Object-based glacier surface change detection using multispectral satellite data

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Abstract

Due to change in global temperature, glaciers all over the Himalayan region including the Karakoram range have been retreating and many small glaciers have already disappeared. Therefore, it is the prime most need to acquire precise information on glacier changes. This study presents an object-based approach that utilizes the Maps to detect the change detection in glacier ice/snow coverage from the temporal signatures of multispectral satellite imageries of Landsat 4-5 Thematic Mapper (TM), Landsat 7 Enhanced Thematic Mapper (ETM+), and Landsat 8 Operational Land Image/ Thermal Infrared Sensor (OLI-TIRS) from year 1997 to 2018. It is observed that the glacier ice/snow cover area is increased by 25.17% during 20 years period.

Study Area and Dataset

- The glacier located in the Aghil Mountains in Eastern Karakoram has been considered as study area that extends between $35^0 52' 57''$N and $76^0 30' 48''$E.
- Total 10 images from 1997 to 2018 acquired at the end of the summer season (August, September) having less/no cloud cover are considered for multiannual glacier change detection.

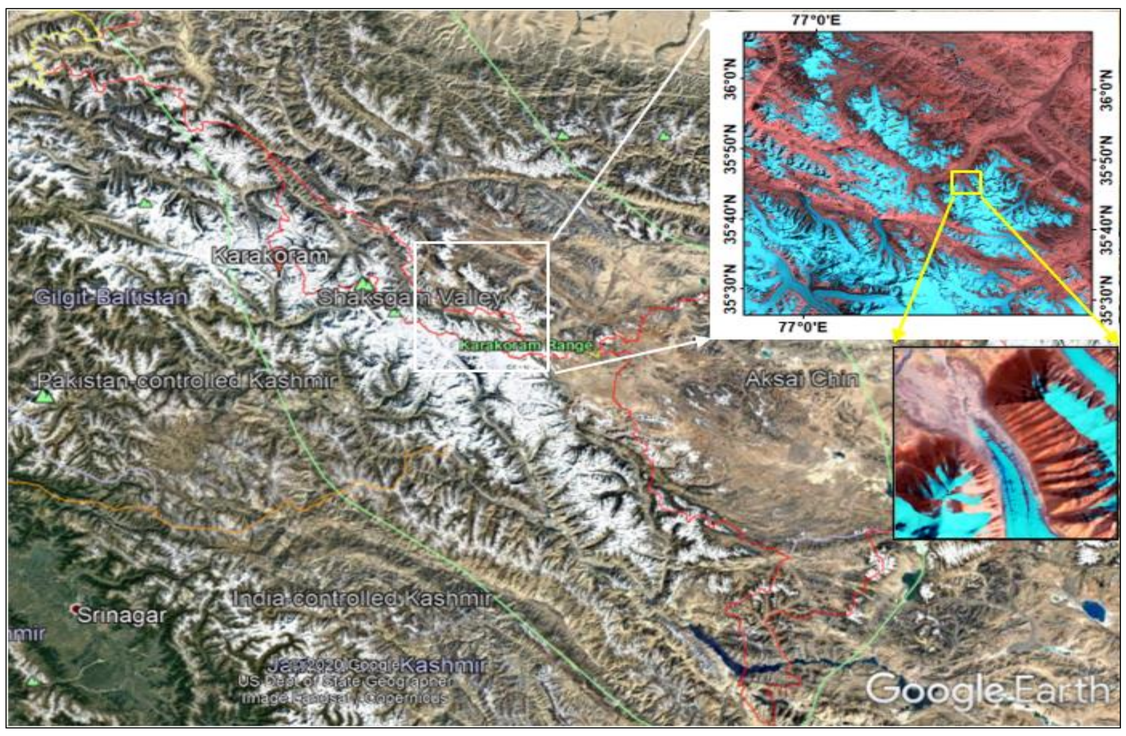
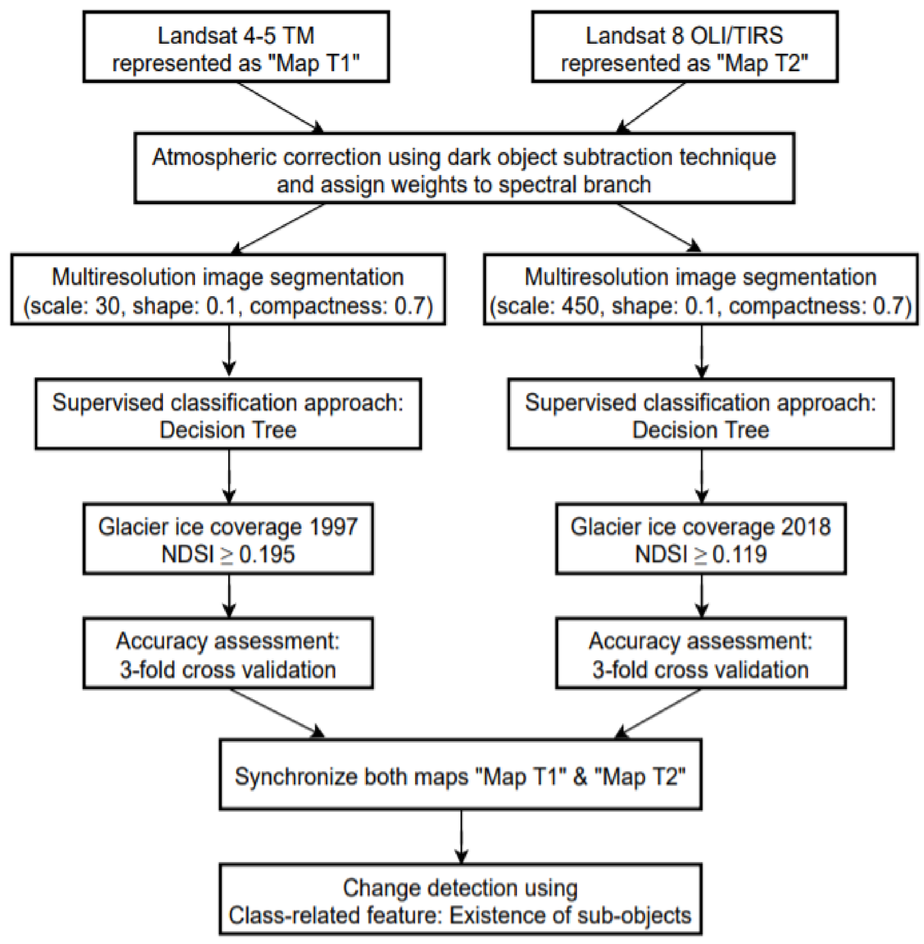


Image courtesy: USGS EarthExplorer and Google Earth

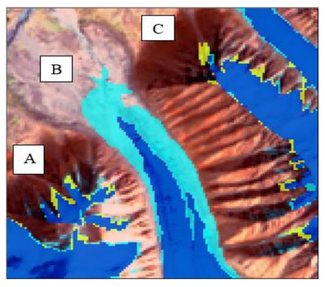
List of the images used for glacier ice cover change detection (path/row: 148/35)

Landsat ID	Sensor	Acquisition Date
For Multiannual Variation		
LT05_L1TP_148035_19970920_20161229_01_T1	TM4-5	20-Sep-1997
LT05_L1TP_148035_19980907_20161222_01_T1	TM4-5	09-Sep-1998
LE07_L1TP_148035_20000803_20170210_01_T1	ETM+7	3-Aug-2000
LE07_L1TP_148035_20010923_20170203_01_T1	ETM+7	23-Sep-2001
LT05_L1TP_148035_20090804_20161026_01_T1	TM4-5	4-Aug-2009
LT05_L1TP_148035_20100823_20161014_01_T1	TM4-5	23-Aug-2010
LT05_L1TP_148035_20110810_20161007_01_T1	TM4-5	10-Aug-2011
LC08_L1TP_148035_20140919_20170419_01_T1	OLI/TIRS	19-Sep-2014
LC08_L1TP_148035_20160924_20170320_01_T1	OLI/TIRS	24-Sep-2016
LC08_L1TP_148035_20180829_20180911_01_T1	OLI/TIRS	29-Aug-2018

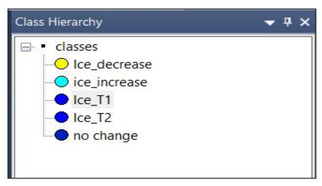
Methodology



Results



(a)



(b)

(a) Glacier ice cover change from 1997 to 2018 (b) Ten Landsat images showing glacier ice cover for different years

Glacial ice coverage area during 1997 to 2018 (for multiannual variation)

Acquisition Date	Area calculated by OBIA approach (Sq. Km)			
	Section A	Section B	Section C	Total
20-Sep-1997	1.44	1.09	1.84	4.37
09-Sep-1998	1.28	1.12	2.09	4.49
3-Aug-2000	3.12	1.35	6.60	11.21
23-Sep-2001	1.58	1.75	1.92	5.25
4-Aug-2009	1.43	2.38	2.09	5.90
23-Aug-2010	1.47	2.36	1.98	5.81
10-Aug-2011	1.57	2.47	2.35	6.39
19-Sep-2014	1.99	2.42	2.58	7.00
24-Sep-2016	1.76	2.37	2.18	6.31
29-Aug-2018	1.34	2.30	1.83	5.47

- Light blue color indicates an increase in ice cover area, whereas yellow color indicates a decrease in ice cover area.
- The whole image is divided into three sections namely A, B, and C.
- Section B represents valley glacier that forms when snow and ice buildup high in a mountain valley.
- Under sections A and C, a slight decrease in ice cover area is found in 2018. Whereas under section B, ice coverage in 2018 increases by 1.01 sq.km. as compared to 1977.
- The rise in global temperature results in the melting of ice causing the movement of ice downstream to the valley.
- A marginal increase of 1.1 sq.km. area of glacier ice cover has observed during 2018 as compared to 1997.

Conclusion and Future Scope

- The retreat of mountain glaciers in the Himalaya region is one of the evidences of climate change, and therefore, it is desirable to monitor glacier surfaces regularly.
- Due to adverse climatic conditions, field-based mapping is difficult. Remote sensing technologies have made it easy to map glaciers changes from time-series data.
- This study presented a multi-annual object-based glacier ice cover change detection over the period of 20 years.
- 25.17% increase in glacier ice cover area has been observed during 1997 to 2018. During 1997-2001, the glacier retreated faster whereas the retreat rate was comparatively slower during 2009-2018.
- As this study was mainly focused on determining the change in glacier ice cover, it can be extended to see the impact of increasing global mean temperature over glacial lakes.

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