** and 2024-**Sub-Aggregation.img** exported. Reclassification tool for ChangeNoChange raster is implemented with value 10 for change and 20 for no Change. Raster Calculation tools is used for exporting the changes (Figure 10).

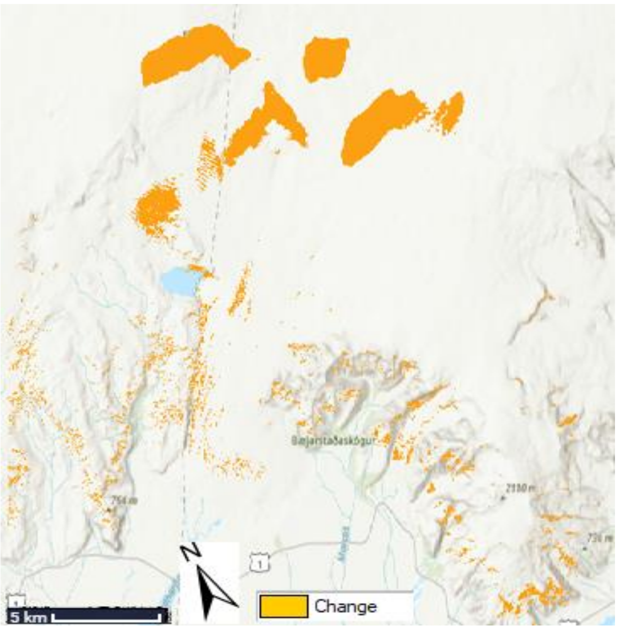

Figure 10: ArcGIS Raster Calculation

5. CONCLUSION

The outcome of analysis and calculation shows a better result Principal Component Analysis with overall 88% accuracy, 100 % accuracy for ice and 93.55% accuracy for water . The combined approach including image differencing, unsupervised classification with area measurement tools in ArcGIS show an estimate of 28 Sq Km of ice affected negatively on the accumulation zone of Skeldorororjokull outlet area between 2014 and 2024 (Figure 11).

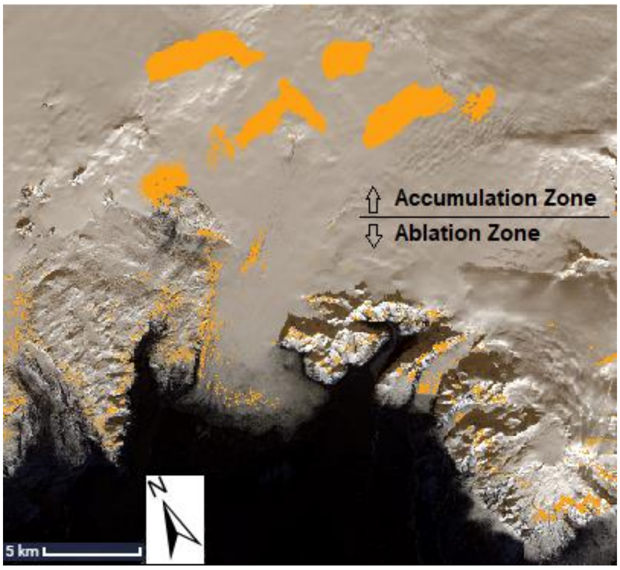

Figure 11: Final image showing the Urban Changes (Base image is 2014-Sub)

REFERENCES

Björnsson, H 1980. The surface area of glaciers in Iceland. Jökull 28, 1978. Google Scholar

National Park Service. 2025. Anatomy of a Glacier. Available Online : Anatomy of a Glacier - Glacier Bay National Park & Preserve (U.S. National Park Service)

Richard S. Williams 2017. Satellite Remote Sensing of Vatnajökull, Iceland. Published online by Cambridge University Press. 20 January 2017.

Vatnajökull National Park. 2025, Discover Vatnajökull National Park. Available Online: Discover Vatnajökull National Park - Vatnajökull National Park