

Climate Change and associated Glacier Retreat in Bhilangana Basin: A Case Study of Khatling Glacier, Uttarakhand from 2000 to 2018

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Abstract

Climate change is the most pressing issues of 21st century which is mostly associated with anthropogenic factors caused due to rapid industrialization. There are various ways of studying climate change like changes in weather pattern, shift in seasons, sea level rise and Monitoring Glaciers is also one of the most efficient tool to assess climate change cause rising temperatures starts melting glacier at a faster pace. Himalayan Glaciers are more vulnerable to climate change and have recorded visible retreat in various parts. Glaciers occupy about 10% of the Earth's land surface (~ 16 million Km²) but hold roughly 77% of its fresh water; more than 96% of glacier ice lies in the Polar Regions, Antarctica and Greenland. In the Himalayas, the glaciers cover approximately 33,000 sq km area and this is one of the largest concentrations of glacier-stored water outside the Polar Regions. Post industrial revolution, with the rise in level of CO₂, the natural climate of earth is susceptible to frequent unpredictable fluctuations. Since glaciers are considered as the best indicators to Climate Change, the study tries to deduce a positive relationship between the increasing temperatures and Climate change by studying Khatling Glacier, the lateral glacier situated in Tehri district (Uttarakhand) which is the source of river Bhilangana. The moraines on the side of the glaciers look like standing walls of gravel mud. In this paper Khatling Glacier is observed for a period from 2000-2017 with the help of Landsat and Sentinel Satellites. The study will help in assessing the glacial change in the region and also find out any developing Glacial Lakes (moraine dammed lakes) in the region which will help in striking a relationship between rising temperature and climate change and also risk mitigation in case of Glacial lake outburst flood in case of dam breach in flood plains.

Introduction

Glaciers occupy about 10% of the Earth's land surface (~ 16 million Km²) but hold roughly 77% of its fresh water; more than 96% of glacier ice lies in the Polar Regions, Antarctica and Greenland. The lofty mountains of the Himalaya are home to the largest ice mass outside the polar regions, aptly termed as third pole. The Indian portion of the Himalaya (21°57' to 37°05' N, 72°40' to 97°25' E) above 1060 masl covers an area of 0.35 million Km² (msk), out of which

0.19 msk lies in J&K, Himachal, Uttarakhand and the rest in the Eastern part of Himalaya (**Shankar and Srivastava, 2001**). It is estimated that the Himalayan glaciers provide around 8.6×10^6 m³ of water annually.

Since industrialization, human activities have resulted in steadily increasing concentrations of greenhouse gases in the atmosphere, leading to fears of enhanced greenhouse effect. The world's average surface temperature has increased **between 0.3 and 0.6°C** over the past hundred years (**ICIMOD 2007**). Globally, the impacts of climate change include among others, rising temperatures, shifts in rainfall pattern, melting of glaciers and sea ice, risk of glacial lake outburst floods (GLOFs), sea level rise and an increased intensity and frequency of extreme weather events (**Ganguly et al. 2010**). Results show that the recession rate has increased with rising temperature. A forecast was made that up to a quarter of the global mountain glacier mass could disappear by 2050 and up to half could be lost by 2100 (**Kuhn, 1993; Oerlemans, 1994; and IPCC, 1996**). For example, with the temperatures rise by 1°C, Alpine glaciers have shrunk by 40% in area and by more than 50% in volume since 1850 (**IPCC, 2001 & CSE, 2002**). Mountain glaciers interact sensitively with climate and therefore they are considered as climate indicators (**Oerlamans, 1994**). The changing climate has had a significant Impact on the accelerated retreat of many glaciers globally. Warmer climates of the past 100 to 150 years have resulted in widespread glacial retreat and the formation of glacial lakes in many mountain ranges (**Clague and Evans 1994, Nakawo et.al. 1999**)

The Himalayas are geologically young and fragile and are vulnerable to even insignificant changes in the climatic system (**Lama et al. 2009**). In this regard the fluctuation of glaciers, change in runoff, annual balance, sediment transportation and their roles in controlling the climate of the subcontinents are of great significance. Glacial retreat thus has become the most important issue in the field of glaciology.

Glacial retreat would initially enhance run off but later the retreating glaciers shall pose a major problem for those dependent on rivers for **fresh water supply** for daily use, **agriculture, industry** and others. With increasing population, the depleting fresh water availability as always has been a great concern. This might even trigger **inter-state conflicts** over sharing of water, apart from reducing navigability of the rivers.

Another important aspect of climate change on glaciers is **glacial hazards**. Any glacier or glacier related process that adversely affects human activities directly or indirectly can be regarded as a Glacial Hazard (**Reynolds, 1992**). This covers a range of processes from avalanches threatening the livelihood and lives of hill farmers, catastrophic glacial lake outbursts destroying vital infrastructure and vulnerable communities through glacial recession from climate change resulting in increased storage of water behind unstable moraine dams at high altitudes.

Continuous change in temperature causes faster melting of glacial ice, resulting in formation of large number of glacial lakes. Glacial lake is defined as water mass existing in a sufficient amount and extending with a free surface in, under, beside, and/or in front of a glacier and originating from glacier activities and/or retreating processes of a glacier (**Banerjee 2013**). Sudden discharge of large volumes of water with debris from these lakes potentially causes glacial lake outburst floods (GLOFs)

in valleys downstream. A GLOF occurs when a lake contained by a glacier or a terminal moraine dam fails. This can happen due to erosion, water pressure, an avalanche of rock or heavy snow, an earthquake or cryoseism, or if a large enough portion of a glacier breaks off and massively displaces the waters in a glacial lake at its base. The collapse of Glacier Lake generates huge debris mixed flash flood downstream. There are many documented cases of GLOF occurrences across the globe.

Cloud Bursts is one meteorological that is directly related to GLOF incidents, Flash Floods, Debris flow, Landslides etc. Cloud burst is an extreme amount of precipitation over a smaller area within a shorter period. Sometime hail and thunderstorm are associated with it and can create flood or flash flood conditions causing loss of life and properties. It is observed that during the Cloud Burst the rate of rainfall can be reached up to 10 cm/hr (**Woolley Ralfer, 1946**). Cloud Burst is not an uncommon event in Uttarakhand Himalaya. In recent past this region has experienced several Cloud Burst incidences such as; Kedarnath (14-15 June, 2013), Rudraprayag (Sept 2012), Munisyari (August 2010) etc.

Avalanches are the other prominent glacial hazards that have the capacity to cause widespread loss to human society. Avalanche is a downward movement of rock mass, ice blocks and snow when internal cohesion decreases or with intrusion of liquid water. The factors that govern the generation of an avalanche are **weather conditions, snow fall, slope steepness, slope orientation, wind direction, terrain conditions, vegetation cover** and **snow peak conditions**. Most of the avalanches occur on 30-45° slopes. A large avalanche might release **300,000 cubic yards of snow** that is equivalent to 200 football fields under 10 feet of snow. Avalanche can reach up to a speed of **394 m/hr**. In Uttarakhand there has so far been no report on the occurrence of avalanche. However, the high Himalayan valleys close to glaciers and which receive winter snow are susceptible to avalanches

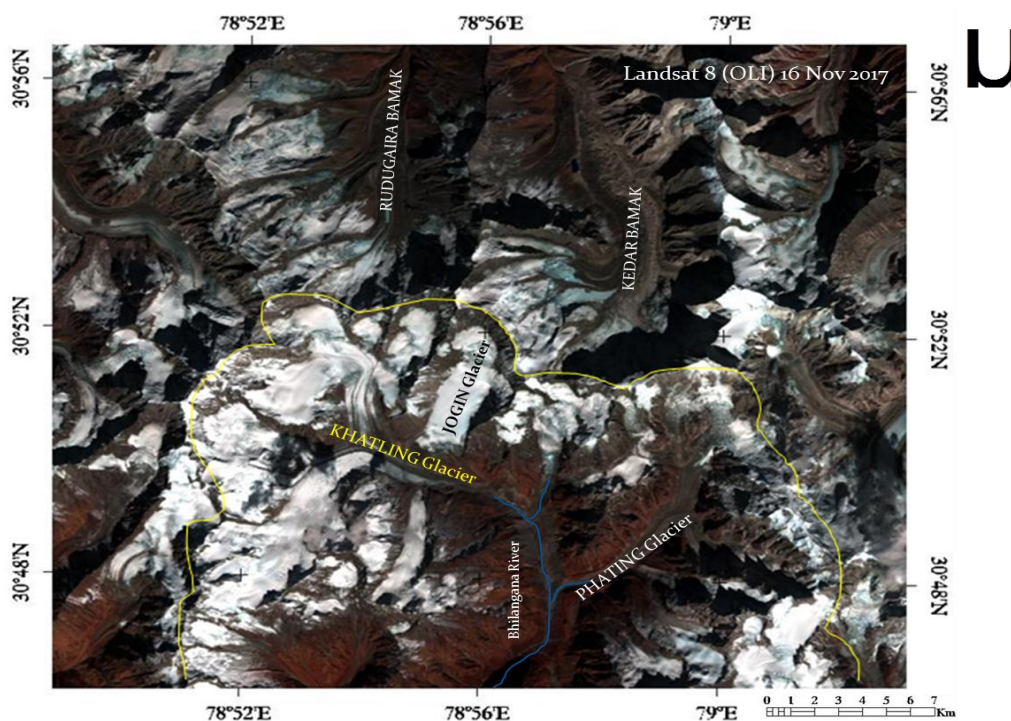
Study Area

The Bhilangana basin is located between **30° 51' 32.33" to 30° 20' 27.88" N latitude and 78° 59' 47.15" to 78° 47' 34.58" E longitude**. The topography of the upper catchment of the Bhilangana River consists of U-shaped valley, moraines, eskers, cirques and high ridges. Permanent pockets of snow occur in moist shady depressions. In its upper course the Bhilangana flows past alpine meadows and thickest of sub alpine forests. Coniferous and broad-leaved forests are found in Bhilangana valley. Bhilangana River is an important tributary of Bhagirathi River near Tehri. It flows from the **Khatling glacier (elevation 3,717 m (12,195 ft))**, approximately 50 km (31 mi) south of Gaumukh and north of Ghuttu in Tehri district of Garhwal region. The river flows along South West direction to join **Bhagirathi River** at Tehri in the Bhagirathi valley. A number of glacial lakes occur in the upper catchment of this river. Small streams emanate from these water bodies and merge with the main stream. The river flows from its source for 205 km (127 mi) before meeting the **Alaknanda River** at an elevation of **475 m (1,558 ft)** in the town of **Devprayag**.

The basin supports a total of 33 glaciers of different morphological types; the major glaciers in the basin are Khatling, Phating, Satling, Bhartekunta, Jogin, Dudhganga and Ratangrian glaciers. Khatling glacier is the largest compound basin, valley glacier orienting south-east, and receives ice from more than two cirques, out of which Janoli peak (6632 m) and Bhetiara Ka Danda (5748 m) are major sources.

J.B.Auden (1940), first mentioned about Khatling Glacier, The Col here is named after him as Auden's Col after he succeeded in climbing the pass/col between the Rudugaria and Khatling,

Important towns around bhilangana are Ghansali, Ghuttu, Reh, Gangi, Biroda, kalyani, Kharsali, BhelBhagi, Tamabakund, Ghonti etc.



Objectives of study

The Objectives of Present Study is to

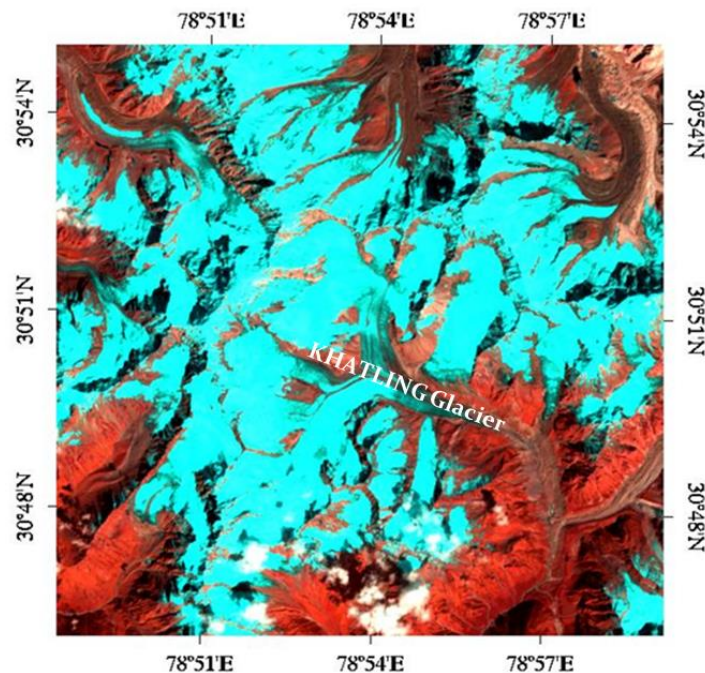
1. Mapping and Studying of Khatling Glacier (Garhwal Himalaya, Uttarakhand)
2. To study the loss in the terminus of the Glacier
3. To assess the loss in area of Glacier
4. To analyze the impact of climate change in recession of the glacier
5. To suggest mitigating steps to contain alarming recession in the area

Dataset and Methodology

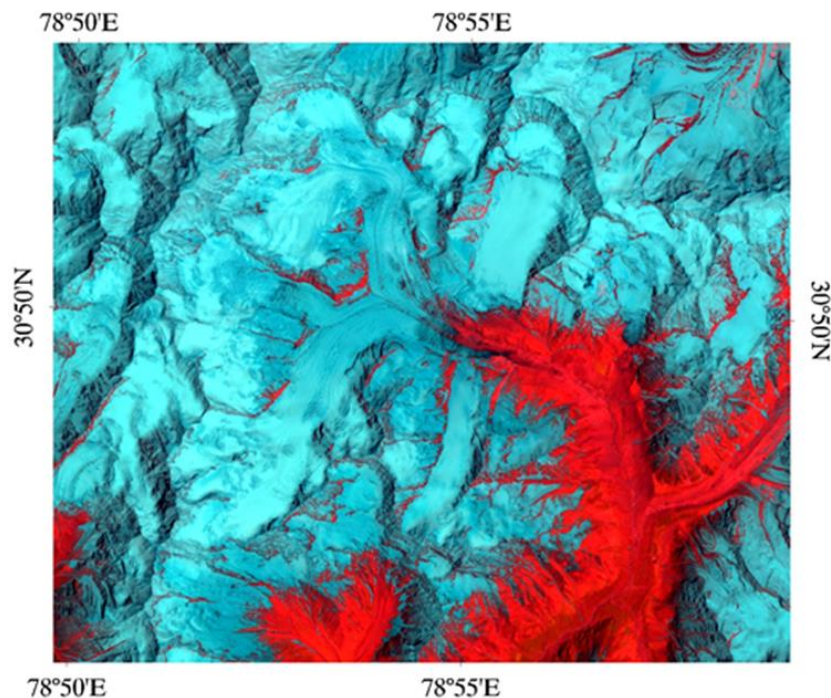
For current assessment of glacier secondary sources are used as follows

Satellite data	Date of Acquisition	Spatial Resolution (m)	Scene ID
Landsat 7 (ETM+)	08 Oct 2000	30 m	LE71460392000282SGS00
Landsat 8 (OLI)	16 Nov 2017	30 m	LC81460392017320LGN00
Sentinel 2B	20 May 2018	10 m	L1C_T44RKV_A006280_20180520T053150

Result and Discussion

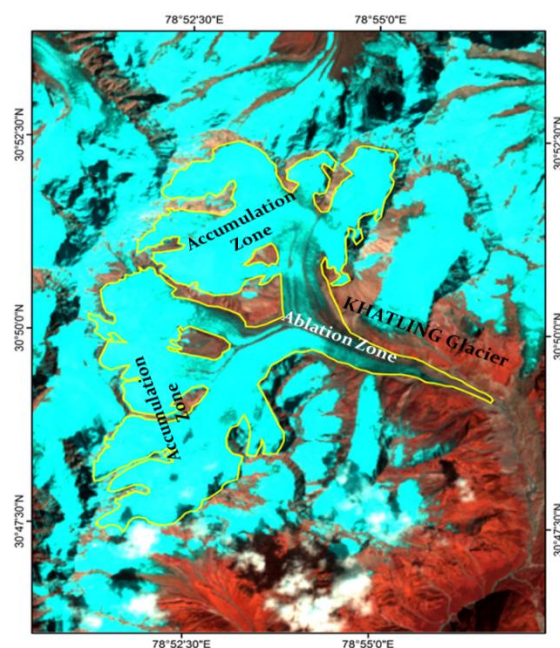


(a) Landsat 7 (ETM+) 8 Oct 2000
FCC (Bands 5,4,3)

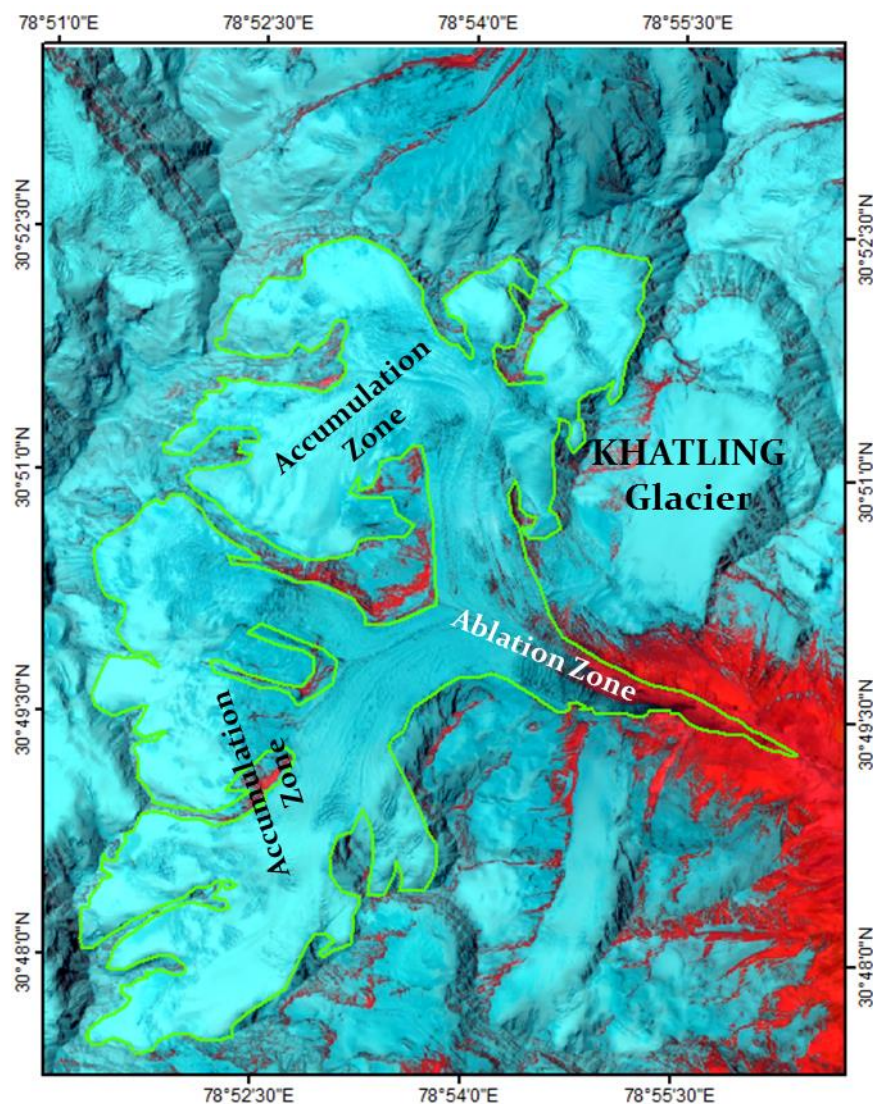


b) Sentinel 2, 20 May 2018
FCC (Bands 11,8,4)

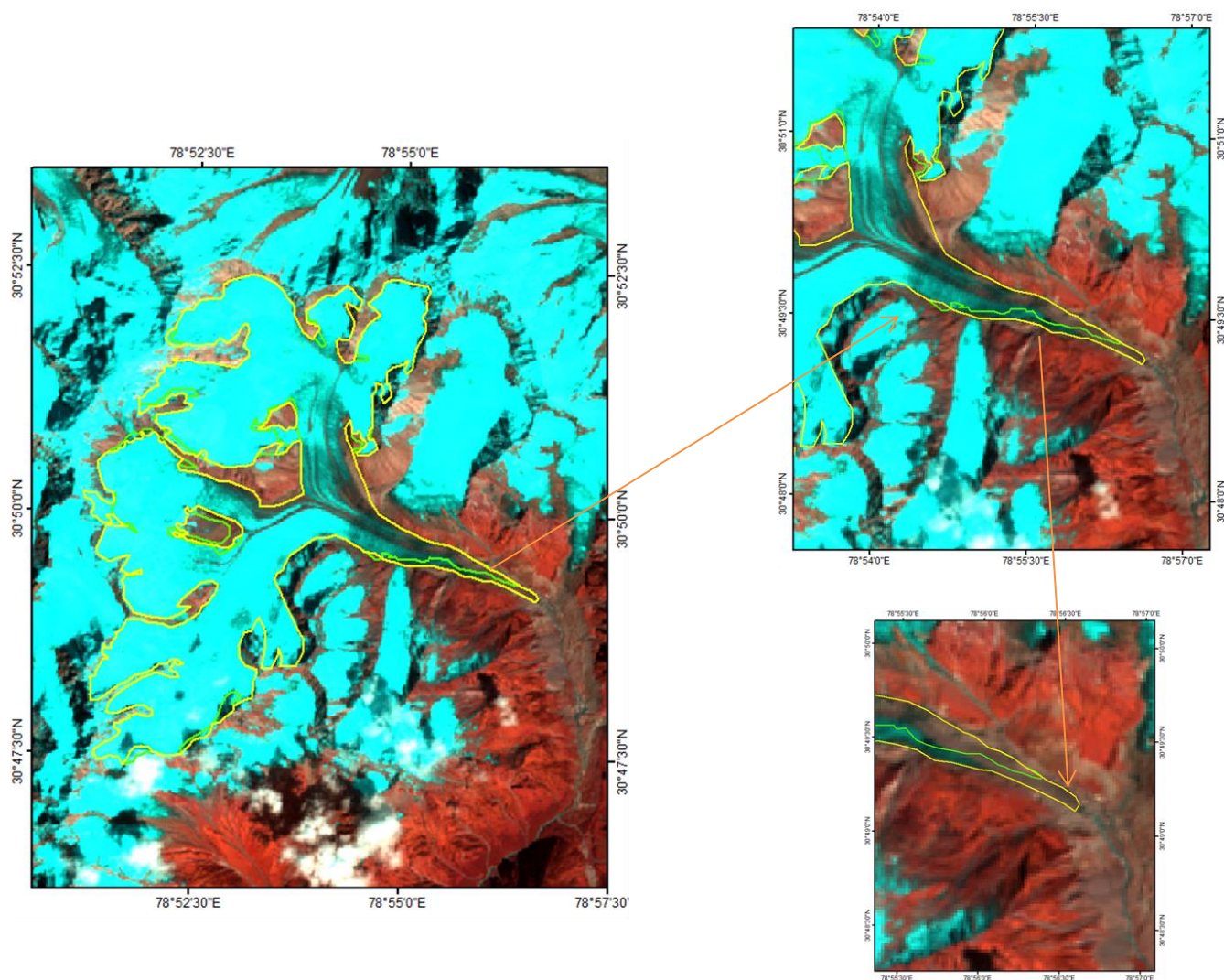
Synoptic view of the Khatling glacier in 2000 (a) and 2018 (b)



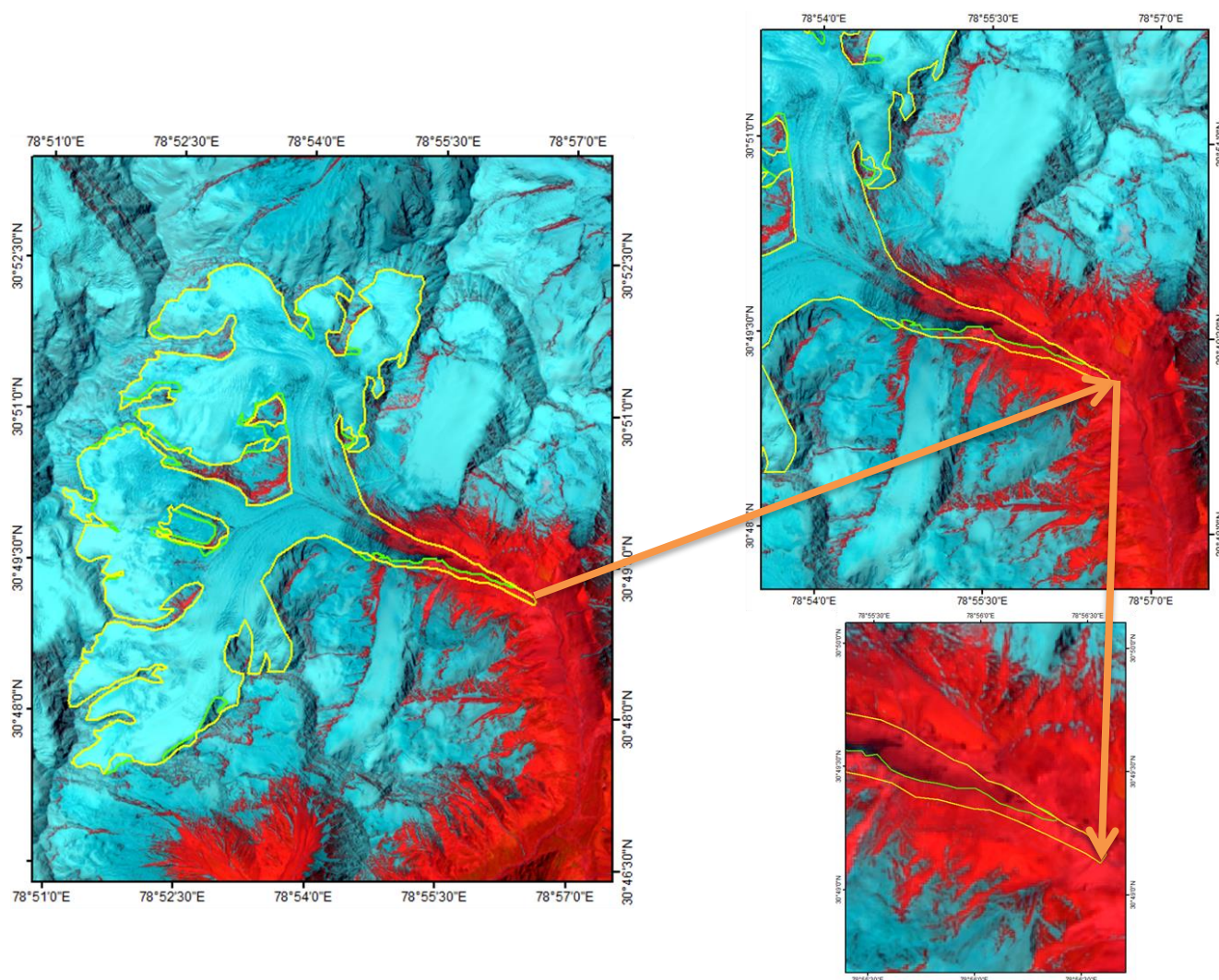
Khatling Glacier Snout mapped from Landsat (ETM+) 2000



Khatling Glacier Snout mapped from Sentinel 2,2018



Glacier Boundary and Snout Change Map Landsat (ETM+)08-Oct- 2000



Glacier Boundary and Snout Change Map Sentinel 2B, 20-May- 2018

Conclusion

Glacier	Data Used	Year	Total area (Sq. KM)	Snout Position		Total Recede In Snout Position	Average Rate of Recede
				Latitude	Longitude		
Khatling	Sentinel 2	2018	30.266	30°49'17.8"N	78°56'22.4"E	456± 7.2 m	26.8±0.4 mY ⁻¹
Khatling	Landsat ETM+	2000	30.870	30°49'8.8"N	78°56'35.9"E		

Over all the study concludes that the Glacier is retreating at an alarming rate of 26.8 meters per year on an average and has lost its area, significantly. There are glacial lakes in the adjoining drainage

basins but no significant lakes were monitored in this region for the given time period. The result is indicative of the fact that Himalayan glaciers are retreating at an alarming rate and government needs key policy interventions to check climate change.

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