Use of Sentinel Products For Cryosphere Monitoring in Bhutan

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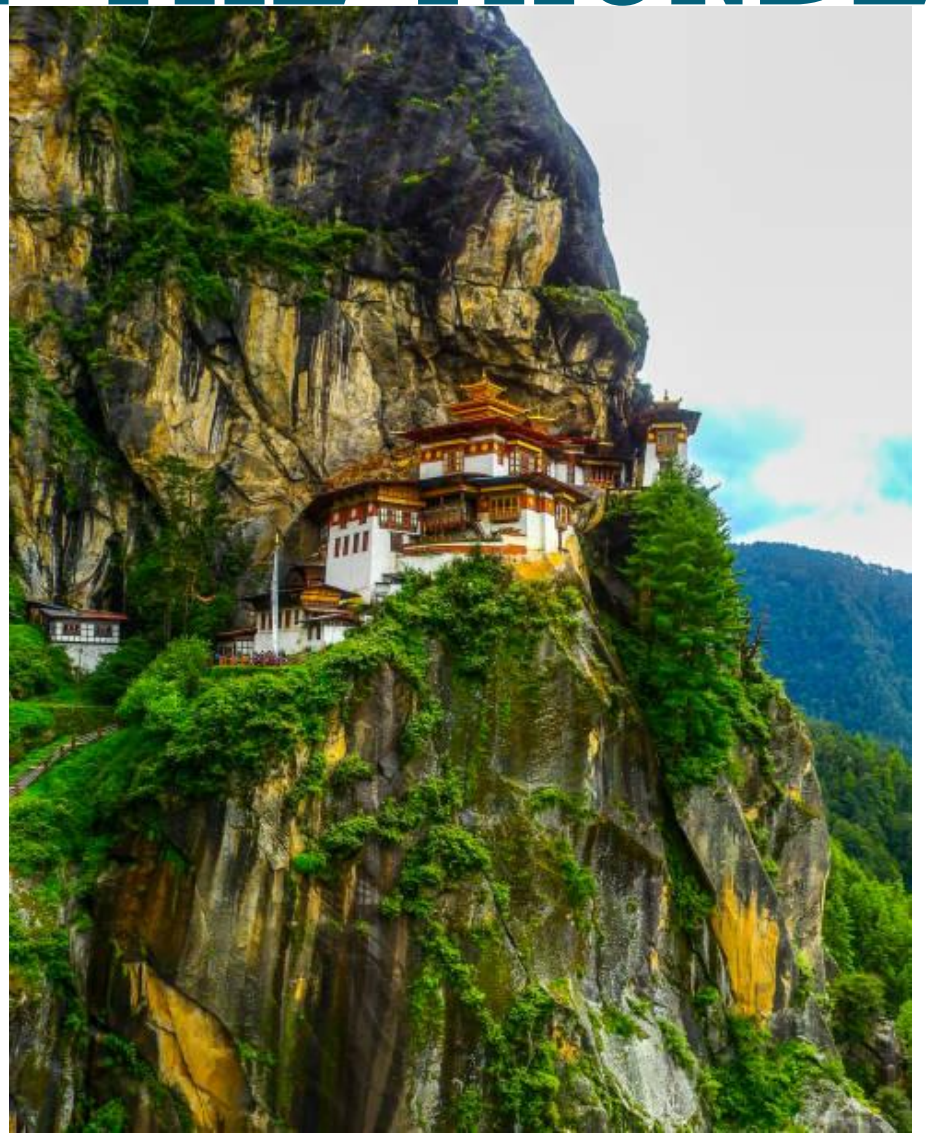
Cryosphere Services Division
National Center for Hydrology and Meteorology

LAND OF THE THUNDER DRAGON



OVERVIEW

1. Country Background
2. Current Threats and vulnerability.
3. Introduction to National Centre for Hydrology &Meteorology.
4. Bhutan Cryosphere Status.
5. Use of Sentinel Products.
6. Sentinel Asia activities.
7. Way forward.

Brief Country Background

Key facts:

Land Area(Sq km):38394

Forest Cover(Percent):69.71

Projected Population,2023:770,256

-Fragile mountainous landscape

Economy

- Heavy dependence and climate sensitive sectors

  - Agriculture

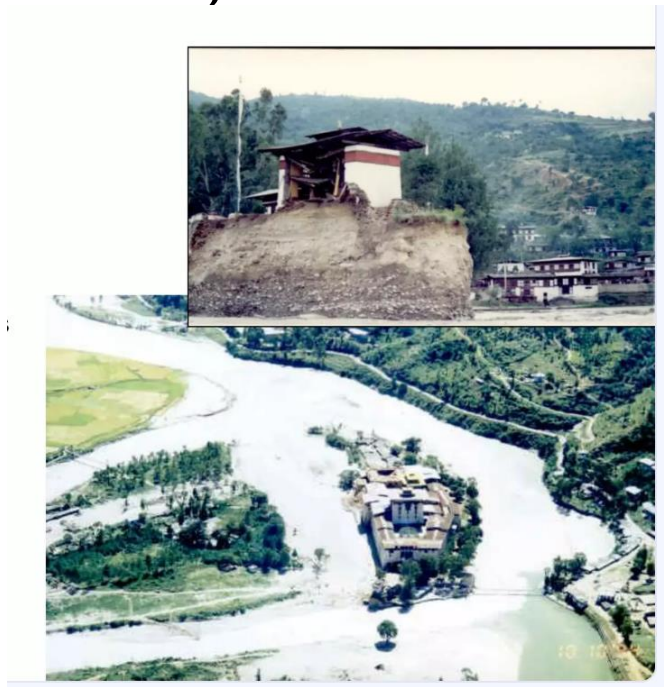
  -Hydropower

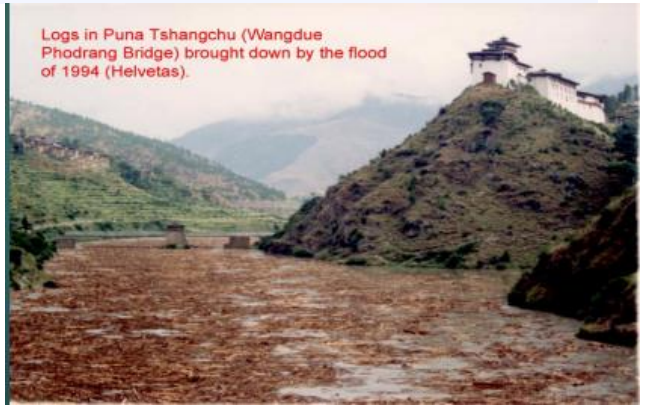
  -Tourism

- Population- 36% Urban & 64% rural
- Mainly dependent on subsistence farming

Current threats & vulnerabilities

1. Glacial Lake Outburst Floods(GLOFs)
2. Flashfloods
3.Earthquakes
4.Landslides
5.Extreme weather events
6. Land Degradation
7. Pest and diseases
8.Wind/thunder/hail storms





National Centre For Hydrology& Meteorology

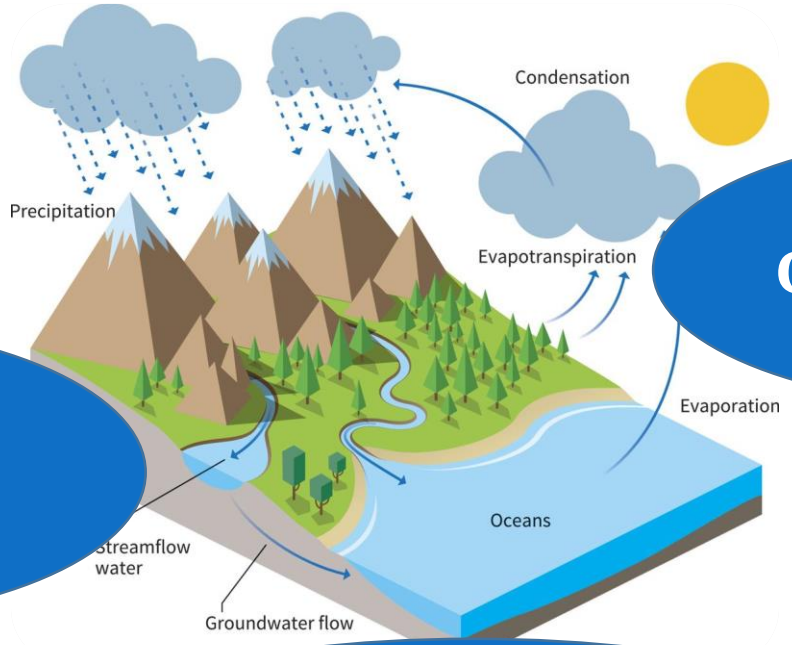
- **NCHM is the Scientific and Technical Autonomous Agency of RGoB .**
- **Nation's focal Agency for Monitoring:**
  -Cryosphere
  -Mitigation of Cryosphere related hazards
  Understanding current and future Water Climate Scenario for food security

Cryosphere Services Division

Weather & Climate Services Division

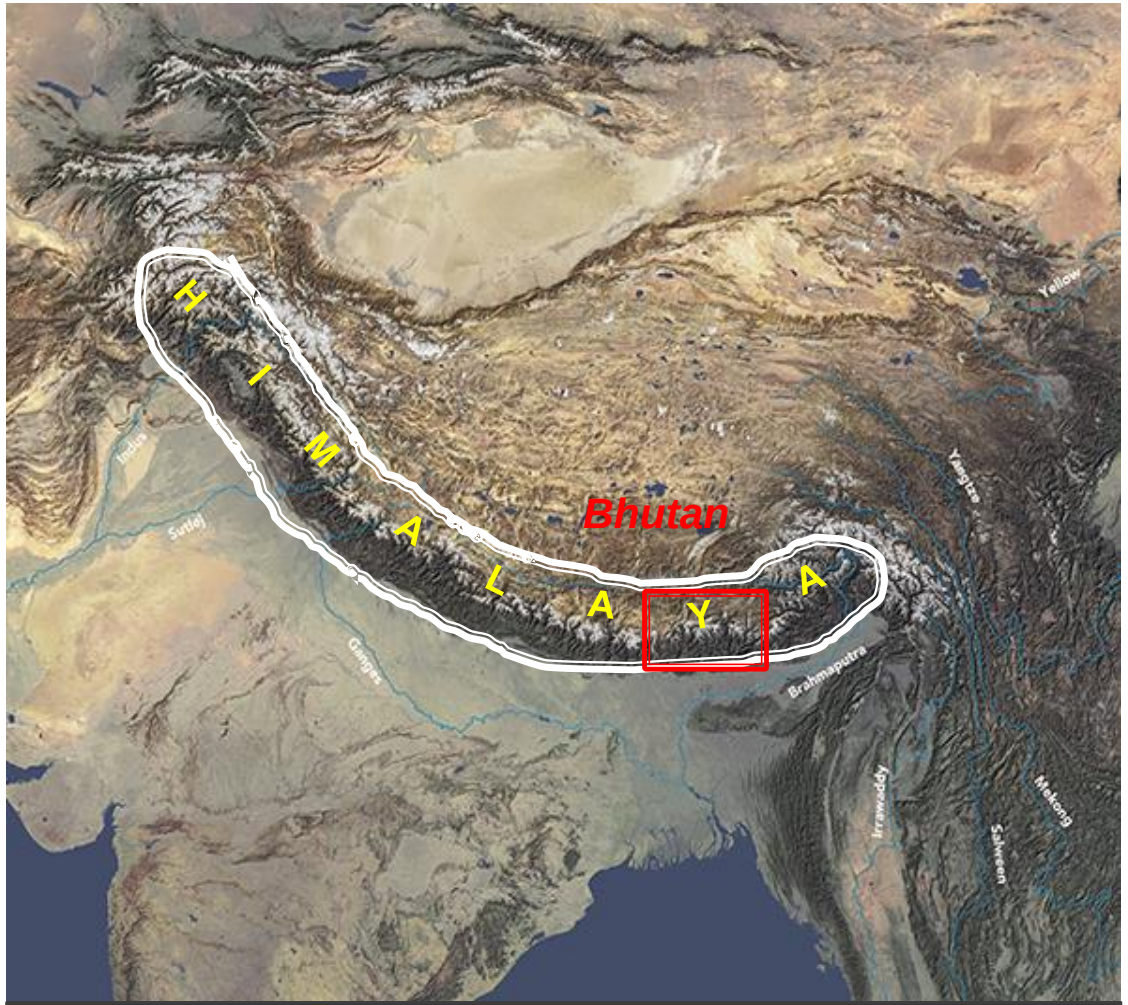
Hydrology and Water Resources Services Division

Technical Standards and Research Division



Glaciers in Bhutan

- Lies in eastern part of Himalaya
- Known to be Summer Accumulation type
- Such glaciers are more sensitive to climate change
  - *mainly driven by temperature*
  - *precipitation phase*



http://more.glacierworks.org/the-rivers/

Importance of Cryosphere in Bhutan

Using geochemical and isotopic chemistry to evaluate glacier melt contributions to the Chamkar Chhu (river), Bhutan

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[2]*Department of Geography, University of Colorado at Boulder, Boulder, CO, USA*
[3]*Center for Climate Change and Spatial Information, Royal University of Bhutan, Sherubtse College, Kanglung, Bhutan*
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ABSTRACT. Water stored as ice and snow at high elevations is a resource that plays an important role in the hydrologic cycle, particularly in the timing and volume of downstream discharge. Here we use geochemical and isotopic values of water samples to evaluate relative contributions of melting glacier ice and groundwater to discharge in Bhutan. River water samples were collected between 3100 and 4500 m in the Chamkar Chhu (river) watershed of central Bhutan's Himalaya. Glacier ice and snow were sampled in the ablation zone of Thanagang glacier. Groundwater was parameterized from spring water at elevations of 3100 and 3600 m. Synoptic sampling was carried out in separate expeditions in July, August and late September 2014, to characterize monsoon and post-monsoon conditions. Results from a two-component hydrologic mixing model using isotopic and geochemical (sulphate) values show that the glacier outflow contributions decrease from ~76% at 4500 m to 31% at 3100 m. A four-component hydrologic mixing model using end-member mixing analysis shows glacier ice melt increasing as a proportion of discharge over the 3 month sampling period, and consistently decreasing with distance downstream of Thanagang glacier terminus. These results indicate that isotopic and

45 % contribution from glaciers

TECHNICAL REPORT

Hydrograph Separation Using Geochemical and Isotopic Chemistry to Evaluate Glacier Melt Contributions to the Paa Chhu (River), Bhutan

Submitted to:
The World Bank Group Bhutan, Thimphu-IBRD

Authors:

17 February 2020

49.6 % contribution from glaciers

Importance of Cryosphere in Bhutan

Sustainability of hydropower sector?????? → **Least knowledge**

Most of the perennial rivers originate from glaciers →

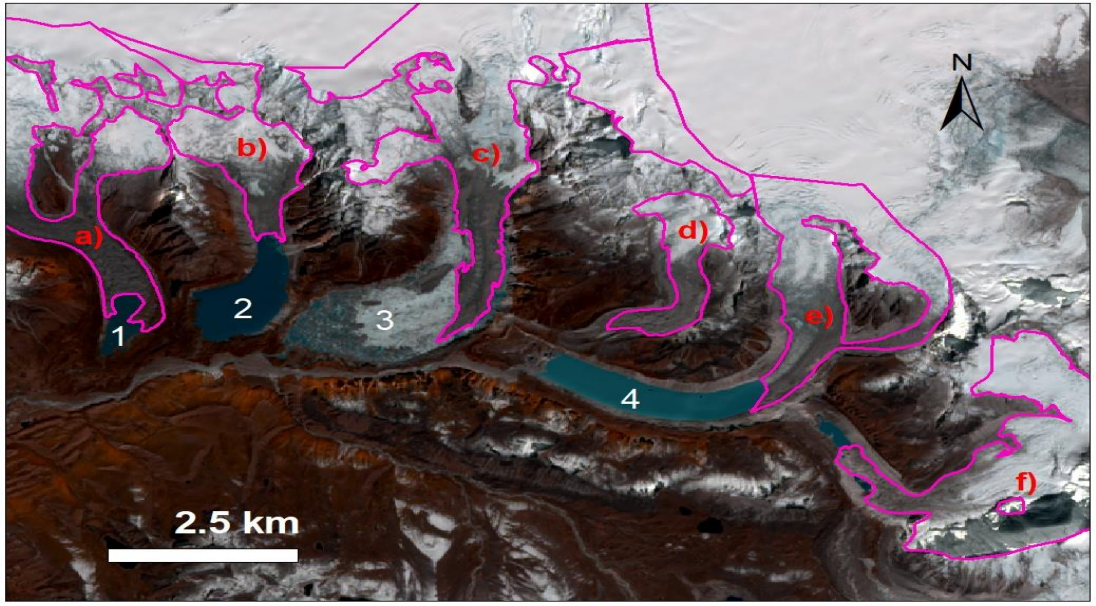
USE OF SENTINEL PRODUCTS AT NCHM:

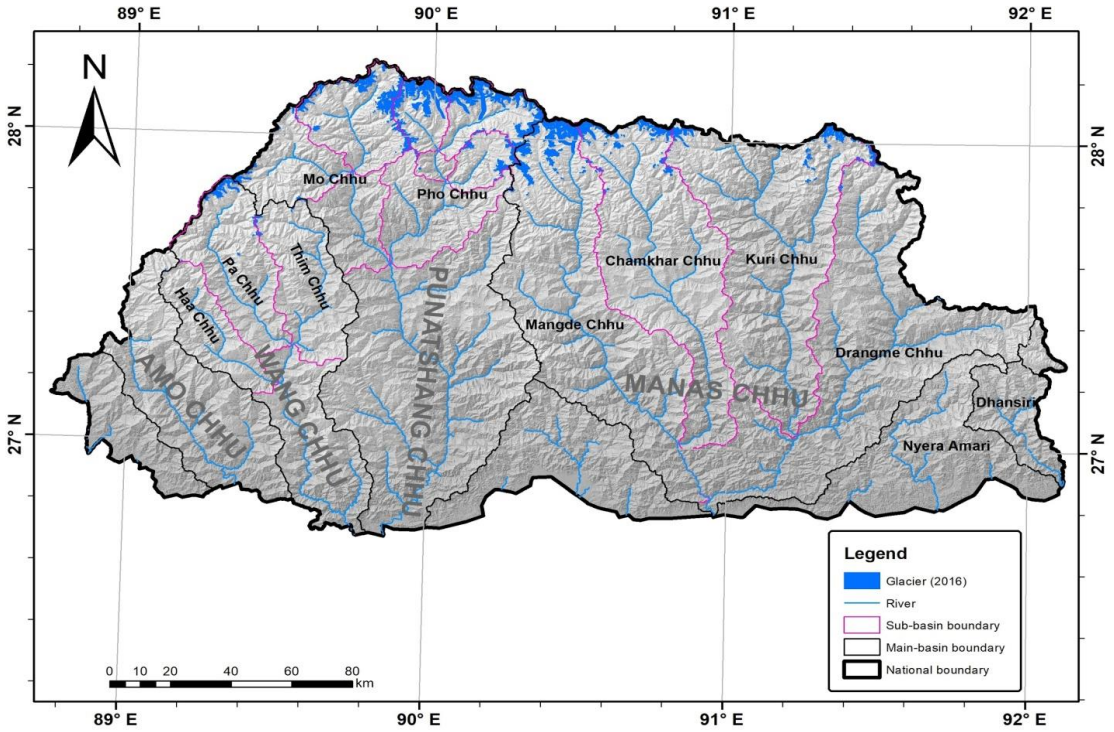
Mainly for cryosphere (glacier & glacial lake) monitoring:

1. **Bhutan Glacier Inventory,2016**

-Sentinel-2A images were used

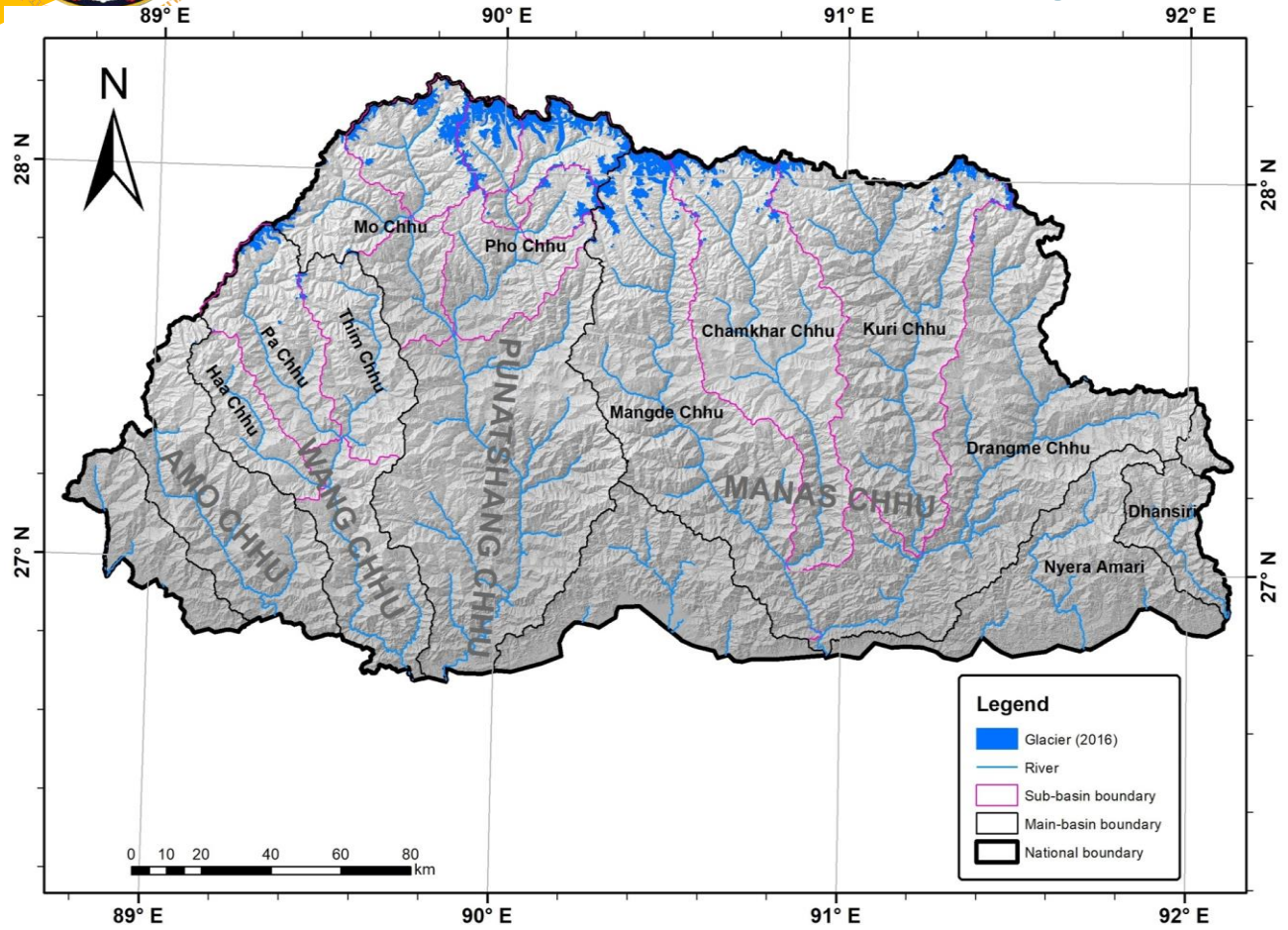
- Manual and automated supervised classification for clean ice glacier





700 glaciers covering an area of of 630 **km^2**

Glaciers of Bhutan



basin	No of glaciers	Area(km^2)
Puna Tsang Chhu	341	361
Wang Chhu	47	33.4
Mangde Chhu	111	108.25
Chamkhar Chhu	90	68.27
Kuri Chhu	90	55.29
Drangme Chhu	21	3.28

Glaciers = 700, 630 km^2

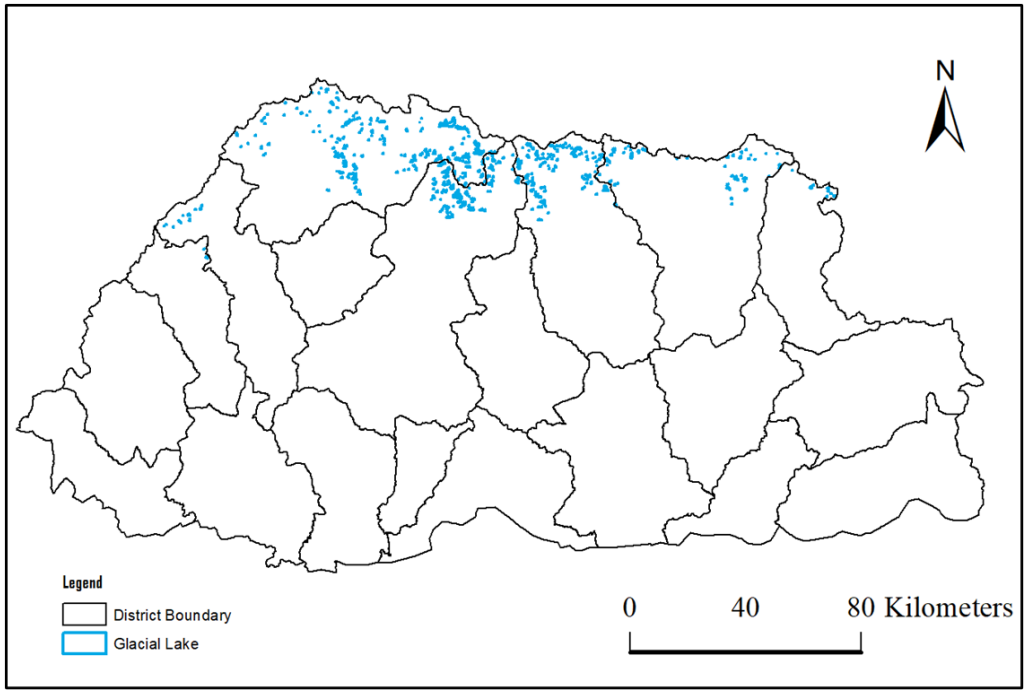
BGI 2018

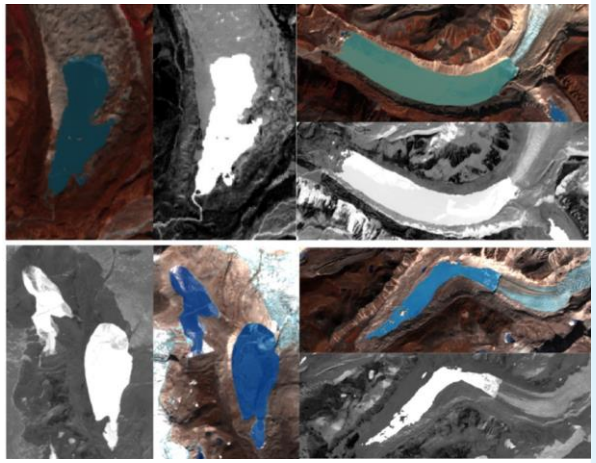
USE OF SENTINEL PRODUCTS AT NCHM:

2. Bhutan Glacial Lake Inventory ,2020.

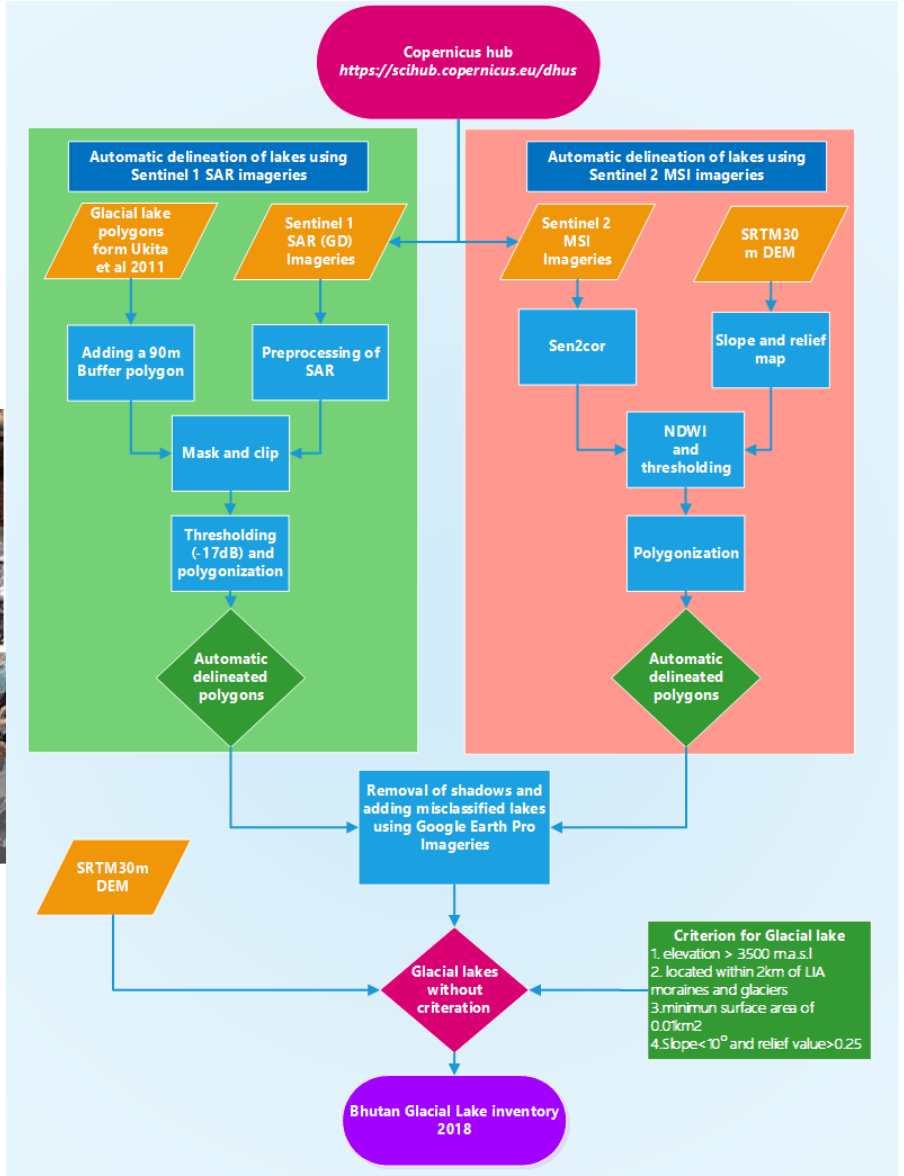
-Sentinel-2A imageries & Sentinel-1, (SAR) imageries were used.

- Manual and automated delineation of water bodies.

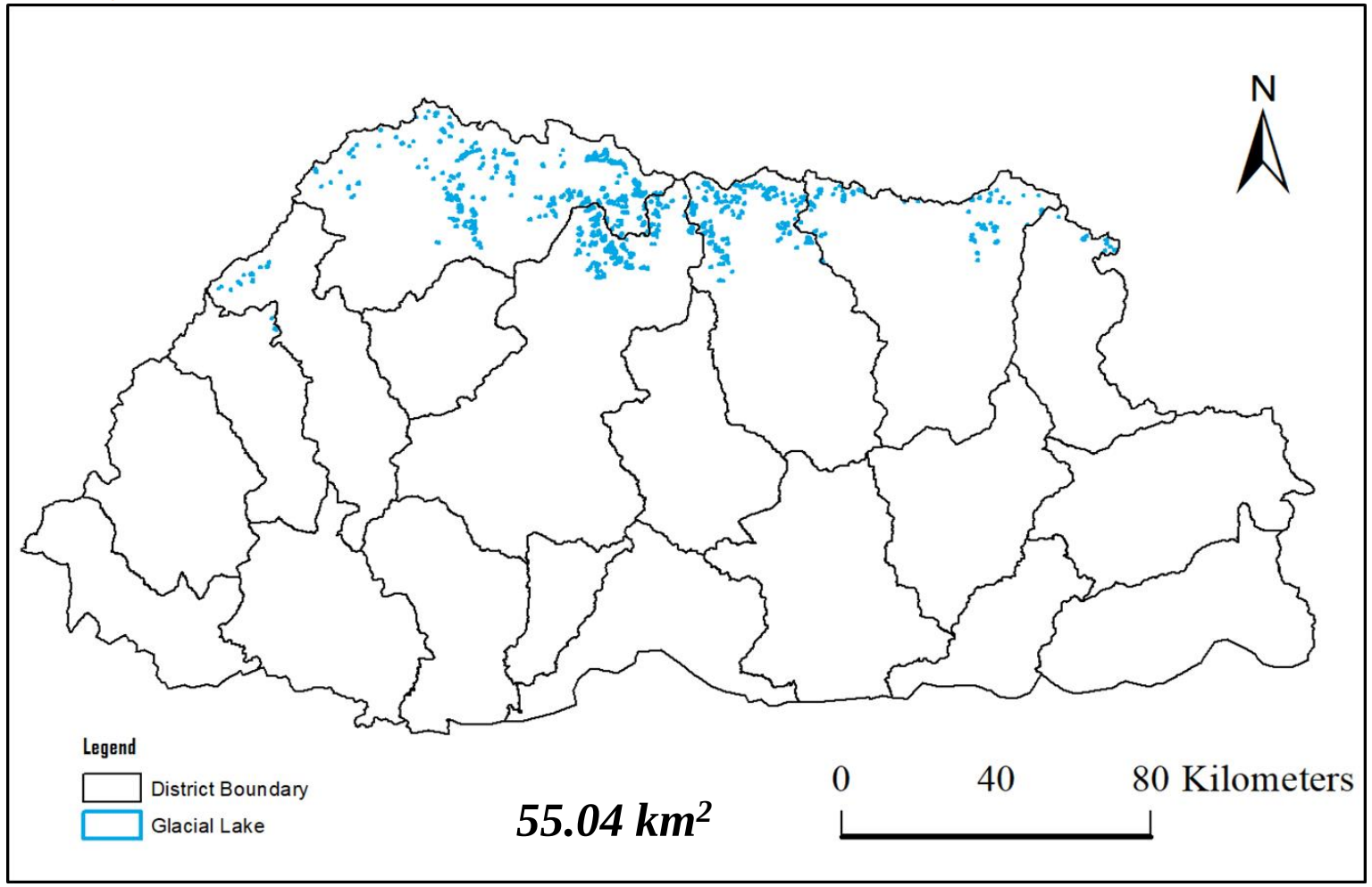




567 glacial lakes covering an area of 55.04 sq.km.



Glacial lakes of Bhutan



SI No	Sub- basin	Basin	No of G.Lake
1	MoChhu	Punatsang Chhu	66
2	Pho Chhu		157
3	Mangde Chhu	Manas	130
4	Chamkhar Chhu		131
5	Kuri Chhu		61
6	Drangme Chhu		9
7	Wang Chhu	Wang Chhu	13
Total			567

Glacial lake elevation ranges from

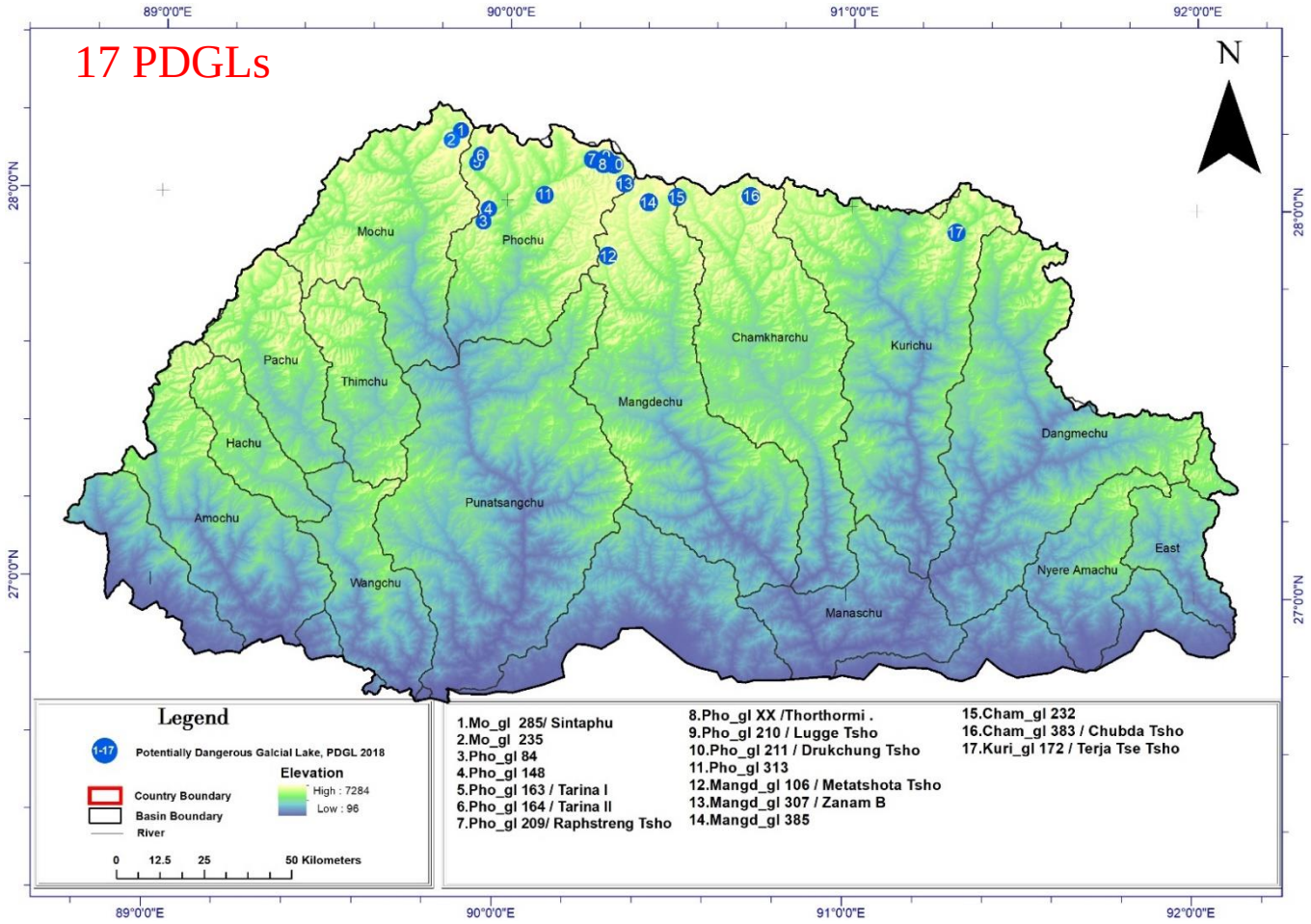
4075 m. to 7361m

BGLI,2021

Glacial lake criteria

1. Elevation above 3500m
2. Surface area >0.01km2
3. Located within 2 km of LIA moraine &glacier

Potentially dangerous Glacial lakes

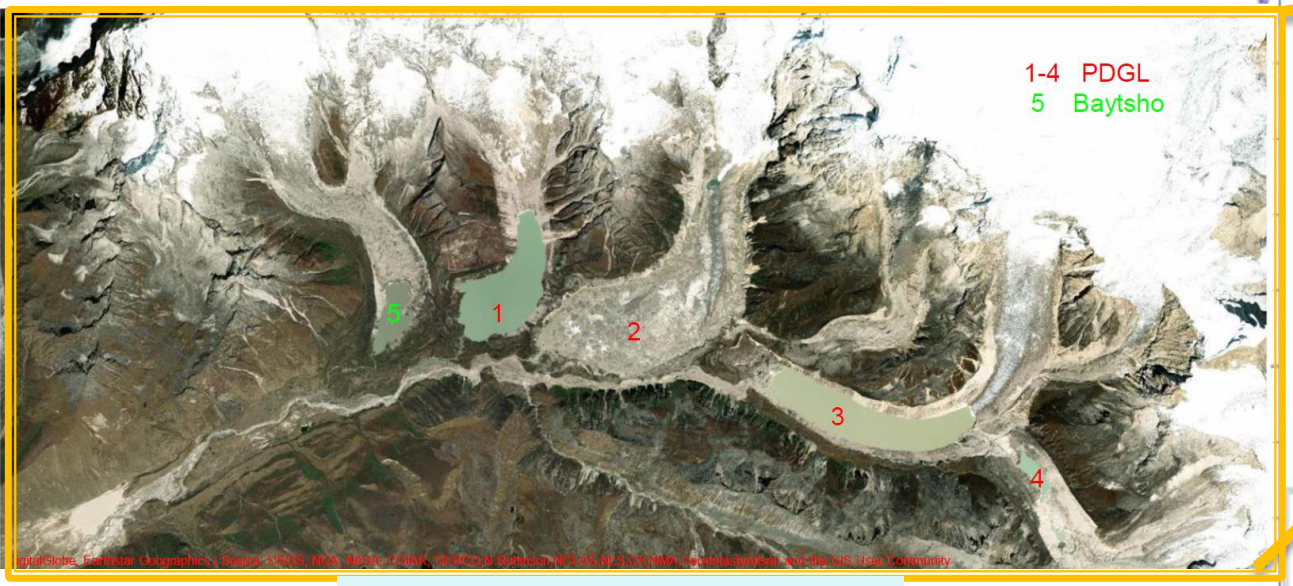


Basin wise distribution of PDGLs

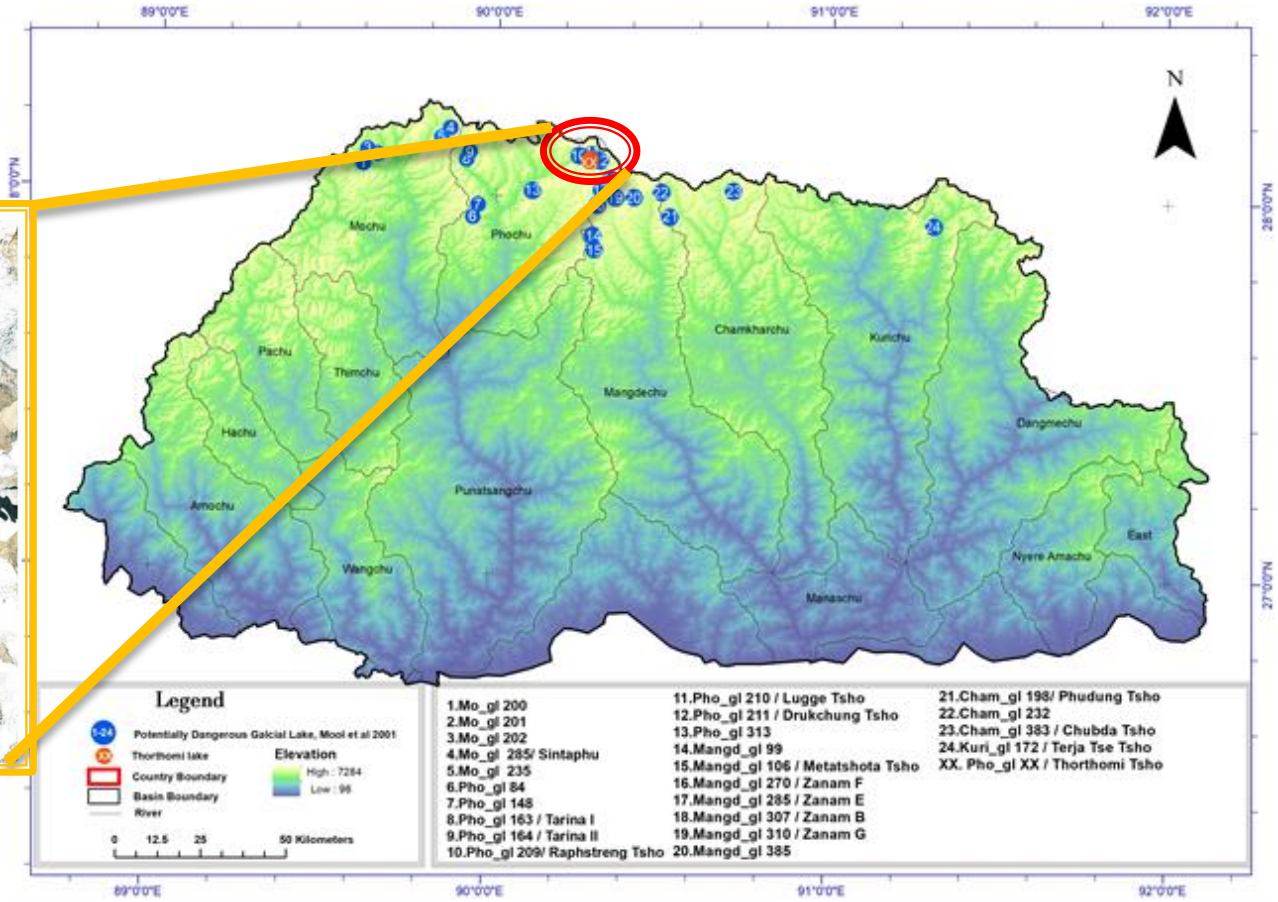
1. Puna Tsang Chhu :
   - Mo Chhu- 2
   - Pho Chhu- 9
2. Mangde Chhu-3
3. Chamkhar Chhu-2
4. Kuri Chhu-1

Glacial Lake Outburst Floods(GLOFs)

- 567 glacial lakes
- 17 Potentially Dangerous glacial lakes



The Lunana Complex



Five GLOF events in the last 30 years:

- 7th October,1994 GLOF from Luggye Tsho
- 29th April,2009 GLOF from Tshojo
- 28th June,2015 GLOF from Lemthang Tsho
- 20th June,2019 GLOF from Thorthomi Tsho
- 30th October,2023 GLOF from Thorthomi Tsho

(Tsho- Lake)

USE OF SENTINEL PRODUCTS AT NCHM:

3. For studying GLOF events:

3.1) June 20,2019 GLOF event from Thorthomi Tsho.

- Right after the GLOF event, a rapid assessment team was formed to visit the site and ascertain the cause of GLOF.
- Sentiniel-1 images were used to analyze displacement on Thorthormi glacier in the month of May and June 2019. The same images were also used to detect the extent and severity of melting corresponding to the same time of the recent Thorthomi incident.

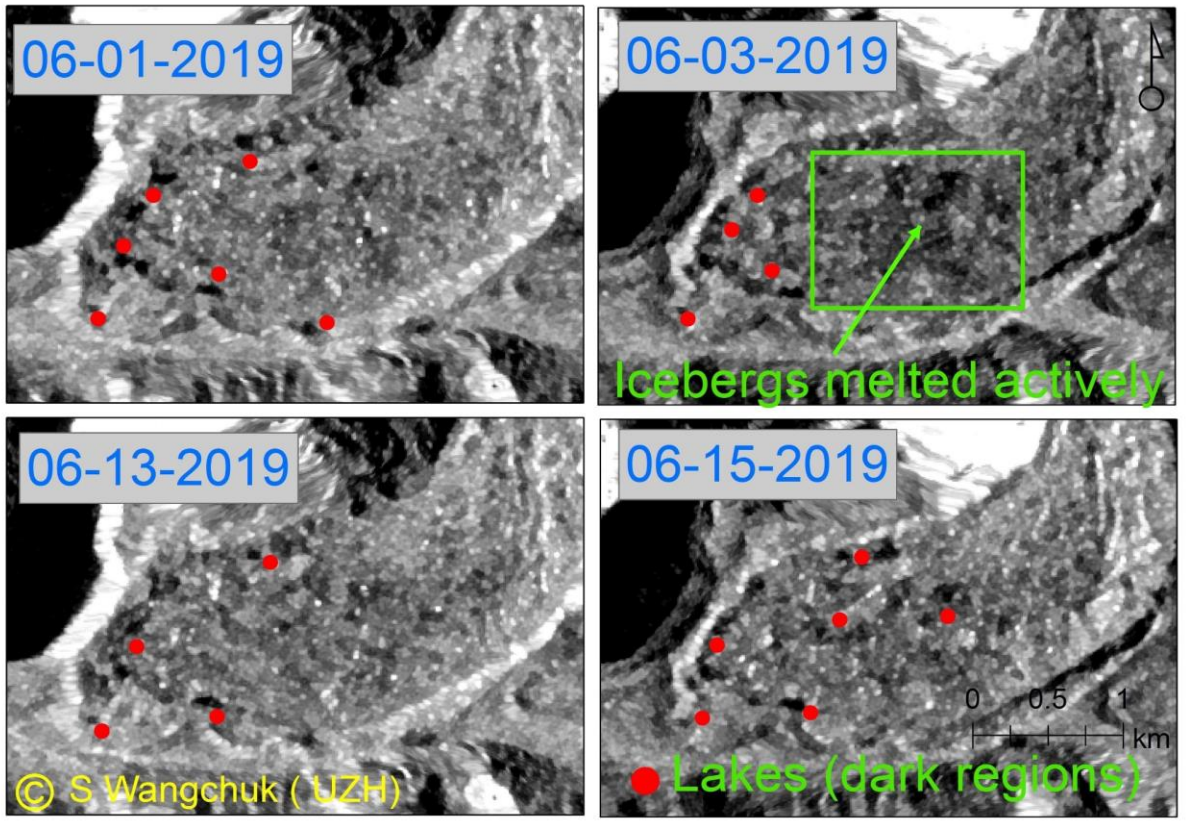
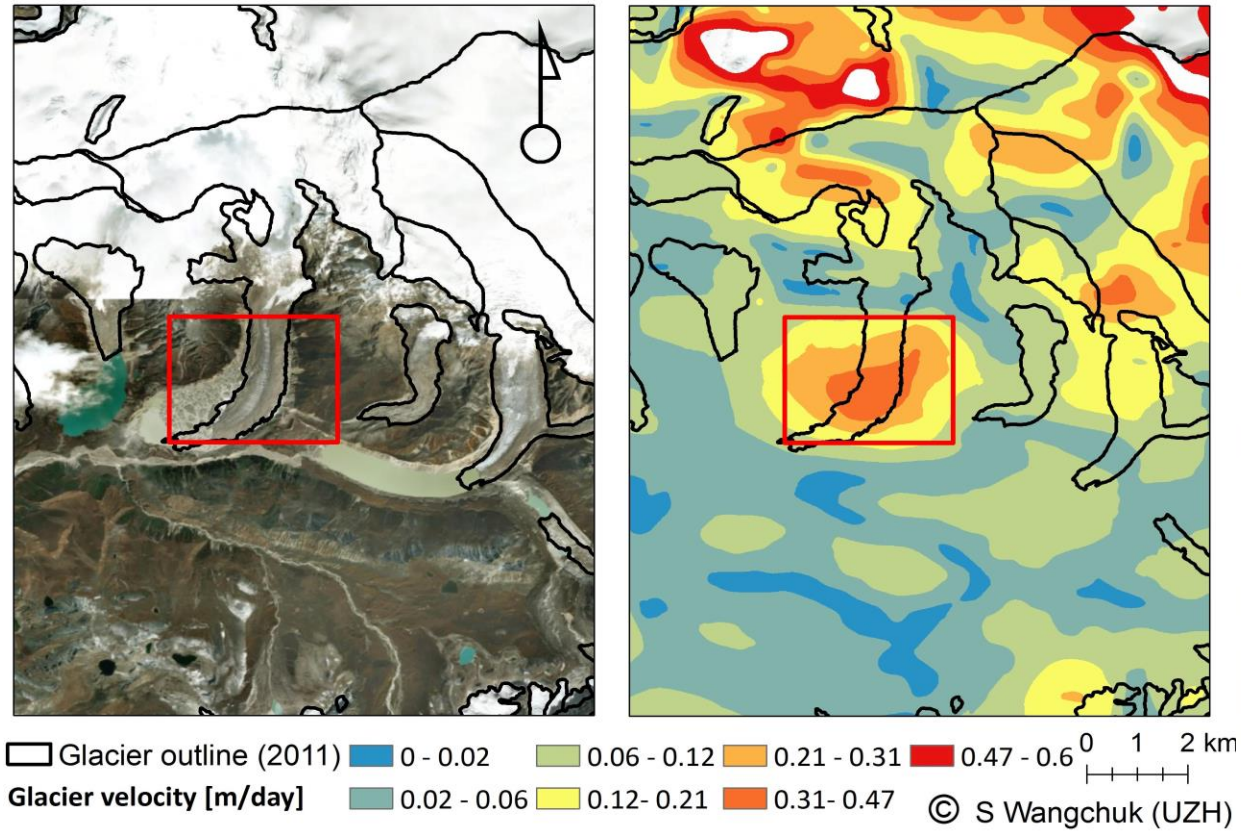


Image showing extensive melting in the month of June 2019

USE OF SENTINEL PRODUCTS AT NCHM:



Radar image showing displacement taken place on Thorthormi glacier on 13th June w.r.t 1st June 2019

(Courtesy: Sonam Wangchuk, University of Zurich, Switzerland)

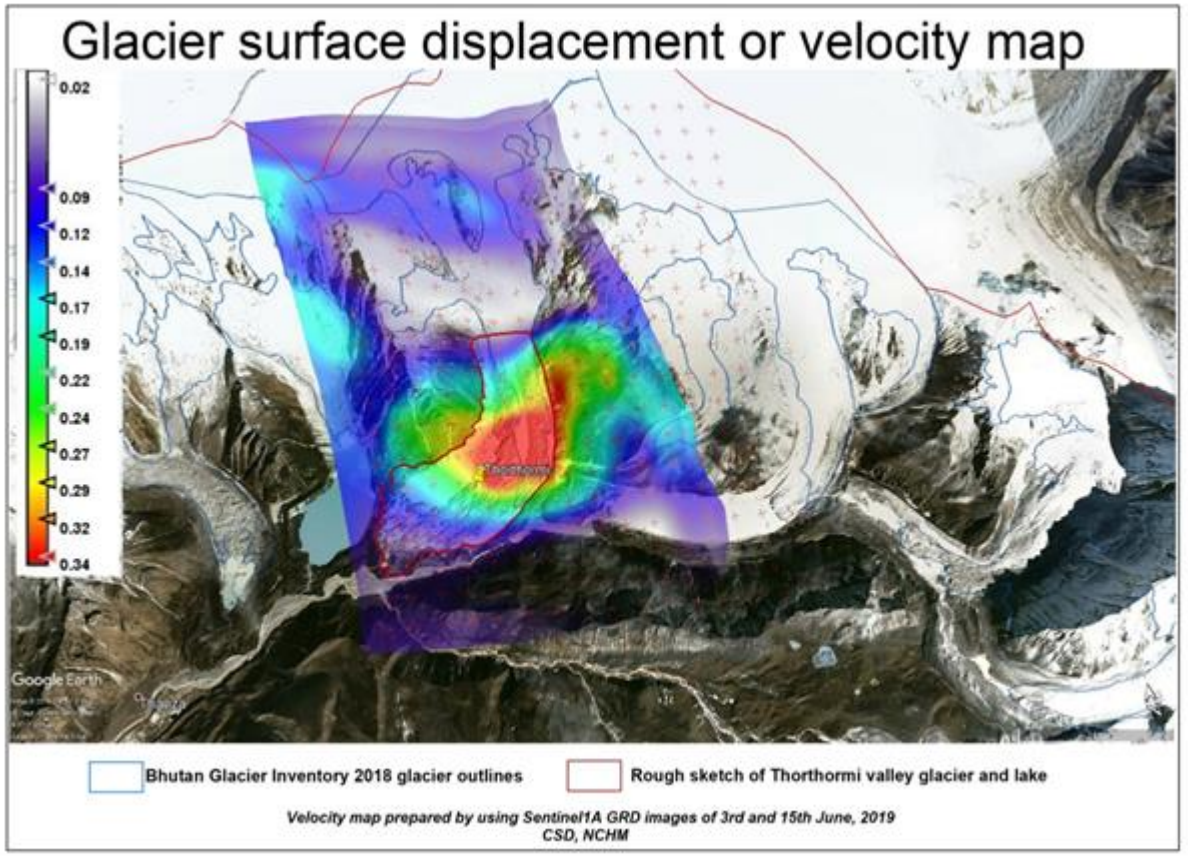
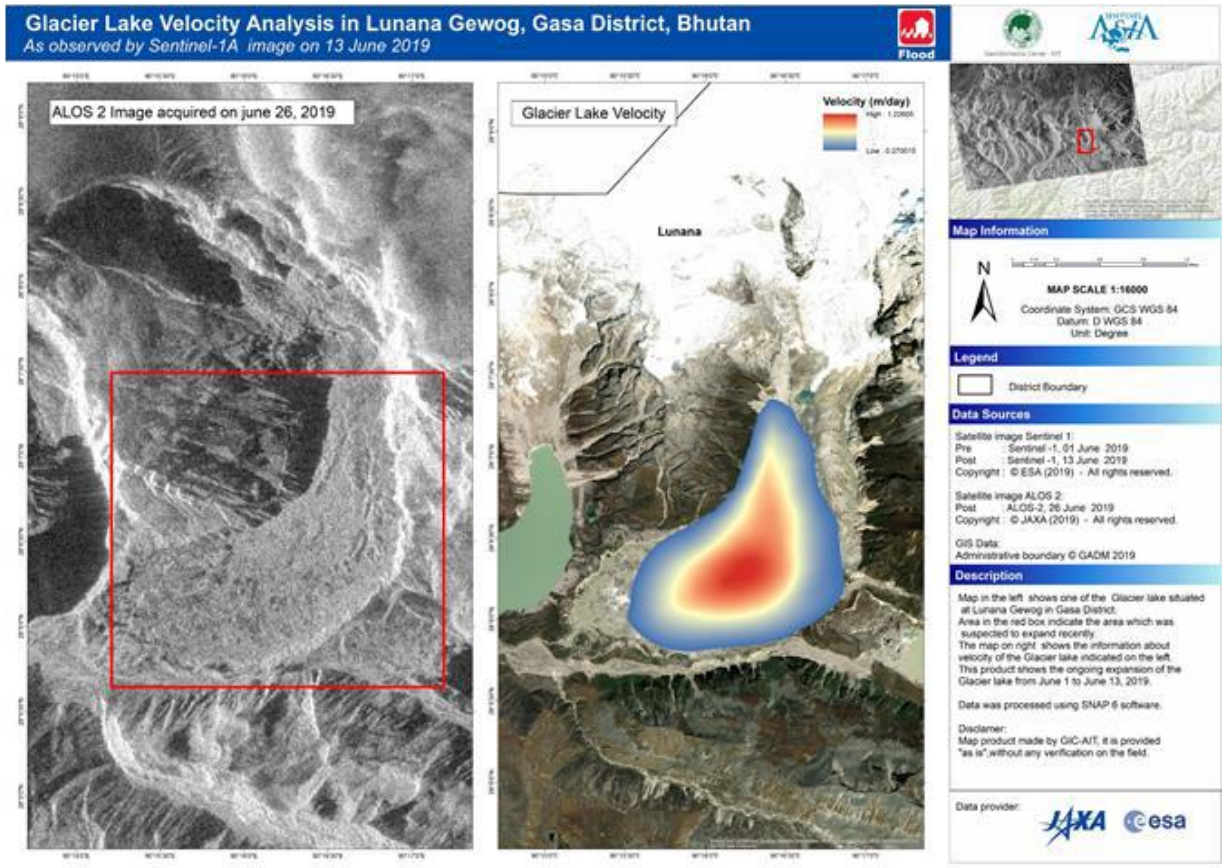


Image showing displacement on Thorthormi glacier between 3rd and 15th June 2019.

USE OF SENTINEL PRODUCTS AT NCHM:

- Emergency Observation Request to the Sentinel Asia was initiated and received the Emergence Observation(pre- post detection map) by ALOS-2 satellite from JAXA and AIT.
- Glacial Lake Velocity Analysis from 1st june till 13rd june shows that there were active movement between as low as 0.2 m to as high as 1.22 m on the Thorthormi glacier.

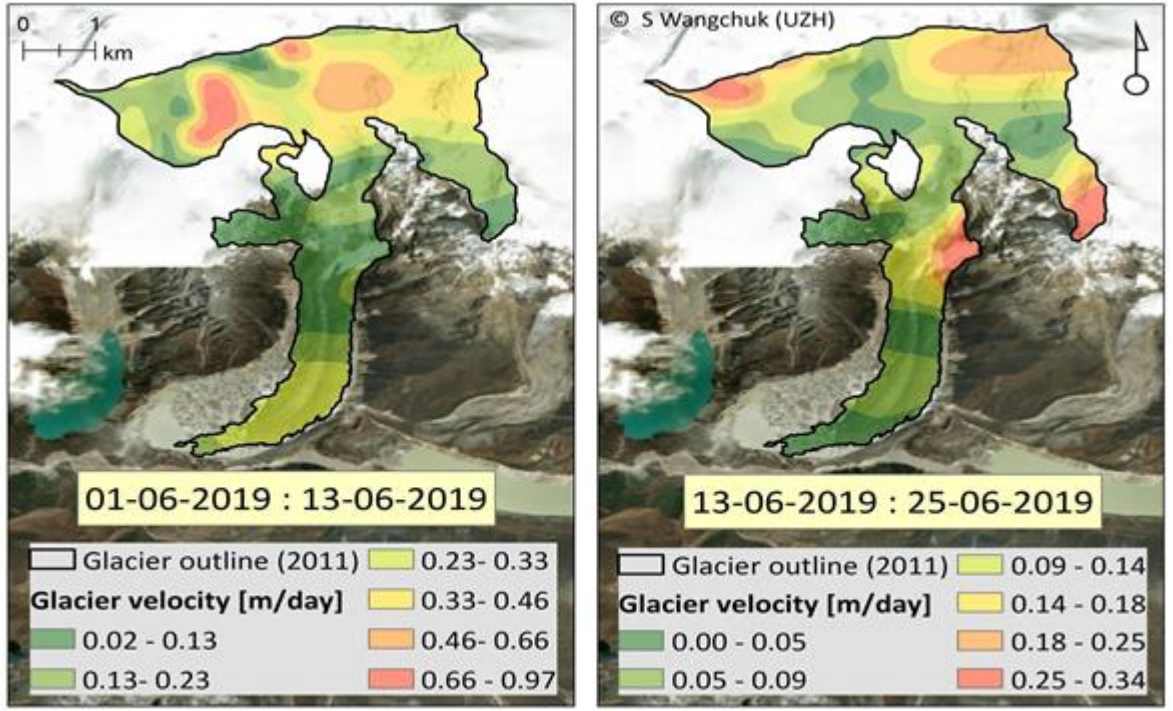
●This concluded that GLOF was not initiated by external triggering agents like landslide or rockfall or avalanche.



Glacier Lake Velocity Analysis by Geo-informatic Center , Asian Institute of Technology

USE OF SENTINEL PRODUCTS AT NCHM:

- displacement activity on Thorthormi glacier subsided after the event on 20th June.
- The velocity measurement in the late 1990s on Thorthormi glacier showed 90 m per year in the upper region and 40 m in the lower region (Joint Japan –Bhutan research report, 2003) which roughly translates into 0.25 m per day and 0.11 m per day which is lower than the movement observed in the month of June 2019.

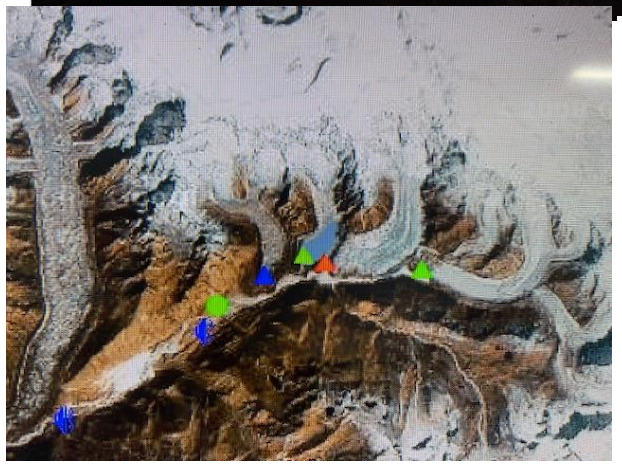


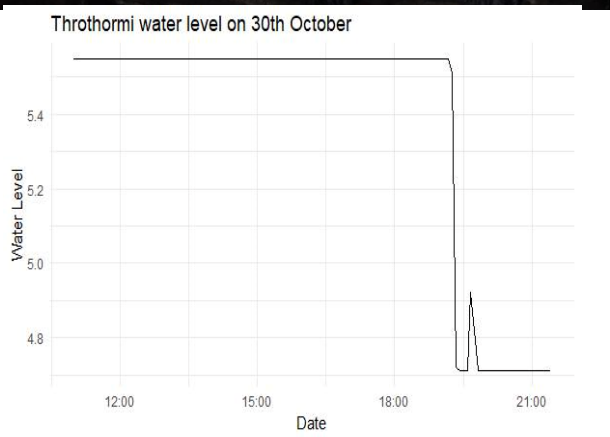
Comparison of displacement on Thorthormi glacier between 1st June, 13th June and 25th June 2019 ***(Courtesy: Sonam Wangchuk, University of Zurich, Switzerland).***

USE OF SENTINEL PRODUCTS AT NCHM:

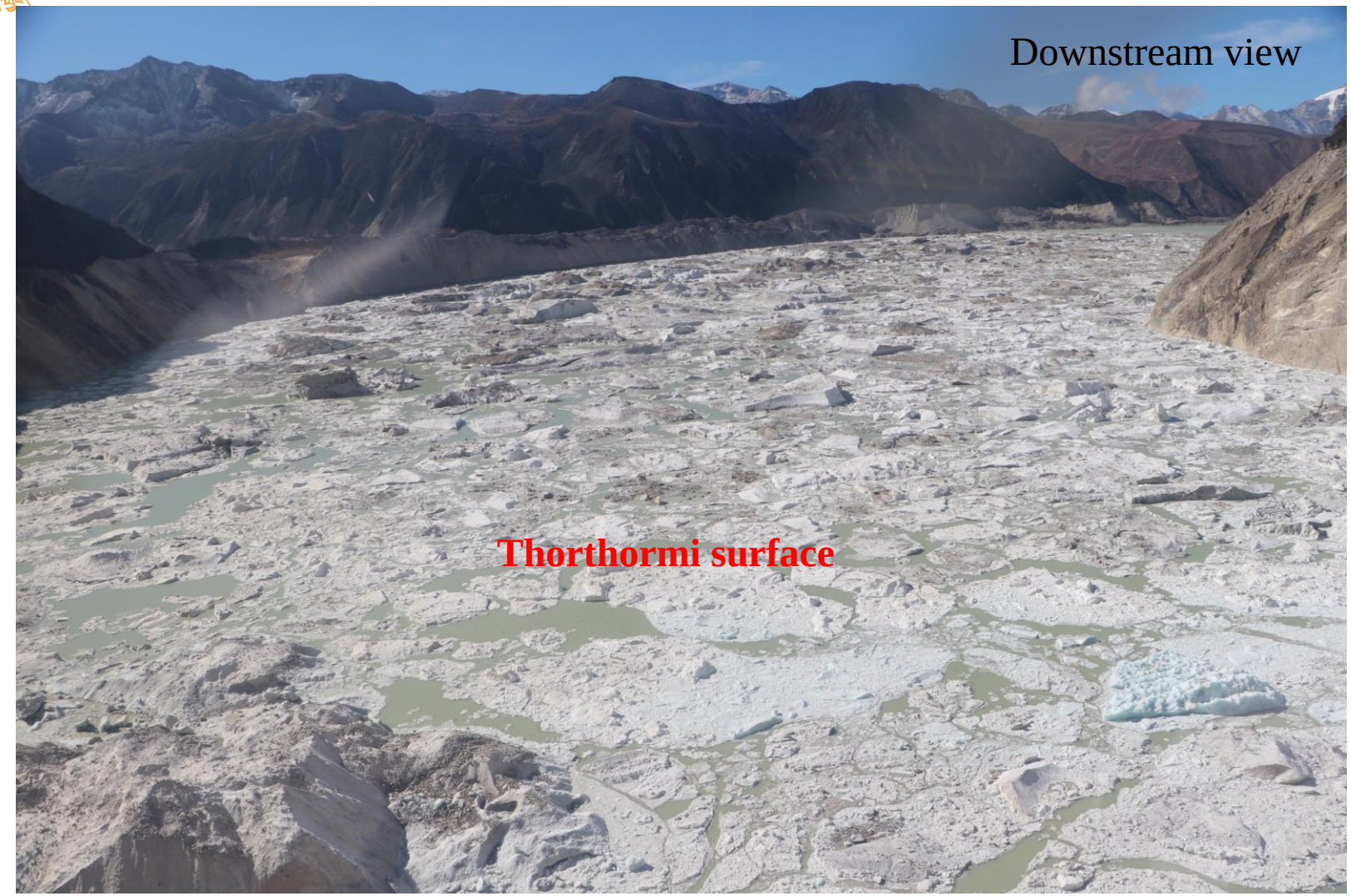
3.2) October 30, 2023 GLOF Event From Thorthomi Tsho

- Increase in water level at Thanza station reported around 19.20 hrs on 30th October 2023.
- A sharp decrease in lake water level on Thorthormi lake detected by Thorthormi GLOF EWS remote monitoring station at the same time.
- NCHM intensified the monitoring through the control rooms at Thimphu and Wangdue and alerted the LGs and related agencies.
- Deputed NCHM team at Lunana for ground verification at Thorthormi lake.
- Abrupt changes on Thorthormi glacier which resulted in high lake discharge reported around 22.17 hrs by NCHM staff at Lunana.
- To assess the situation a decision was made to depute a technical team from NCHM to Lunana on 31st October 2023





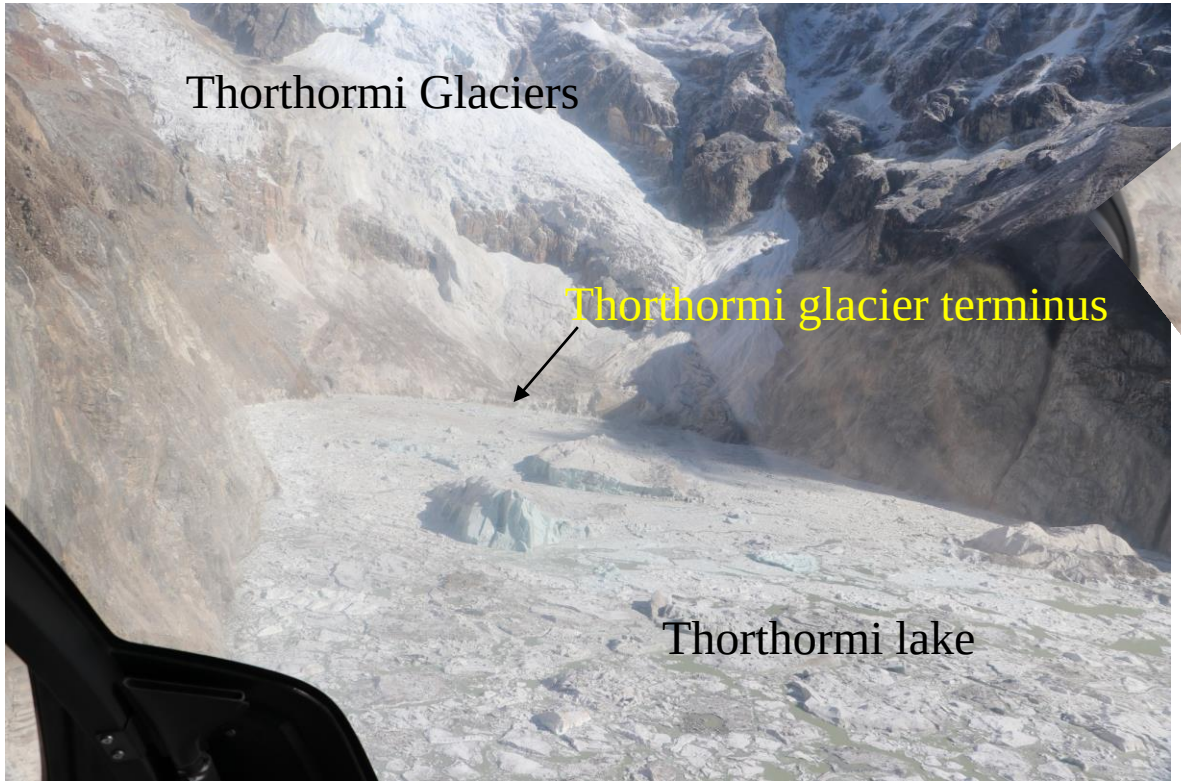
Observation




Outlet area


Google

Upstream


Thorthormi Glaciers
Thorthormi glacier terminus
Thorthormi lake


Thorthormi glacier terminus
Thorthormi lake

Thorthomi- Raptshreng Barrier

USE OF SENTINEL PRODUCTS AT NCHM:

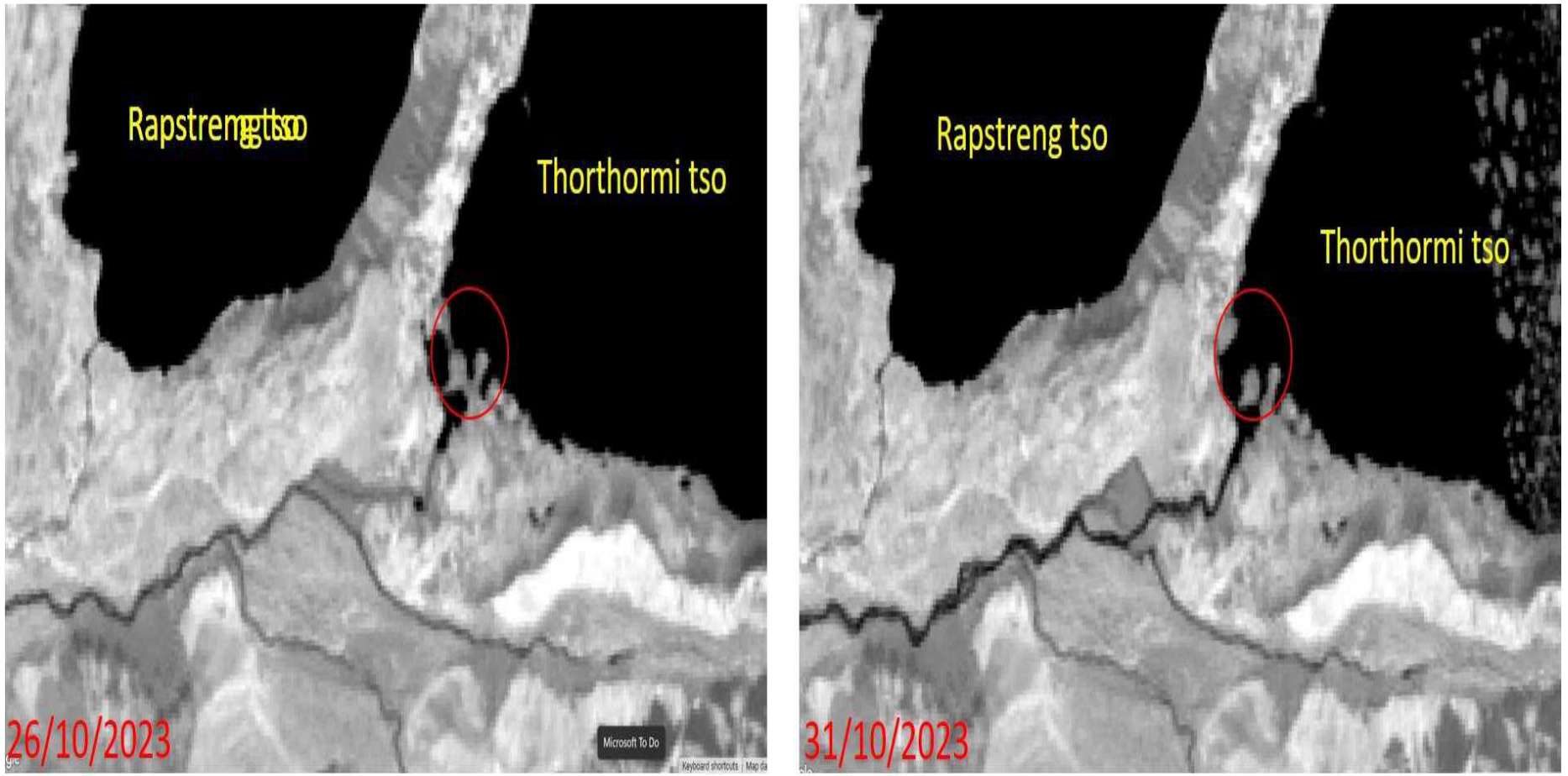
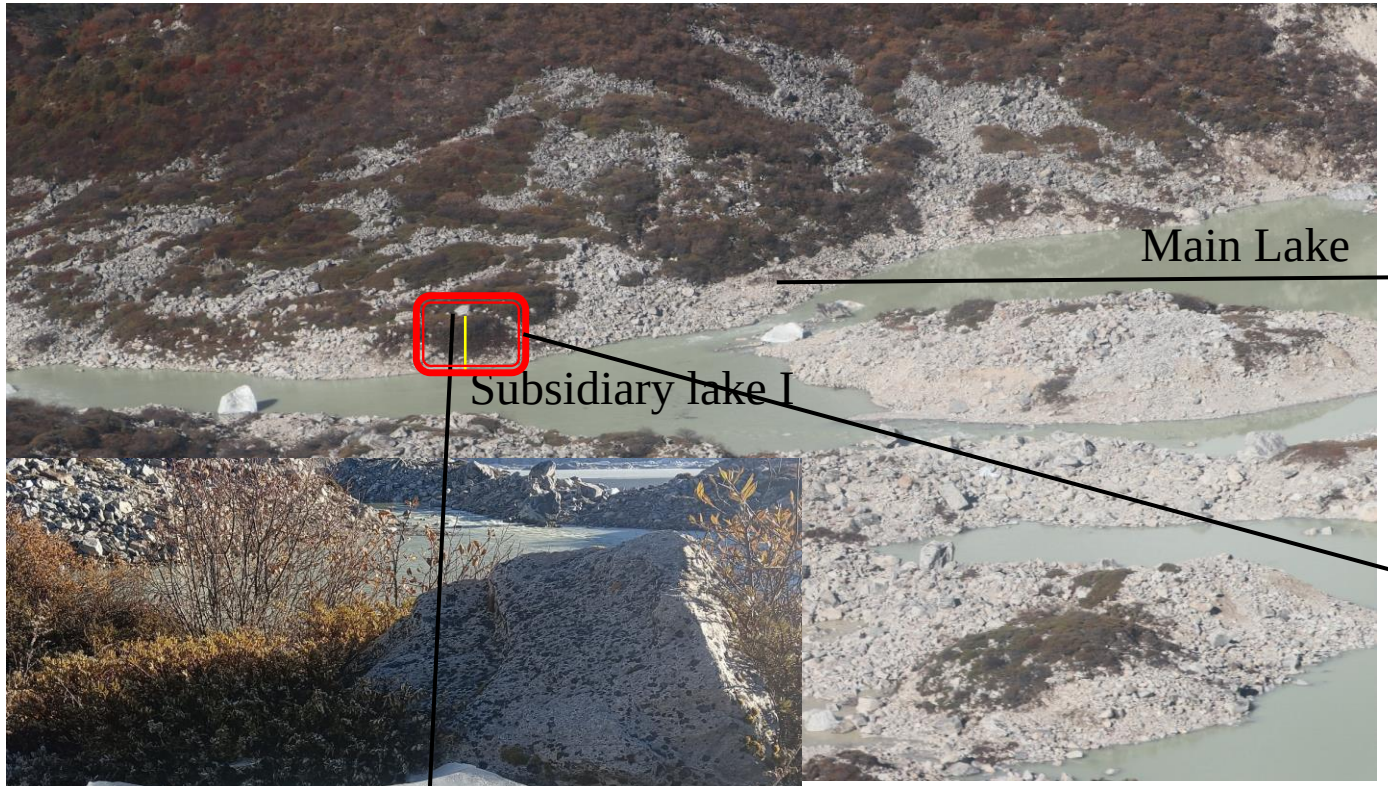
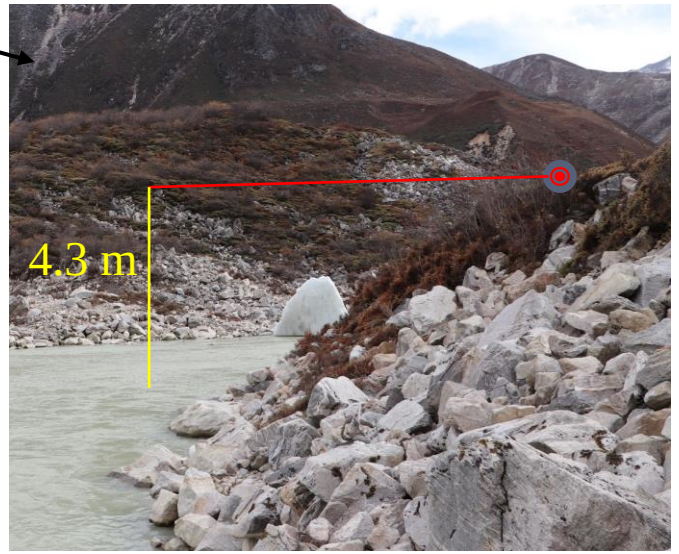


Image showing erosional impact at the outlet of main Thorthormi tso before and after 30th October 2023 GLOF event

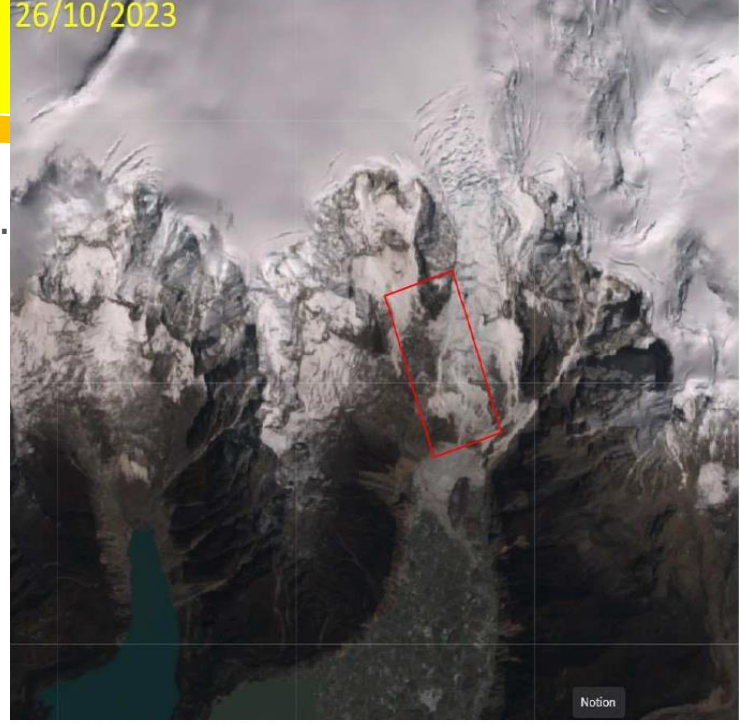
Displaced ice blocks

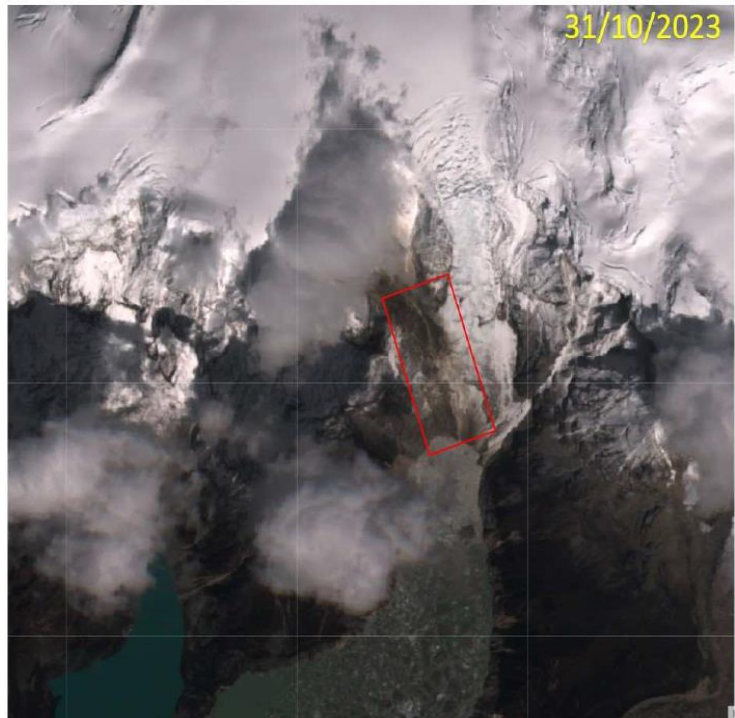




Cause & tigger :

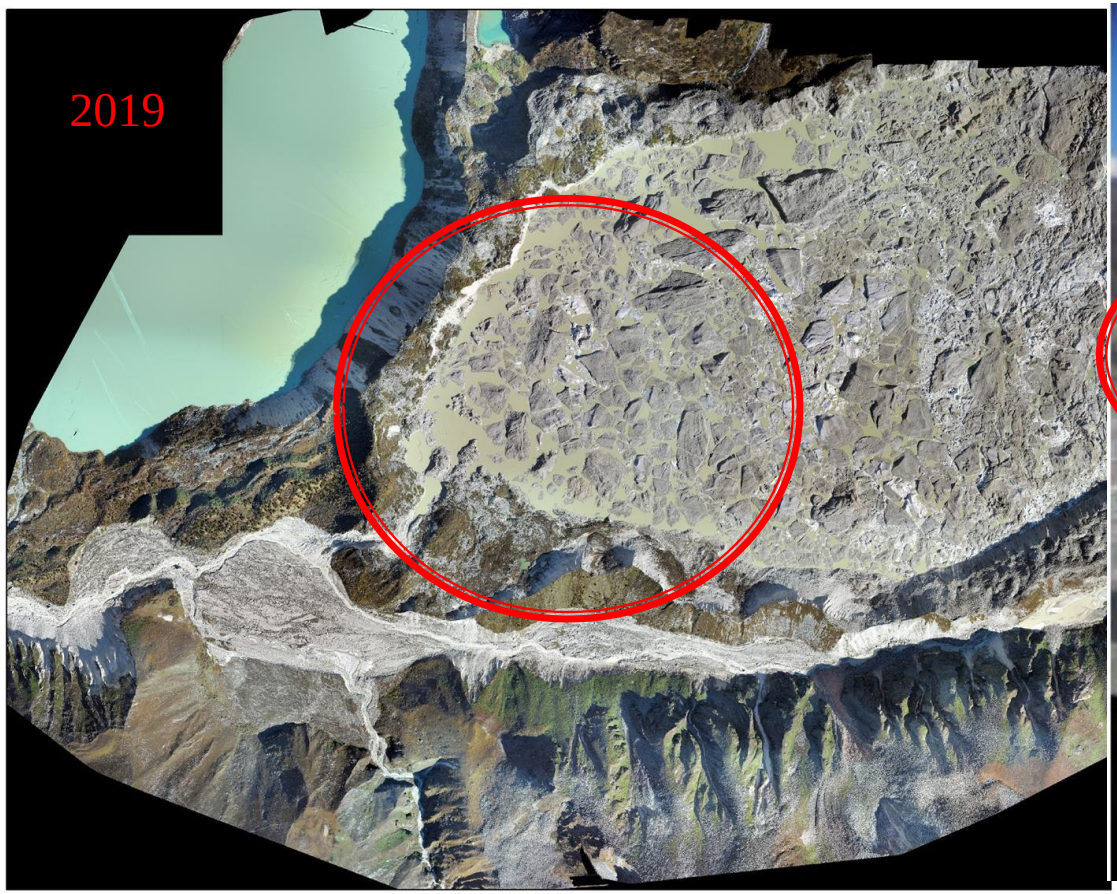
- An extensive satellite images of the area reveals that Thorthormi glacier had been quite active since April 2023 with lot of ice movement taking place on the ablation area of Thorthormi glacier.
- October 2023 Image analysis shows that there was a major mass movement taken place in the accumulation area of the glacier.
- The rapid assessment concluded that the most probable cause of the incident on 30th October 2023 could be an avalanche from the top of the accumulation area which triggered the ice fall from the steep rock cliff on the lower part and falling on the ablation area of Thorthormi glacier.





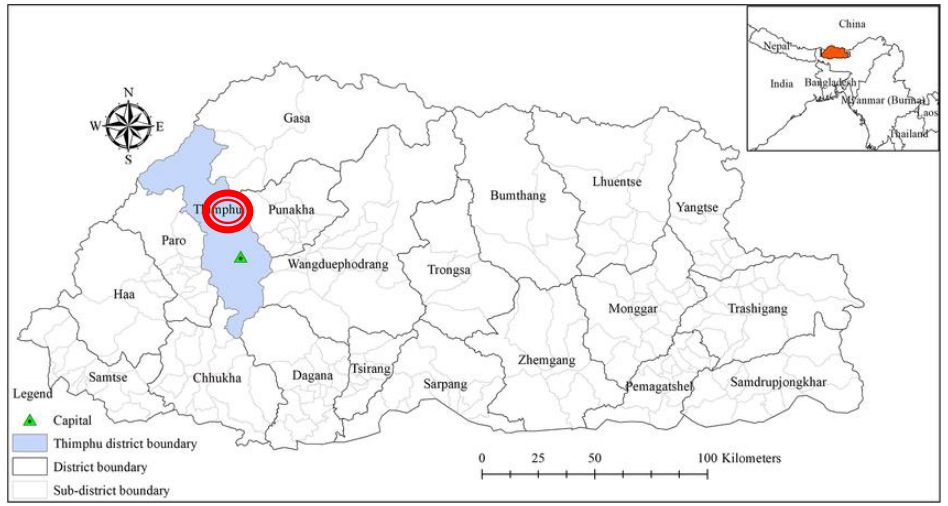
Current situation

Current situation



Other Sentinel Asia Activities:

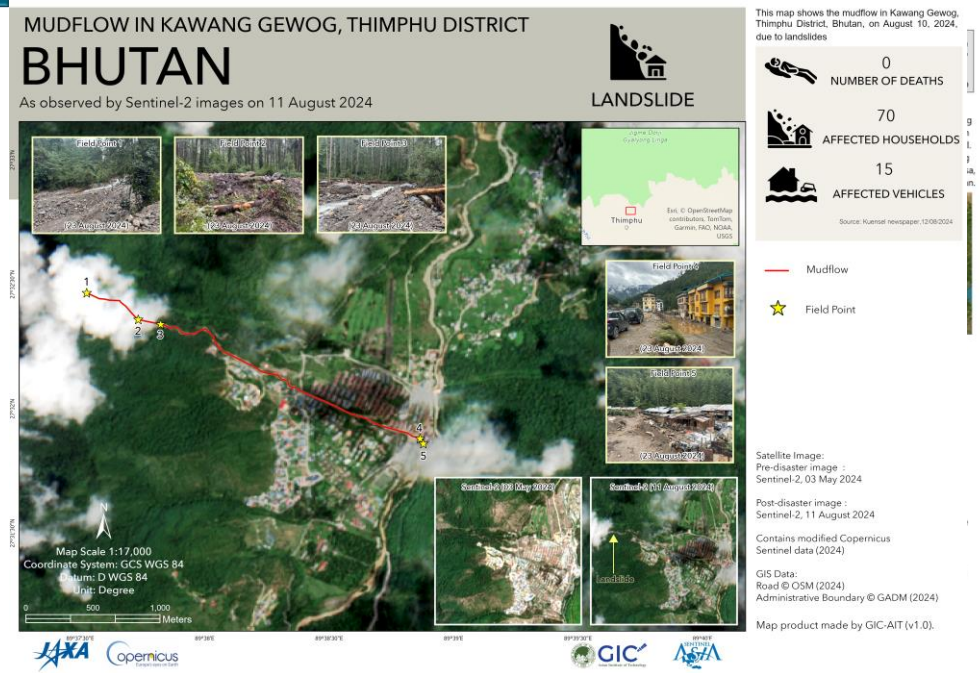
Dechencholing Stream Flashflood, 10th August 2024.

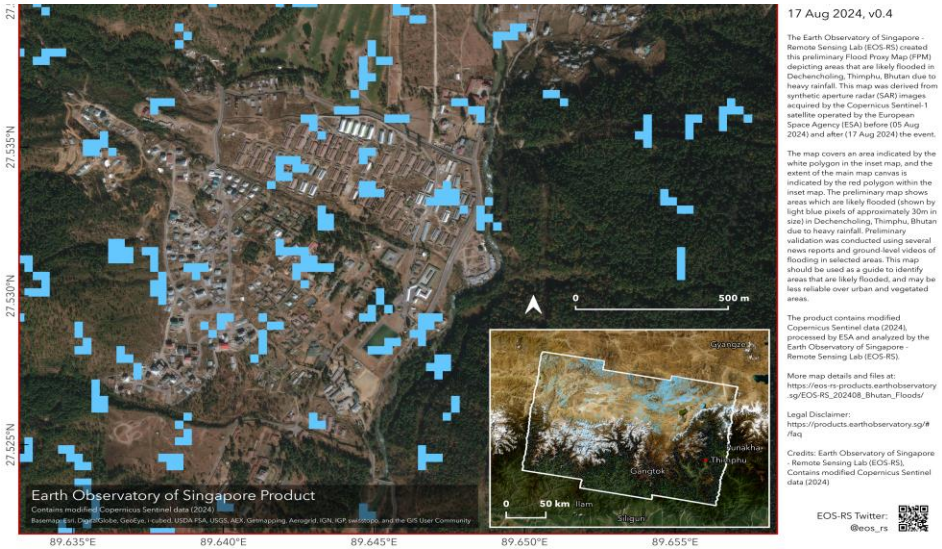


Other Sentinel Asia Activities:

An EOR was sent to Sentinel Asia on 10/08/2024.

- ISRO provided the EOS-4 and Resourcesat-2A AWiFS data of DOP:13-Aug-2024.
- JAXA conducted an emergency observation of ALOS-2 at 06:00 on August 15(UTC) &provided data.
- EOS has uploaded a preliminary Flood Proxy Map (FPM) using Sentinel-1 data (17 August 2024), to be used as a guide to identify areas that are likely flooded.
- GIC-AIT uploaded a value-added product, produced using Sentinel-2 data for pre-data on 2024.05.03 and observed-data on 2024.08.11.
- Mohammed Bin Rashid Space Centre (MBRSC) provided flood &standing water maps.





Other Sentinel Asia Activities:

- Sentinel Asia Training on Glacial Lake Outburst Flood (GLOF) Mapping using Earth Observation Satellite Data was conducted from 19 – 21 Aug 2024,NCHM collaboration with JAXA and AIT.

Other Sentinel Asia Activities:

Objectives

1. To introduce the participants to the Sentinel Asia initiative and its mechanisms for activating

Emergency Observation Requests (EOR), as well as highlight successful case studies.

2. To familiarize the participants with various earth observation satellite data relevant to GLOF mapping and monitoring.

3. To equip the participants with practical skills in utilizing open-source software for satellite

image analysis, particularly for GLOF mapping.

-Atended by 15 participants from various Disaster related orgnizations-DDM,DGM,DOE,DOFPS.

Way Forward

- Continue as a member of Sentinel Asia and look forward to Strengthened data-sharing mechanisms to facilitate timely and accurate disaster monitoring and response.
- Increase technical expertise in interpreting satellite data and modeling disaster scenarios.
- Engage in regular knowledge-sharing sessions to stay updated on technological advancements and best practices in disaster observation.
- Enhance the accuracy and efficiency of early warning systems for better disaster preparedness.
- Pursue joint research initiatives focusing on artificial intelligence, machine learning, and big data analytics for better disaster forecasting and assessment.

THANK YOU

Raphstreng Tsho, one of the biggest glacial lake in Bhutan