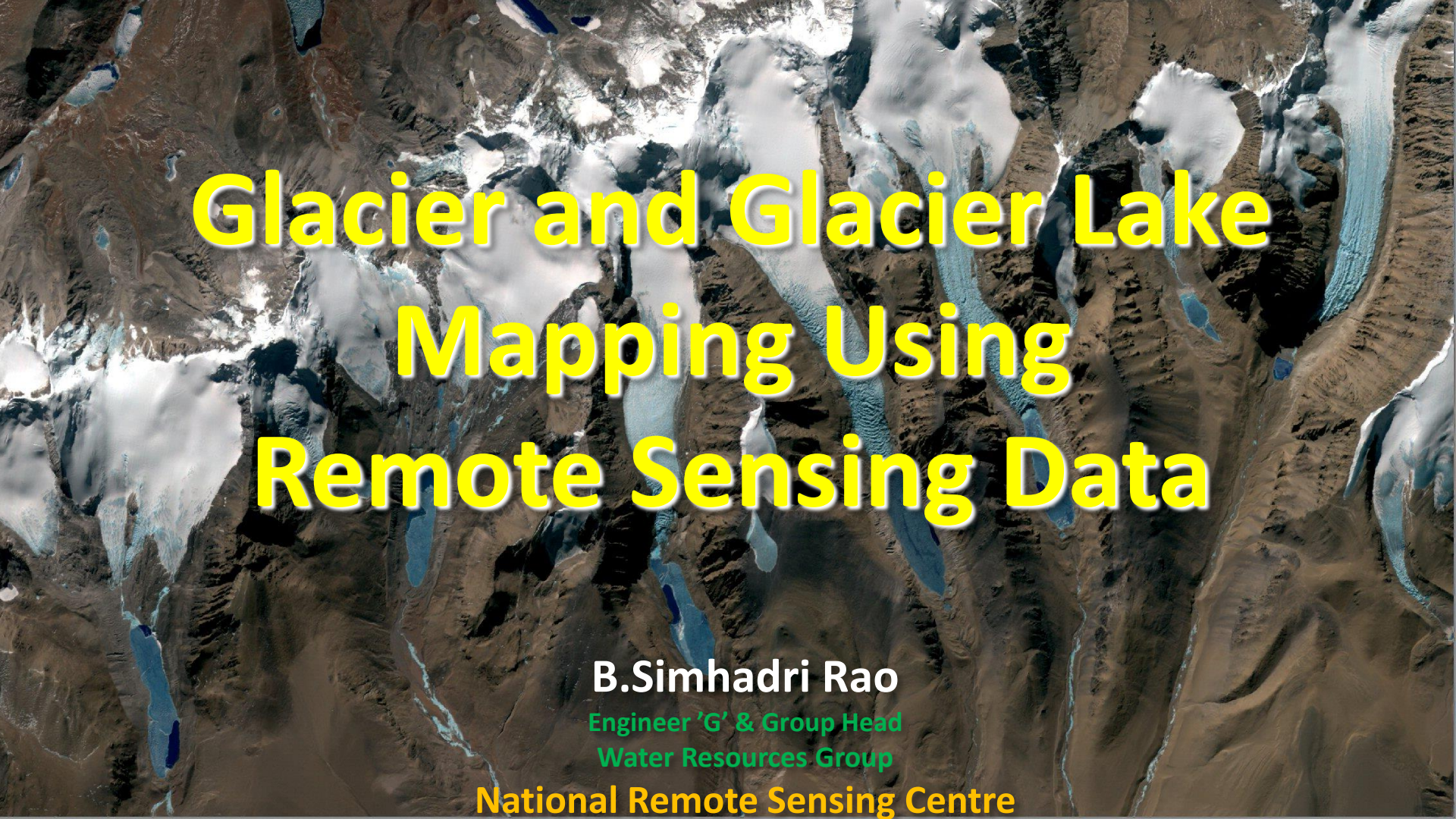


Glacier and Glacier Lake Mapping Using Remote Sensing Data

B.Simhadri Rao

Engineer 'G' & Group Head

Water Resources Group

National Remote Sensing Centre

Glacier and Glacier Lake Mapping Using Remote Sensing Data

Presentation Outline

- *Introduction to Remote Sensing*
- *Identification of Glaciers*
- *Identification of Glacier Lakes (Optical RS)*
- *Identification of Glacier Lakes (Microwave RS)*
- *Monitoring of Glacier Lakes*
- *Updated Database of Himalayan Glacier Lakes*

Brief

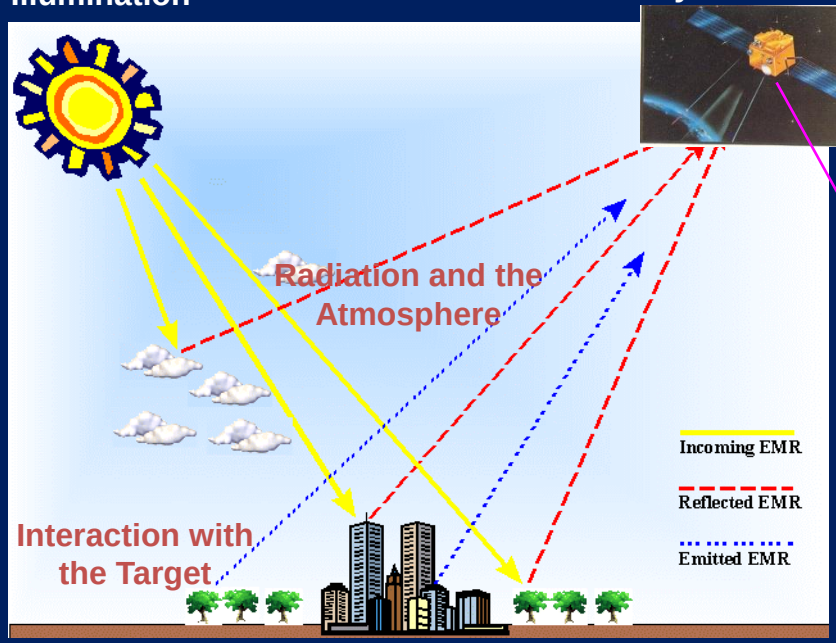
Introduction to Remote Sensing

Glacier and Glacier Lake Mapping Using Remote Sensing Data

Energy Source or Illumination

Remote Sensing

Recording of Energy by the Sensor



Remote Sensing is the technology of obtaining information about an object, area or phenomenon through the analysis of data acquired by a device that is not in physical contact with the object, area or phenomenon under investigation and deriving information about them.

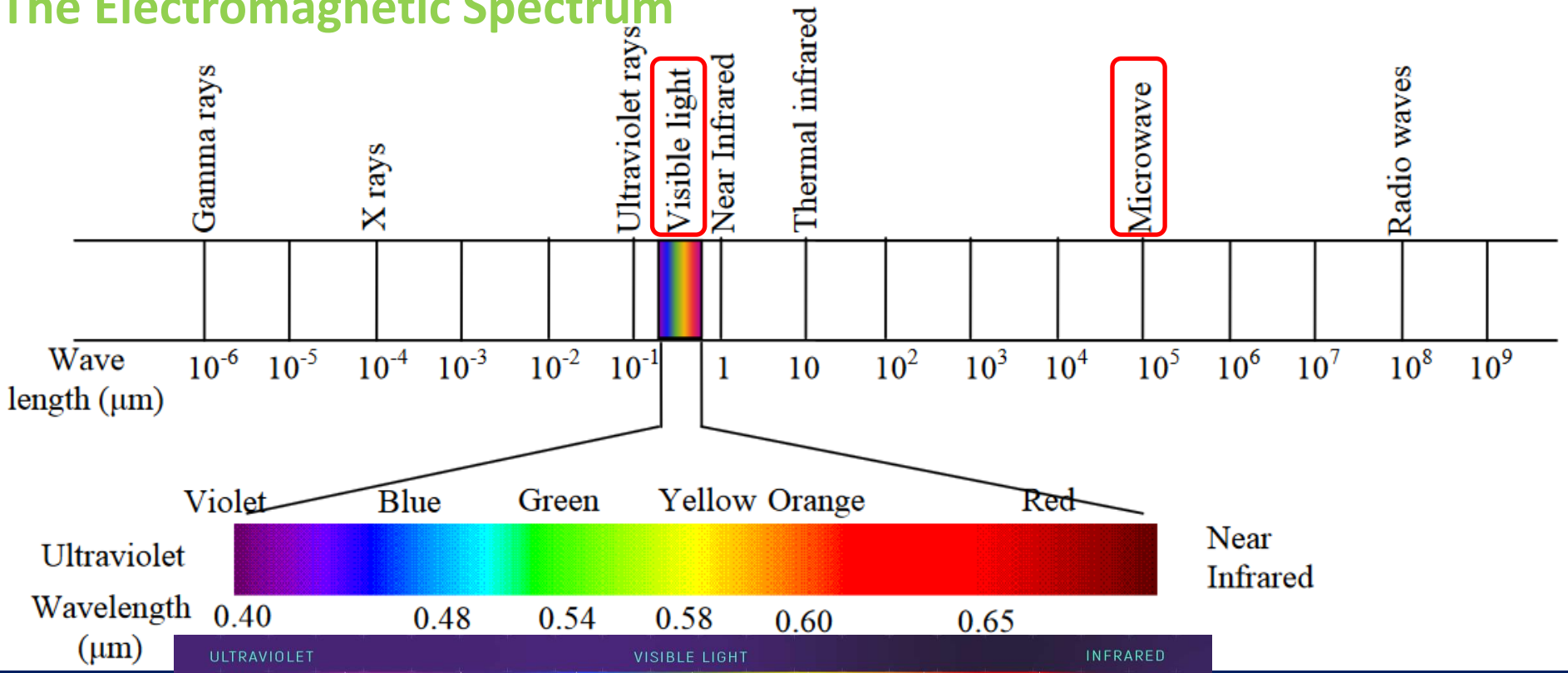
Transmission

Reception & Processing

Interpretation, Analysis & Application

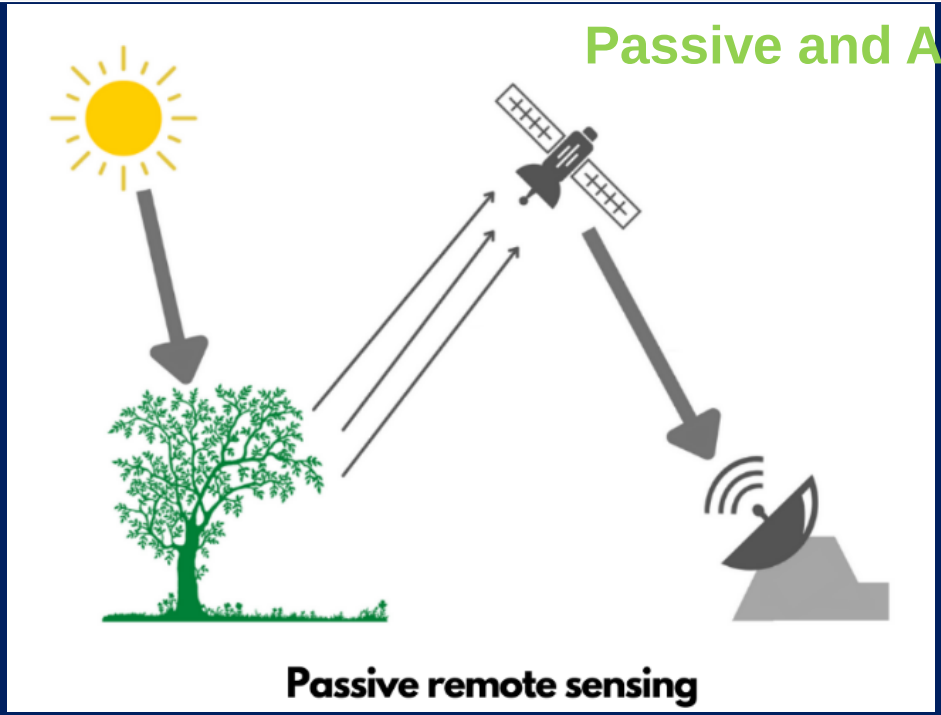
The process of Remote Sensing

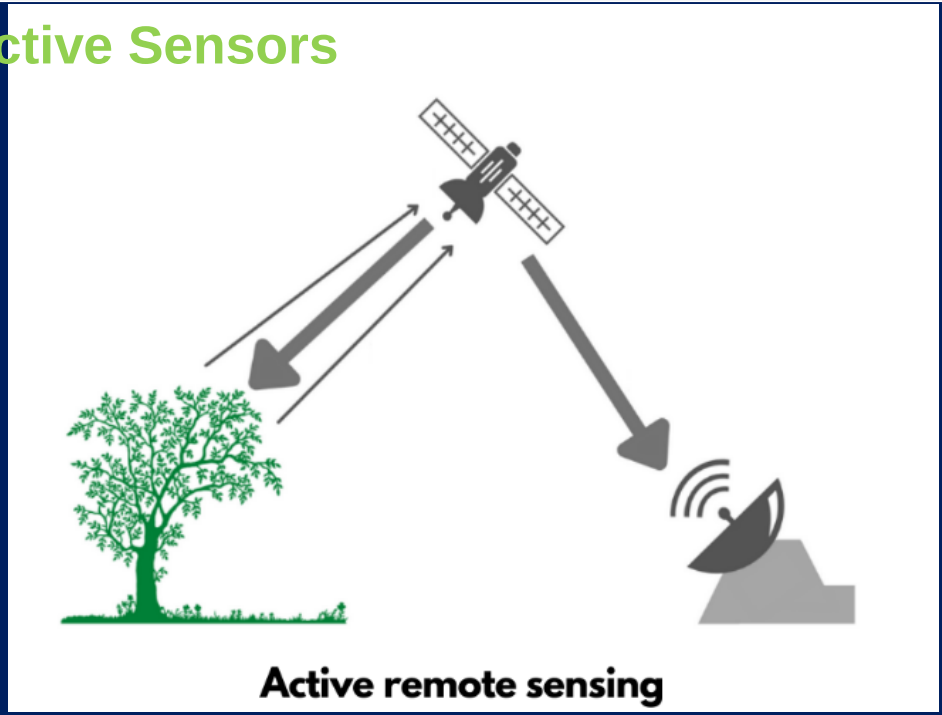
The Electromagnetic Spectrum



Glacier and Glacier Lake Mapping Using Remote Sensing Data

Passive and Active Sensors





- **Passive sensors** detect sunlight radiation reflected from the earth and thermal radiation in the **visible and infrared of the electromagnetic spectrum**.

- **Active sensors** (example: Radar) **emit own source of radiation to monitor the earth surface or atmospheric features**.
  - Weather independent: microwave radiation can penetrate clouds, light rain and snow.
  - Sunlight independent: can be operated day and night

Glacier and Glacier Lake Mapping Using Remote Sensing Data

Optical Imaging

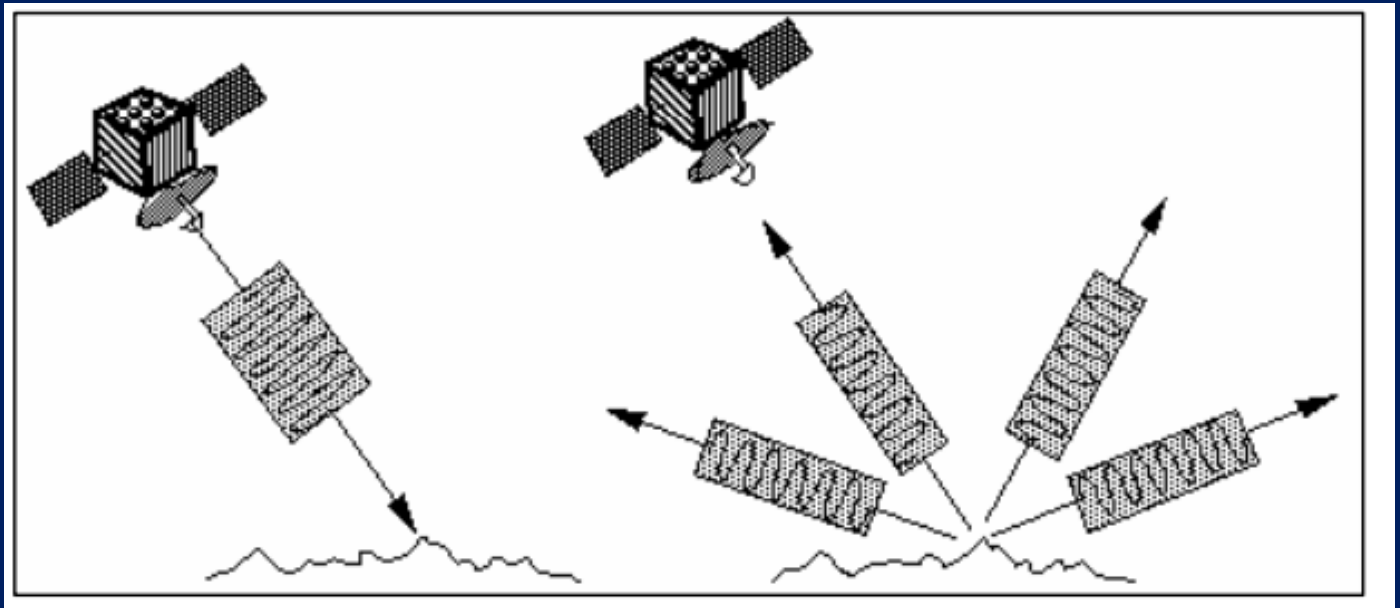
Natural Colour Composite (321)

False Colour Composite (432)

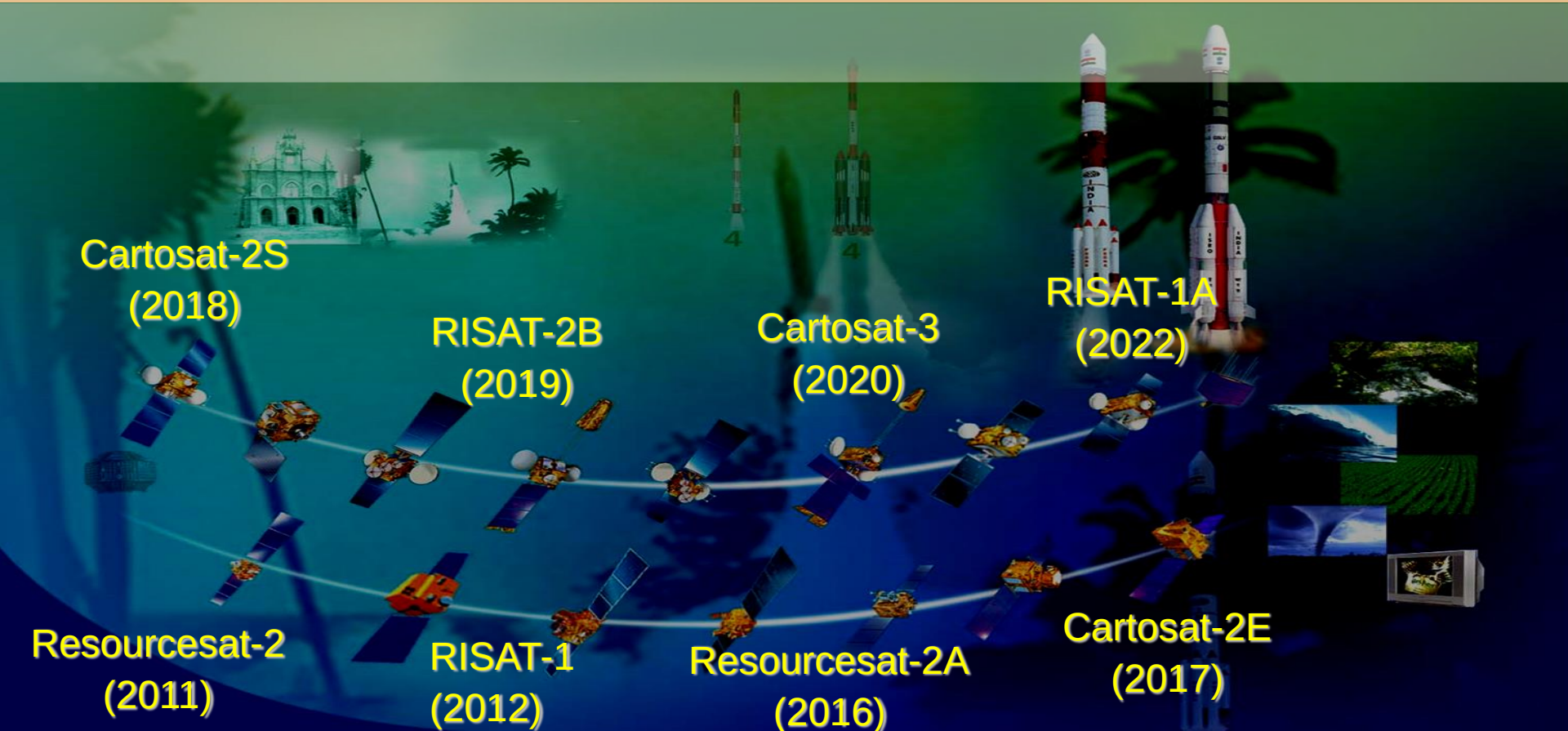
Glacier and Glacier Lake Mapping Using Remote Sensing Data

Microwave (SAR) Imaging

- Imaging Radar is an active illumination sensor system.
- An antenna mounted on top of a satellite transmits an intense pulsed signal towards the earths surface in side looking direction.
- The pulse upon striking the targets, scatters in multiple directions depending on the geometry and surface roughness.
- The direct return signals called the back-scatterers are measured in magnitude and phase to reconstruct the image.

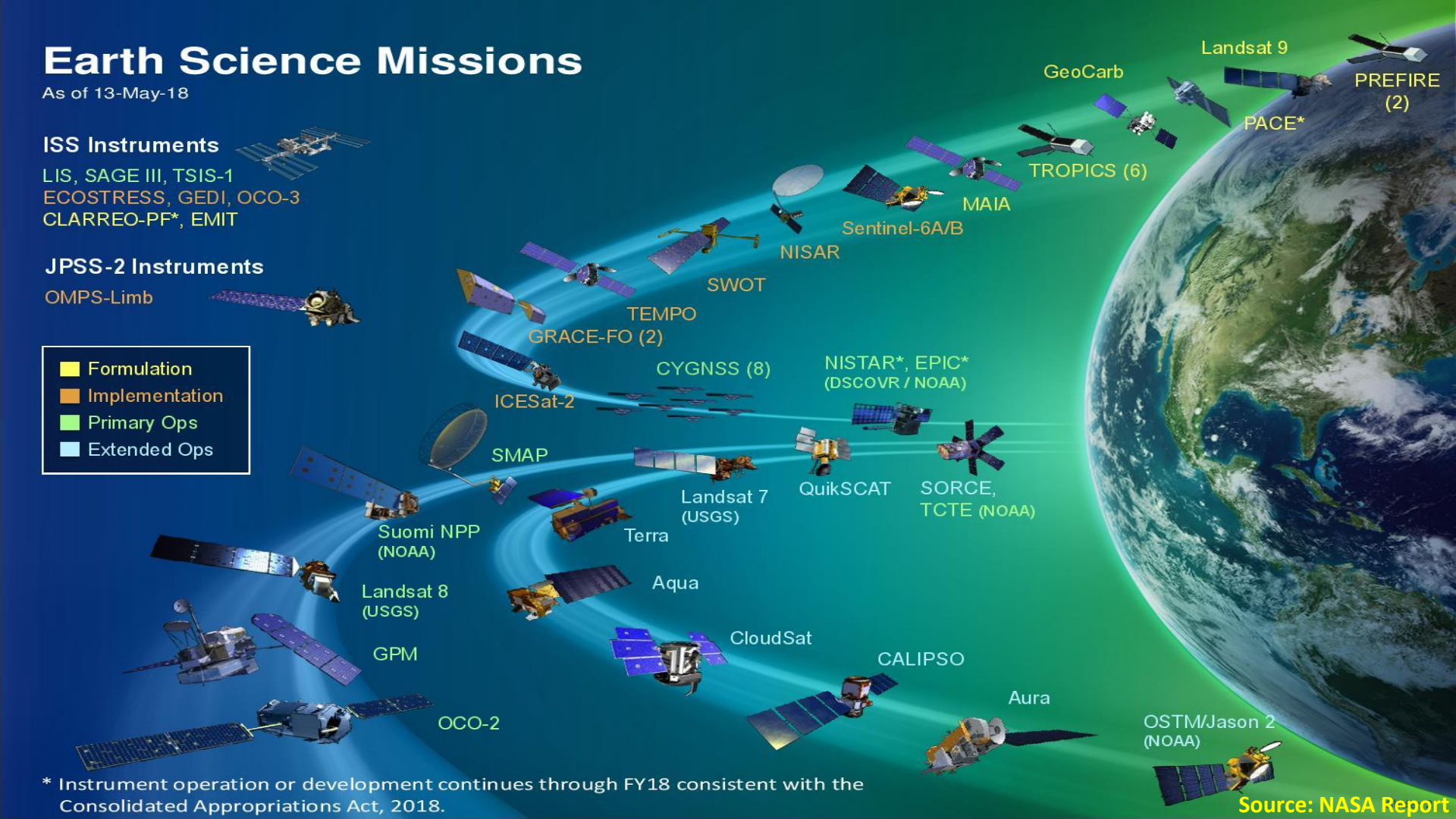


A Constellation of Indian Earth Observation Satellites



Earth Science Missions

As of 13-May-18



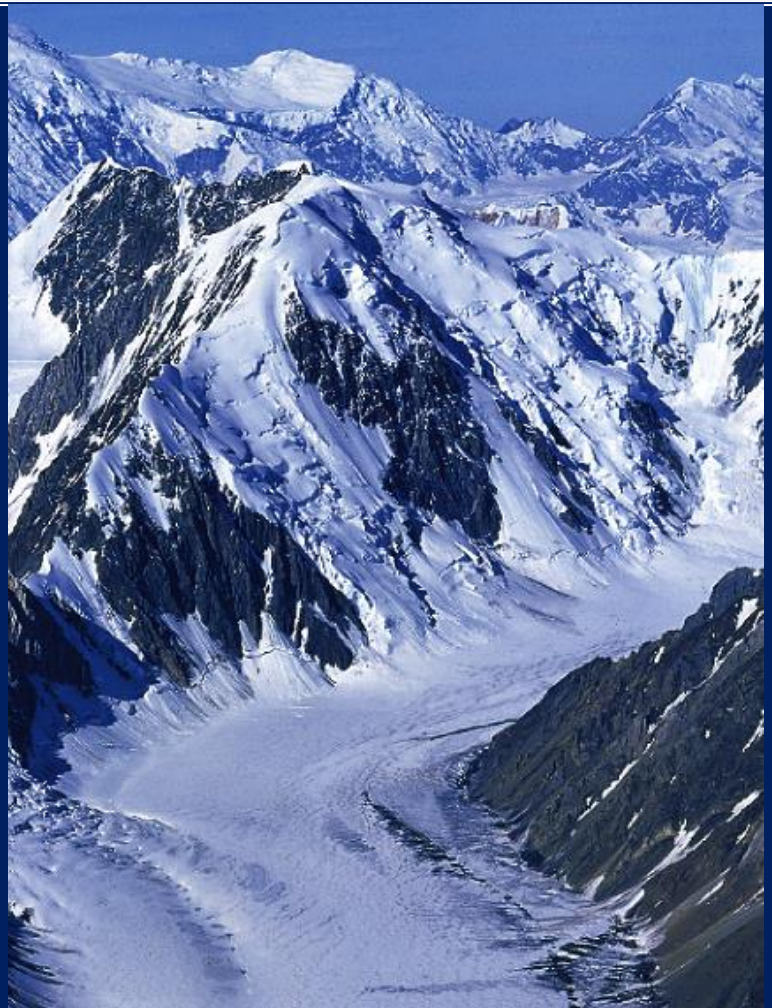
* Instrument operation or development continues through FY18 consistent with the Consolidated Appropriations Act, 2018.

Source: NASA Report

Glacier Identification and Mapping Using Remote Sensing Data

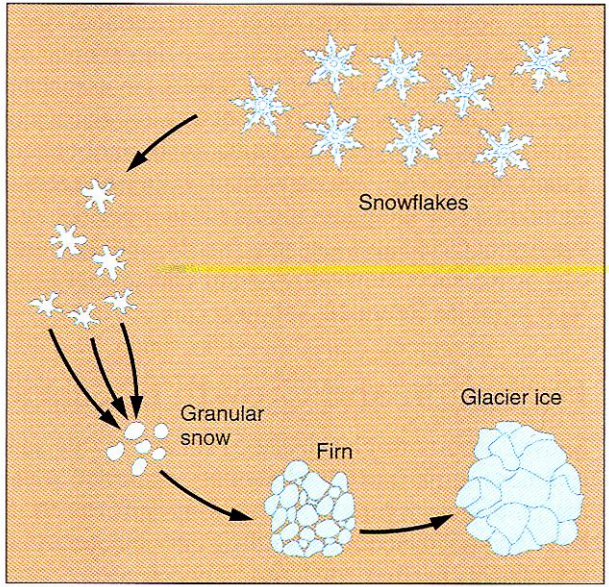
Glacier and Glacier Lake Mapping Using Remote Sensing Data

- A *glacier* is a large mass of ice, formed on land, that moves downhill under its own weight
- Glaciers are part of Earth's *hydrosphere*
- Occupy ~10% of land area
- About 70% of the world's supply of fresh water is held in the form of glacial ice
- According to USGS, a glacier, areal extent must be > 0.1 sq. km (area smaller than 0.1 sq. km won't have sufficient mass to flow under gravity influence)

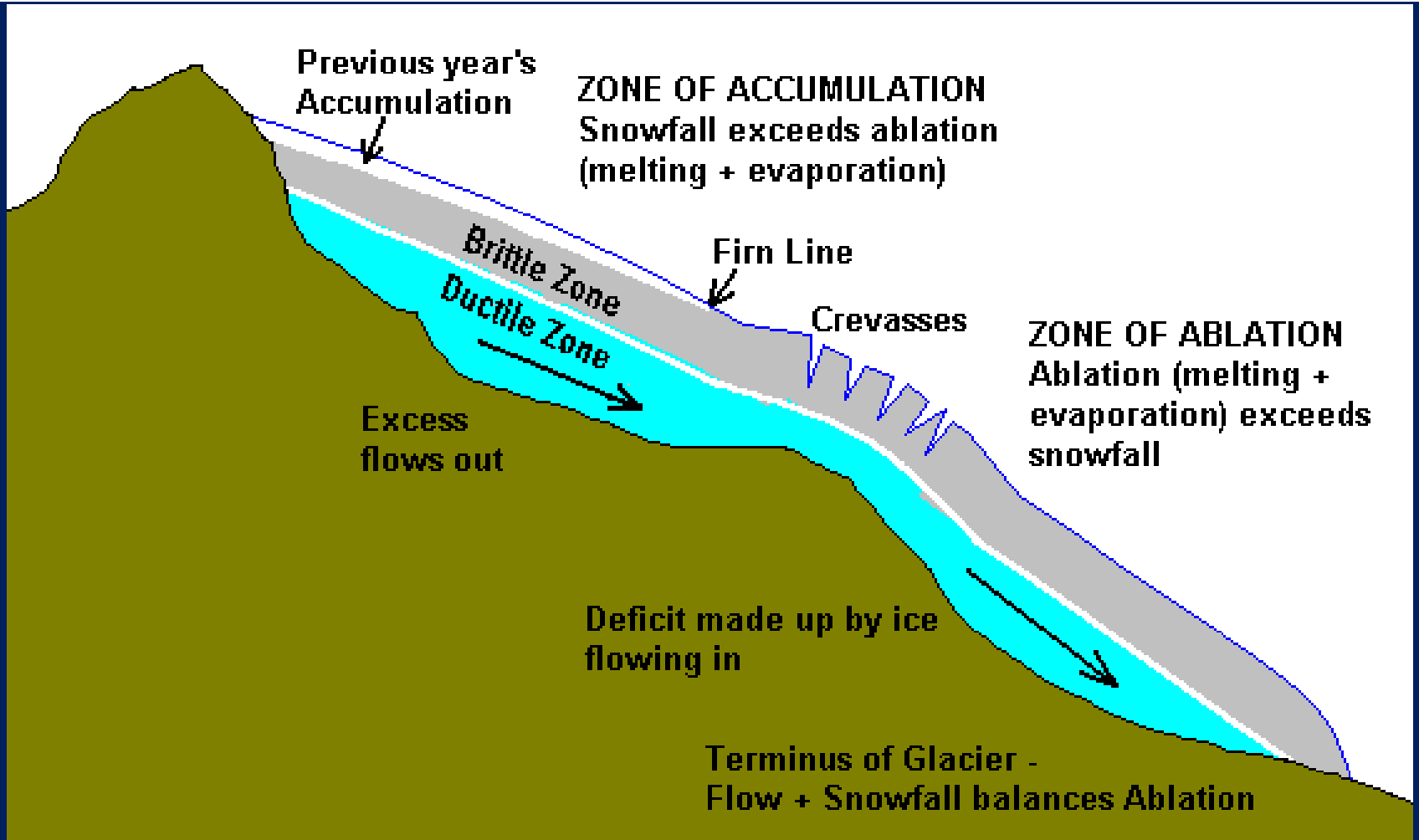


Glacier and Glacier Lake Mapping Using Remote Sensing Data

- Glaciers develop as *snow* is compacted and recrystallized, first into *firn* and then *glacial ice*
- A glacier can only form where *more snow accumulates during the winter than melts away* during the spring and summer
- Two types of glaciated terrains on Earth:
  - *Alpine glaciation* occurs in mountainous regions in the form of *valley glaciers*
  - *Continental glaciation* covers large land masses in Earth's polar regions in the form of *ice sheets*
  - Glaciation occurs in areas cold enough to allow accumulated snow to *persist from year to year*



Glacier and Glacier Lake Mapping Using Remote Sensing Data

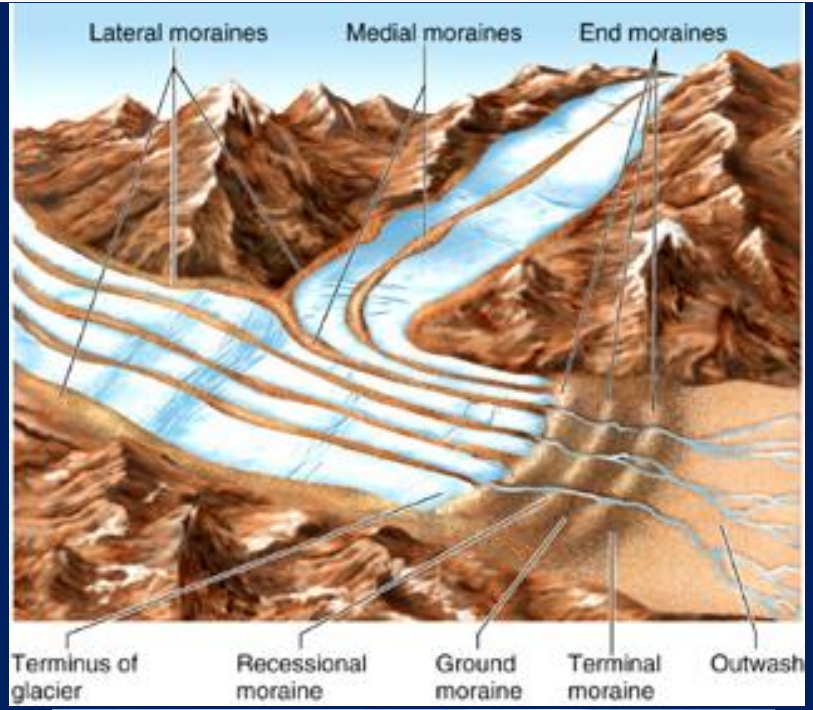


Glacier and Glacier Lake Mapping Using Remote Sensing Data

- Valley glaciers and ice sheets move downslope under the force of *gravity*
- Movement occurs by *basal sliding* and *plastic flow* of the lower part of the glacier, and passive “riding along” of an overlying *rigid zone*
  - *Crevasses* are fractures formed in the upper rigid zone during glacier flow
- Due to friction, glacier flow is fastest at the top center of a glacier and slowest along its margins

Glacier and Glacier Lake Mapping Using Remote Sensing Data

- ***Medial moraines*** are lateral moraines trapped between adjacent ice streams
- ***End moraines*** are ridges of till piled up along the front end of a glacier
- Moraines piled up along side of the glaciers are ***lateral moraines***
- Successive end moraines left behind by a retreating glacier are called ***recessional moraines***



Glacier and Glacier Lake Mapping Using Remote Sensing Data

Mountain glacier

Cirque glacier

Piedmont glacier

Rock glacier

Valley glacier

Outlet glacier

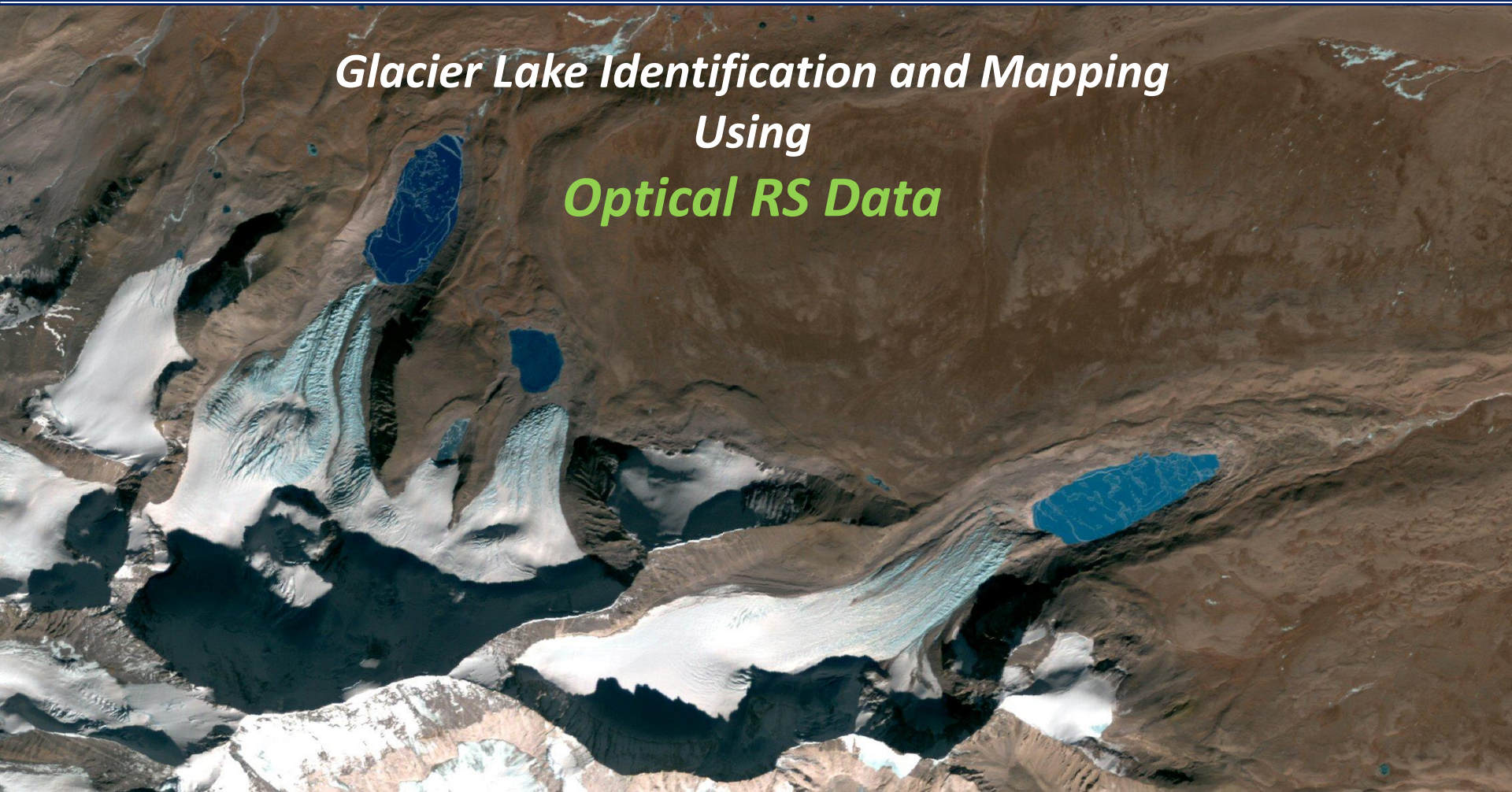
Glacier and Glacier Lake Mapping Using Remote Sensing Data

Optical Satellite Image of a Glacier

Source – Sentinel 2

Glacier and Glacier Lake Mapping Using Remote Sensing Data

Source – Sentinel 1 VH dated 23.08.2024


Glacier Lake Identification and Mapping
Using
Optical RS Data

Glacier and Glacier Lake Mapping Using Remote Sensing Data

Glacier Lake

A glacier lake is defined as a water mass existing in a sufficient amount and extending with a free surface beside and/or in front of a glacier and originated by glacier activities and/or retreating processes of a glacier.

Glacier and Glacier Lake Mapping Using Remote Sensing Data

- Glacial lakes associated glaciers are common in high mountain areas like Himalayas
- As the glaciers recede, new glacial lakes are forming and existing glacial lakes are expanding
- At times glacial melt water stored in these glacial lakes suddenly gets released causing the flash floods called Glacial Lake Outburst Floods (GLOF)
- These flash floods create havoc to the downstream areas of the river reach affecting people and infrastructure like roads, hydropower plants, agriculture, etc.
- Many GLOF events happened in the Himalayas and increasing in trend

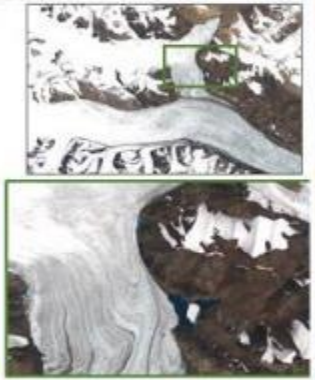



Glacier and Glacier Lake Mapping Using Remote Sensing Data

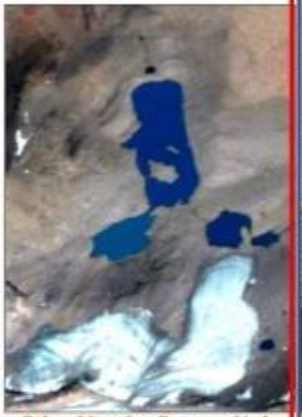
(M) Moraine Dammed Lakes

End-Moraine Dammed Lake
M(e)

Lateral Moraine Dammed Lake
M(l)



Lateral Moraine Dammed Lake (with Ice)
M(lg)



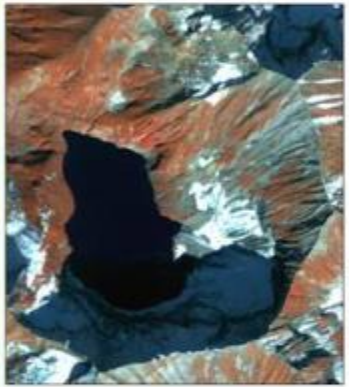
Other Moraine Dammed Lake
M(o)

(I) Ice Dammed Lakes

Supra-glacial Lake
I(s)

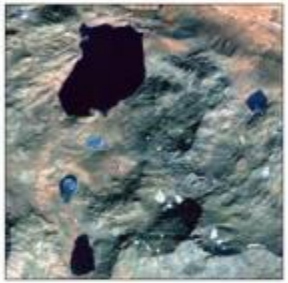
Glacier Ice-dammed Lake
I(d)

(E) Glacier Erosion Lakes



Cirque Erosion Lake
E(c)

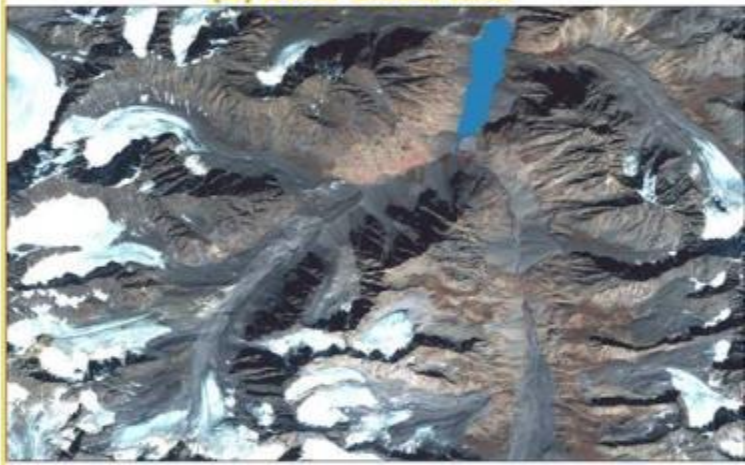
Glacier Trough Valley Erosion Lake
E(v)



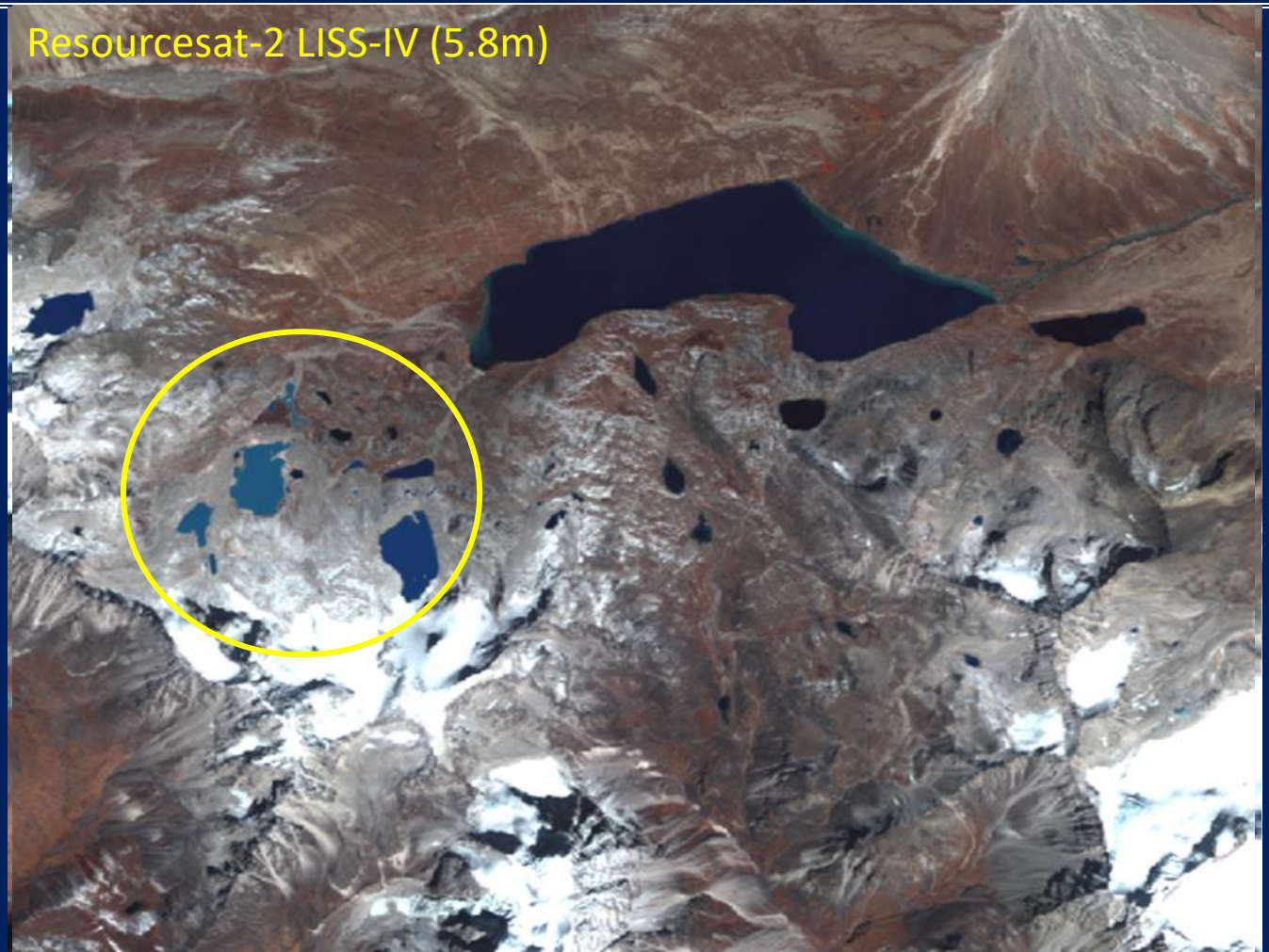
Other Glacial Erosion Lake
E(o)

Type of Glacial Lakes

(O) Other Glacial Lake

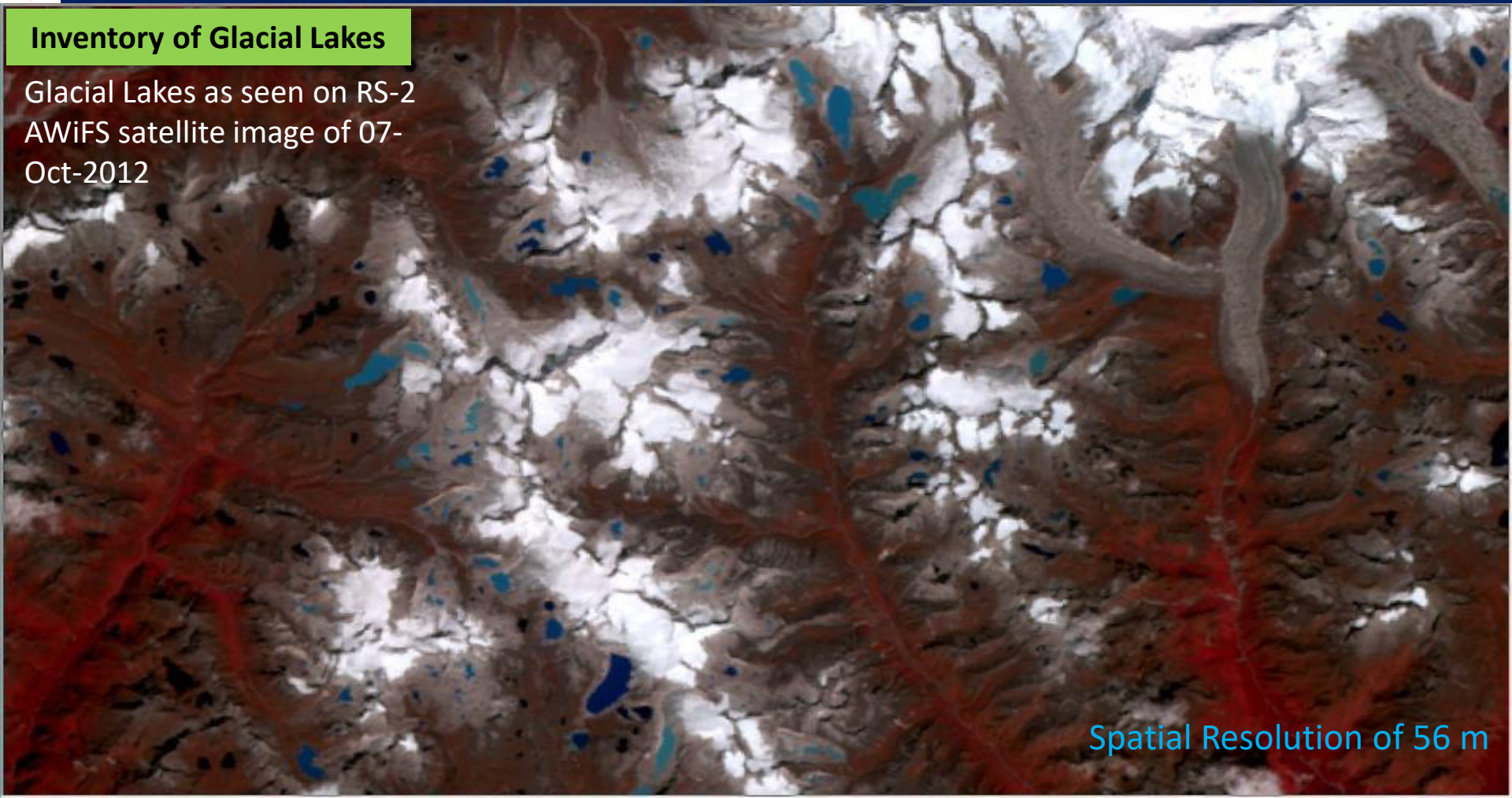


Glacier and Glacier Lake Mapping Using Remote Sensing Data



Glacier and Glacier Lake Mapping Using Remote Sensing Data

Inventory of Glacial Lakes

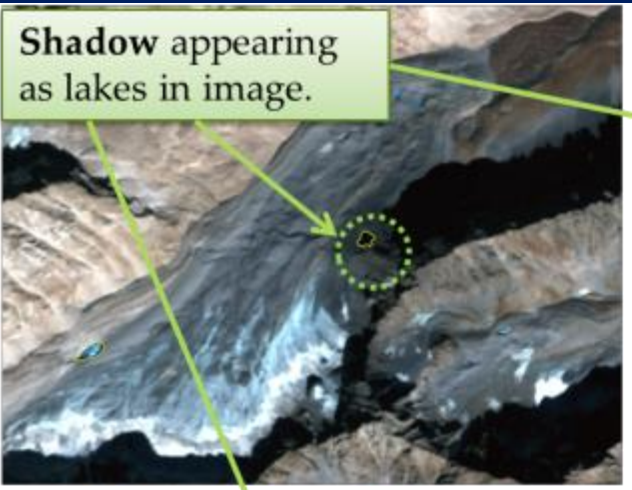


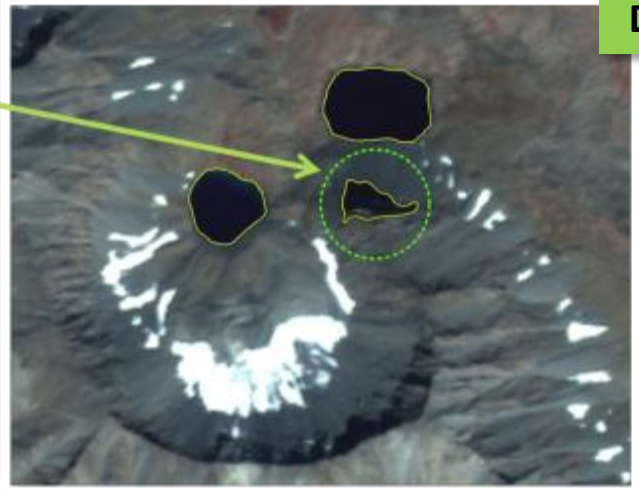
Glacier and Glacier Lake Mapping Using Remote Sensing Data

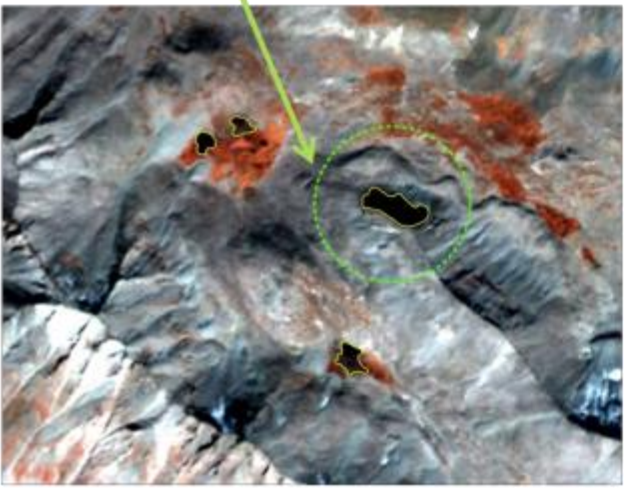
Inventory of Glacial Lakes

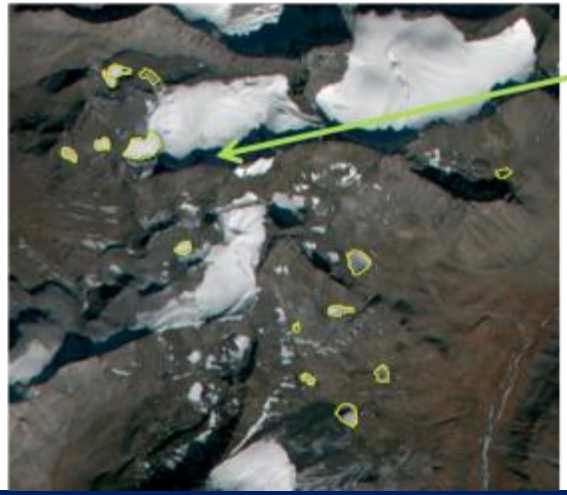
Glacier and Glacier Lake Mapping Using Remote Sensing Data

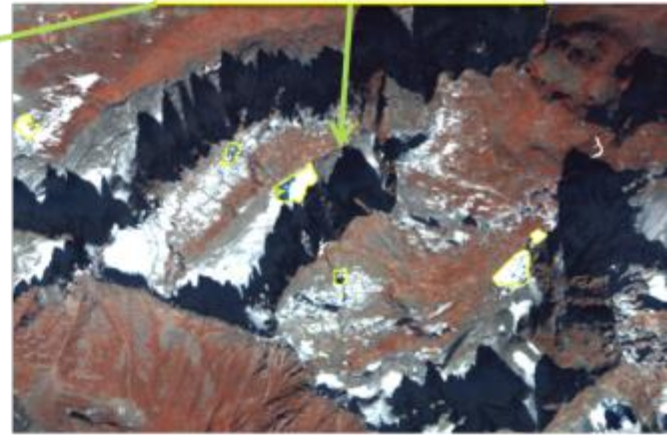
Difficulties in Satellite Interpretation





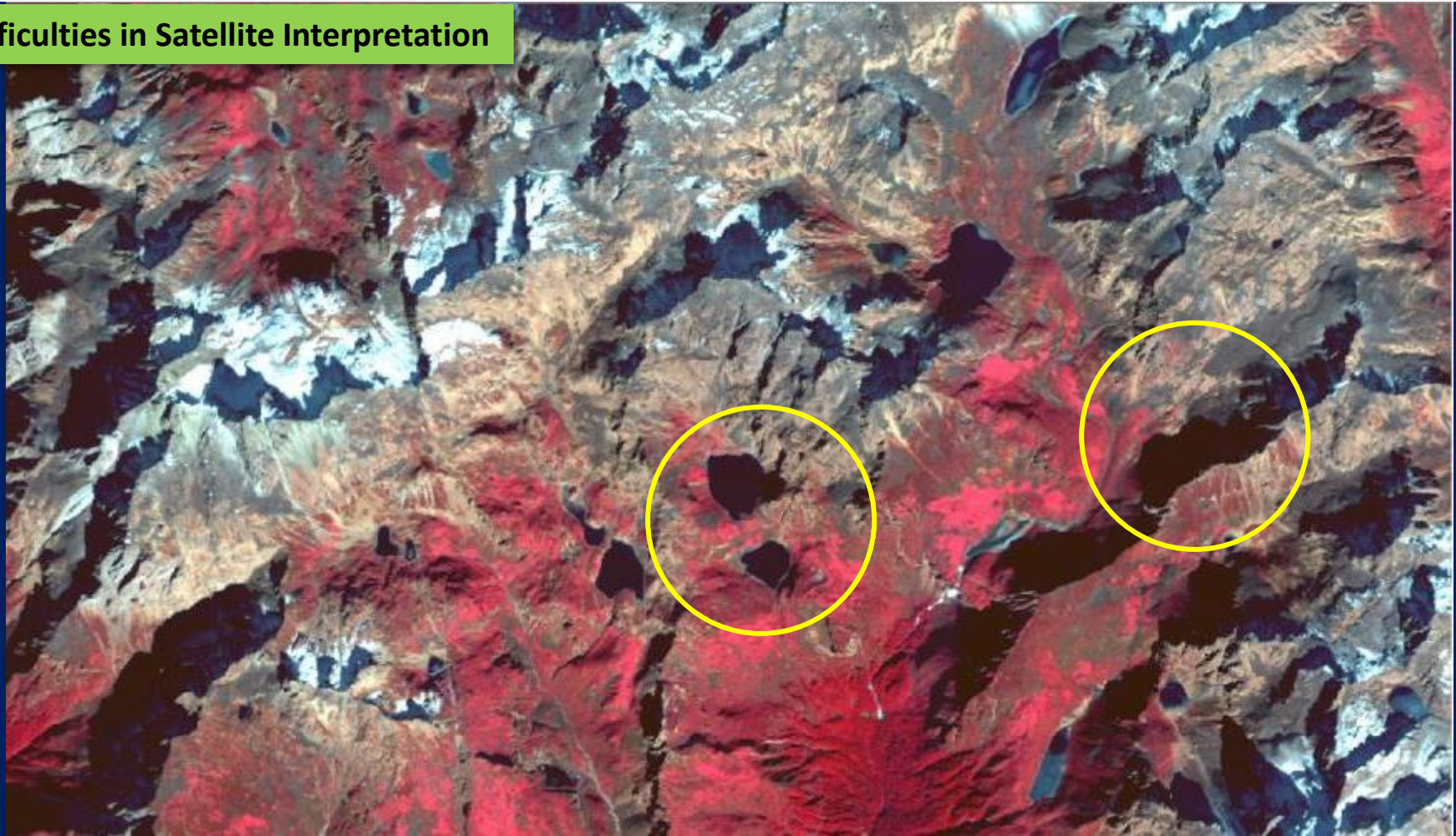






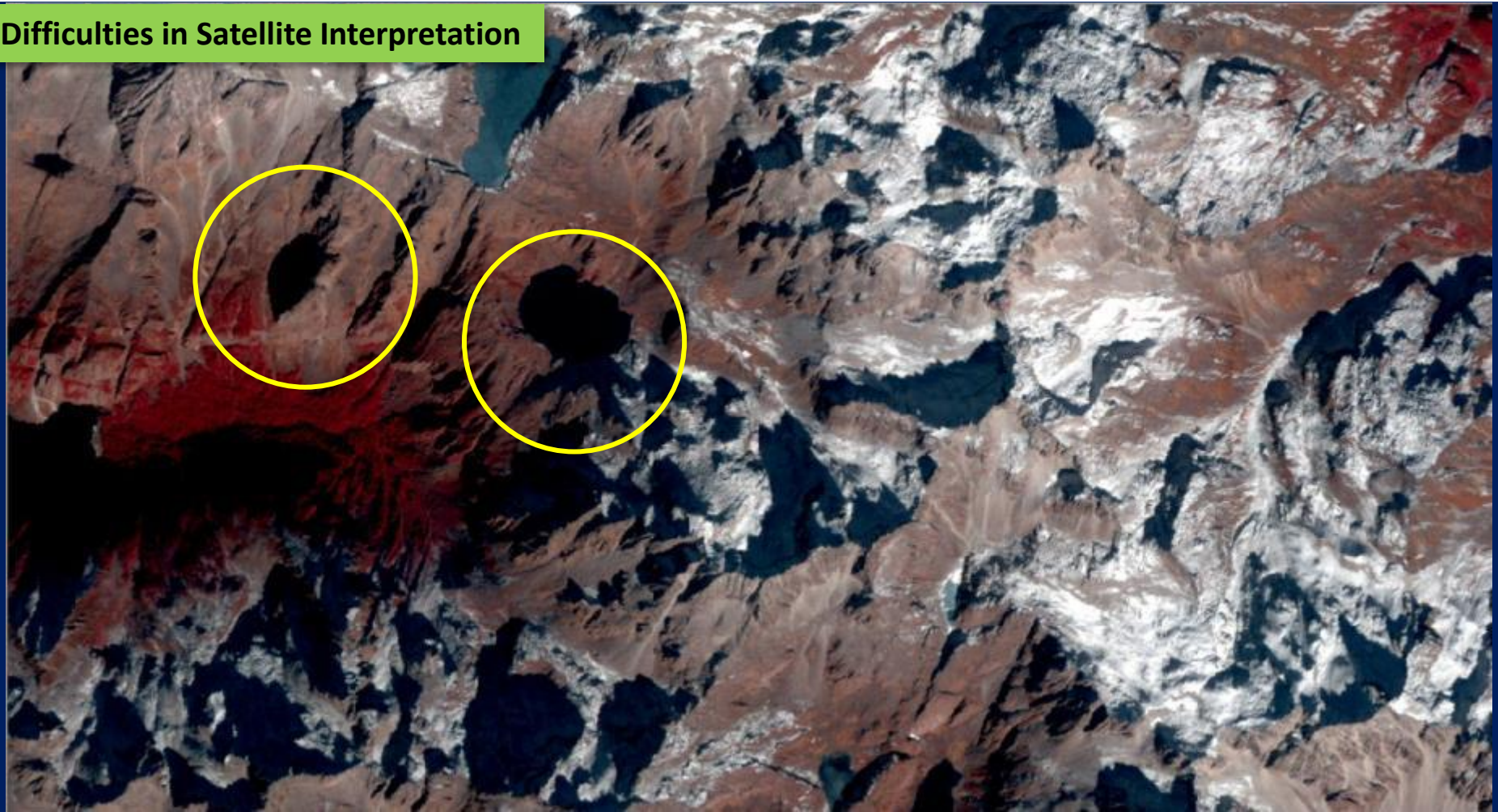
Glacier and Glacier Lake Mapping Using Remote Sensing Data

Difficulties in Satellite Interpretation



Glacier and Glacier Lake Mapping Using Remote Sensing Data

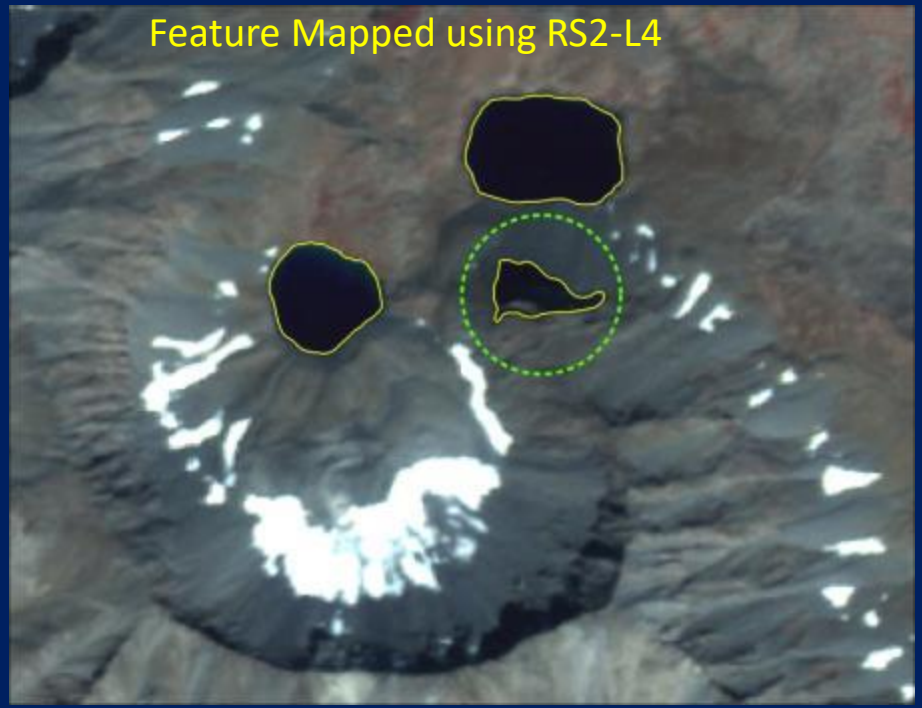
Difficulties in Satellite Interpretation



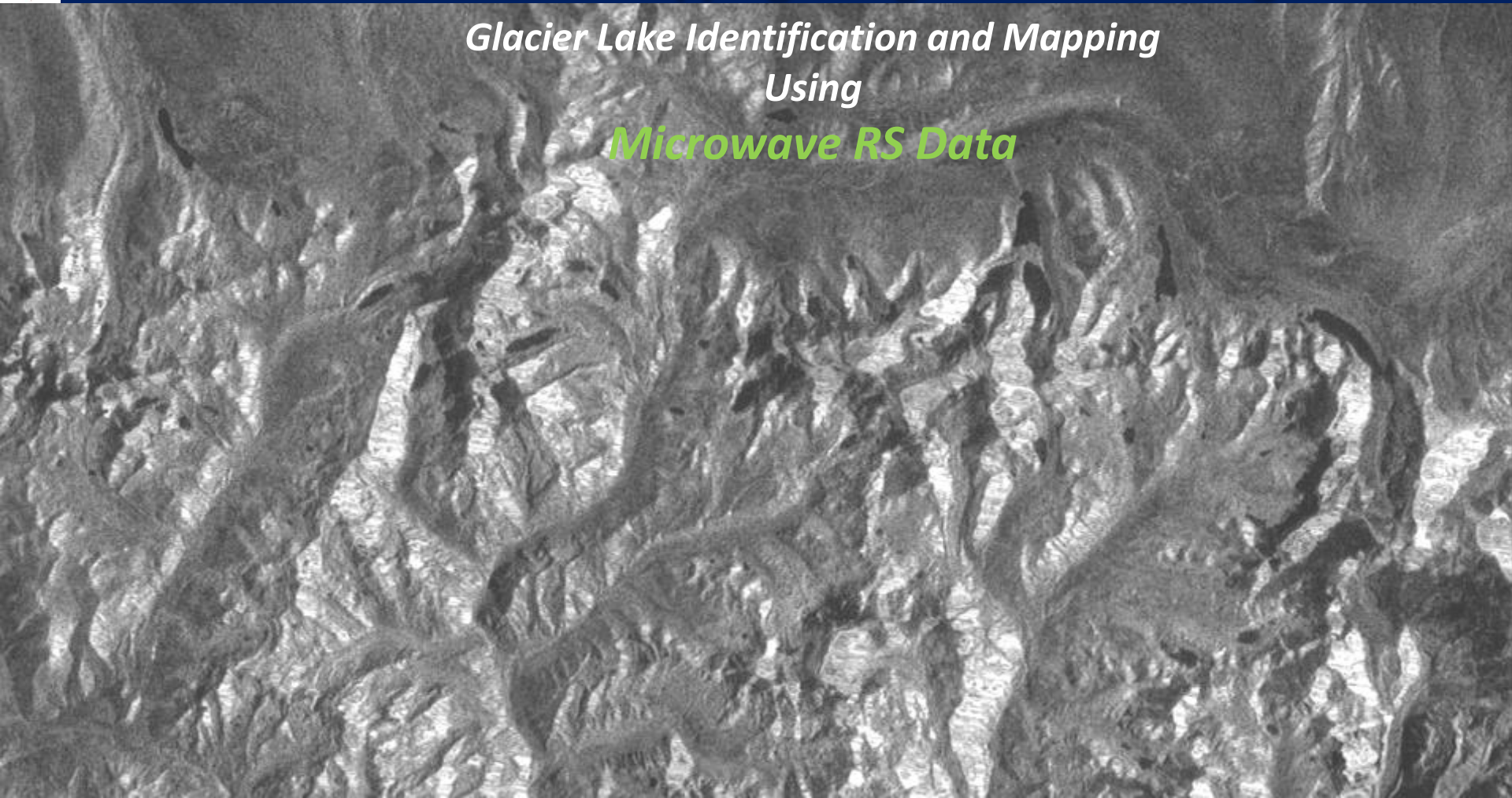
Glacier and Glacier Lake Mapping Using Remote Sensing Data

Difficulties in Satellite Interpretation

- Presence of snow or cloud over glacial lakes
- Glacial lakes under frozen condition
- Glacial lakes under mountain shadow

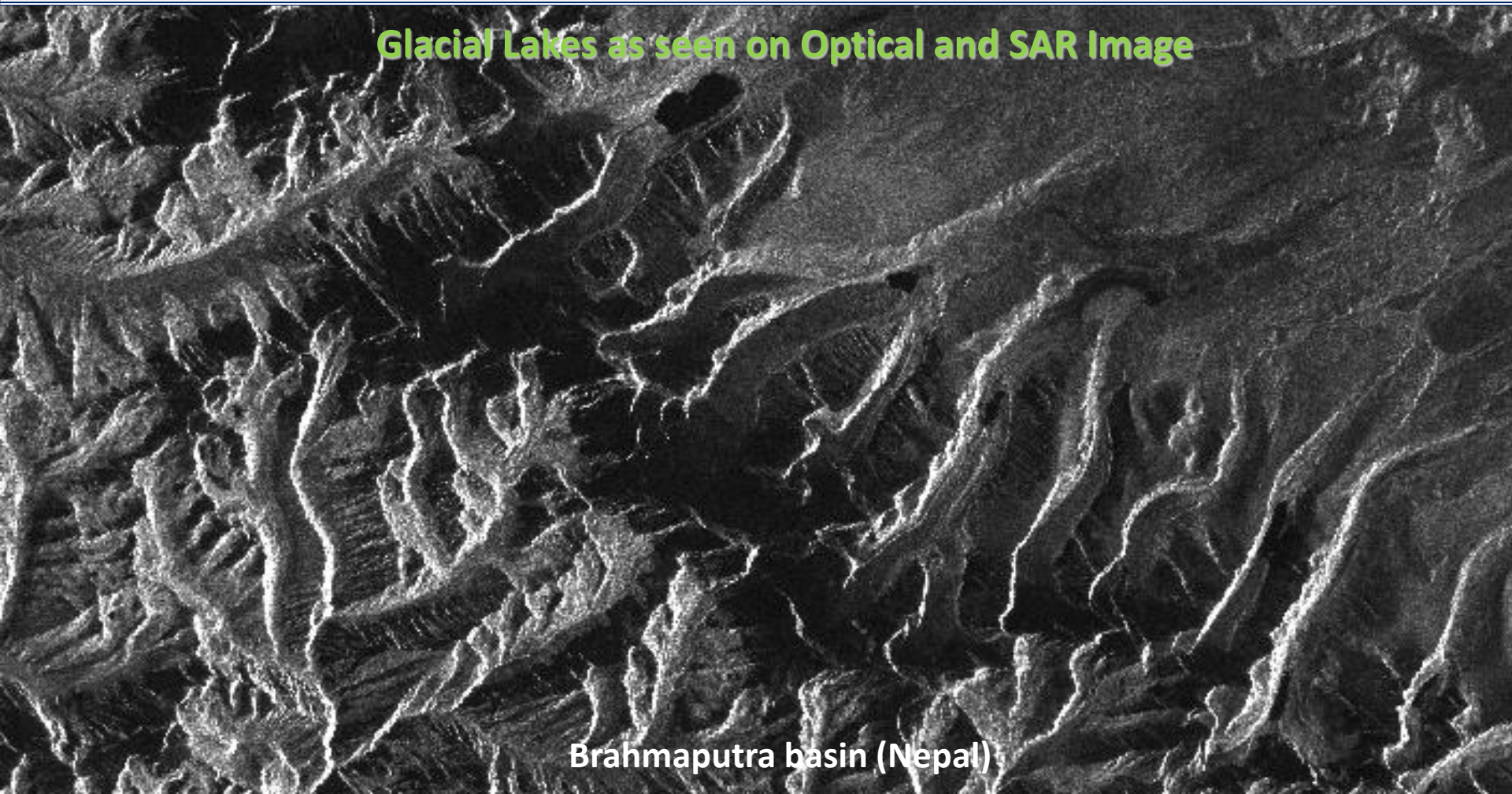


Glacier and Glacier Lake Mapping Using Remote Sensing Data



Glacier and Glacier Lake Mapping Using Remote Sensing Data

Glacial Lakes as seen on Optical and SAR Image

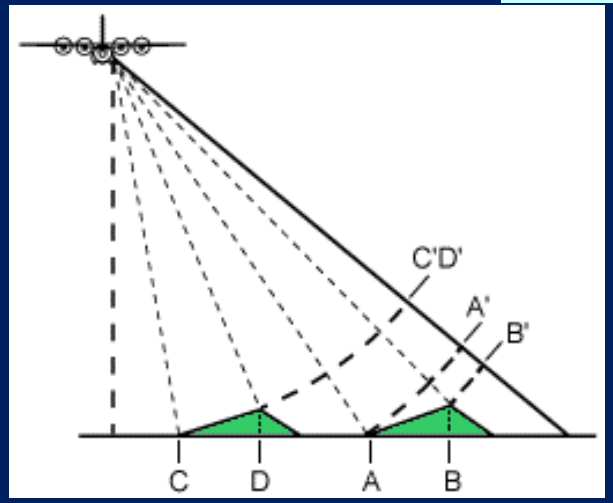


Brahmaputra basin (Nepal)

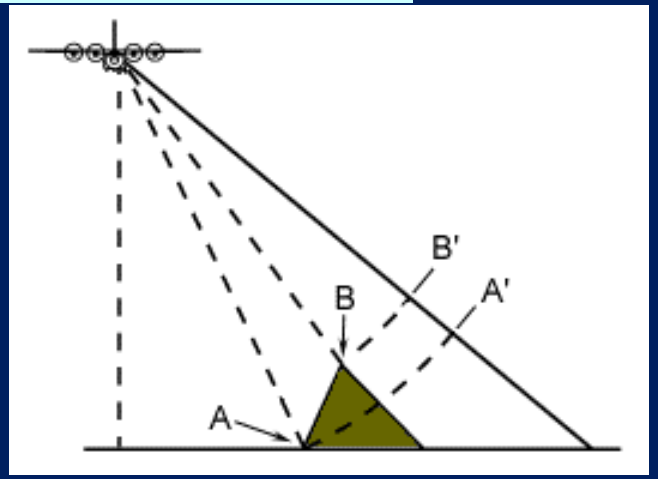
Glacier and Glacier Lake Mapping Using Remote Sensing Data

Geometric Effects in SAR

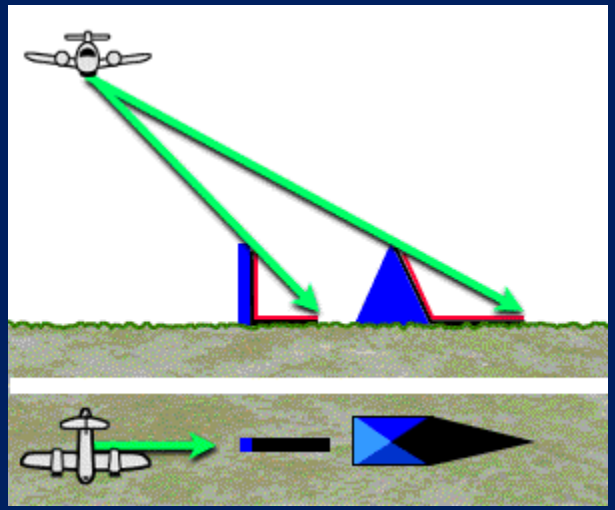
Foreshortening



Layover

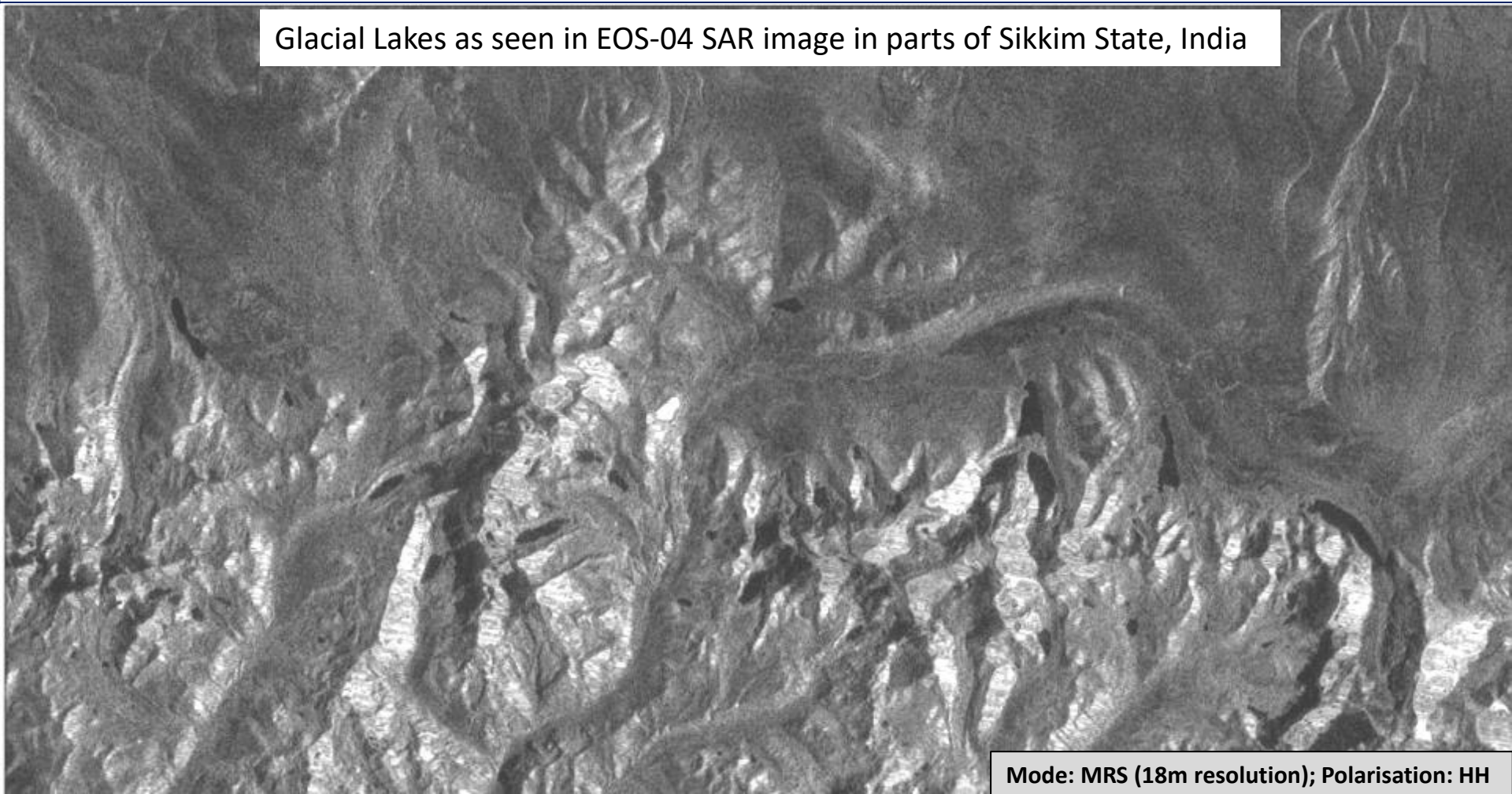


Shadows



Glacier and Glacier Lake Mapping Using Remote Sensing Data

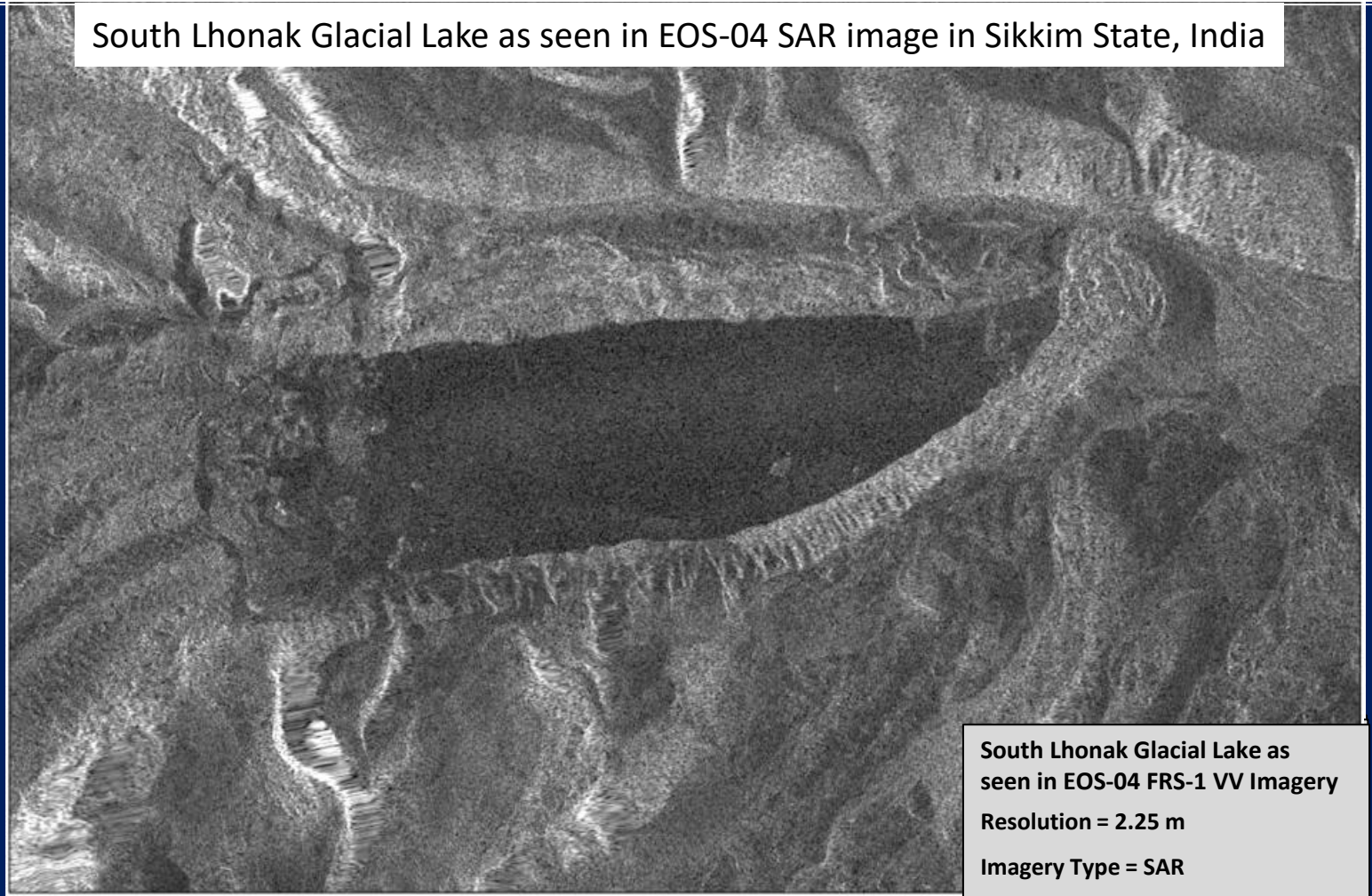
Glacial Lakes as seen in EOS-04 SAR image in parts of Sikkim State, India



Mode: MRS (18m resolution); Polarisation: HH

Glacier and Glacier Lake Mapping Using Remote Sensing Data

South Lhonak Glacial Lake as seen in EOS-04 SAR image in Sikkim State, India



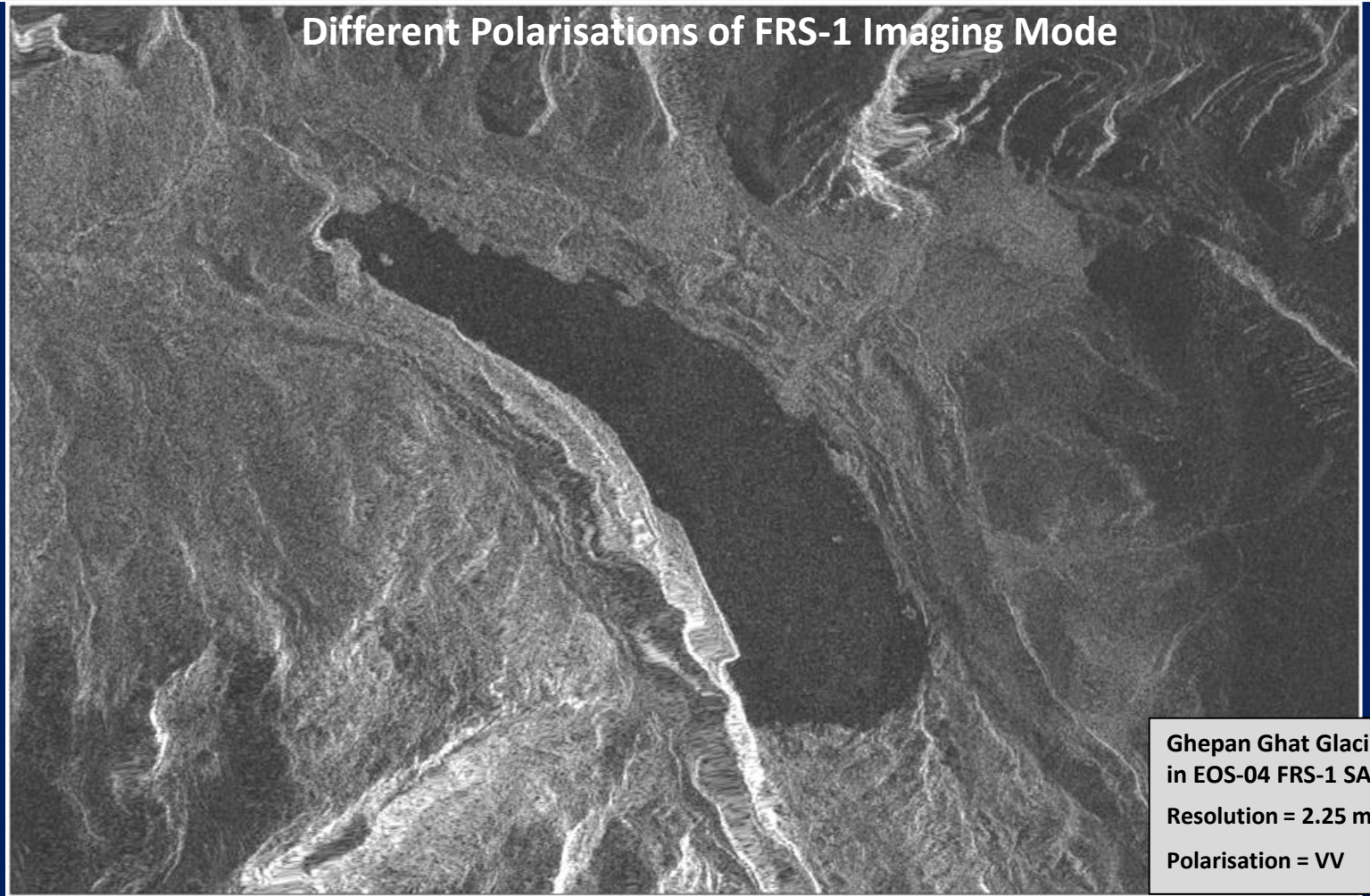
South Lhonak Glacial Lake as seen in EOS-04 FRS-1 VV Imagery

Resolution = 2.25 m

Imagery Type = SAR

Glacier and Glacier Lake Mapping Using Remote Sensing Data

Different Polarisations of FRS-1 Imaging Mode



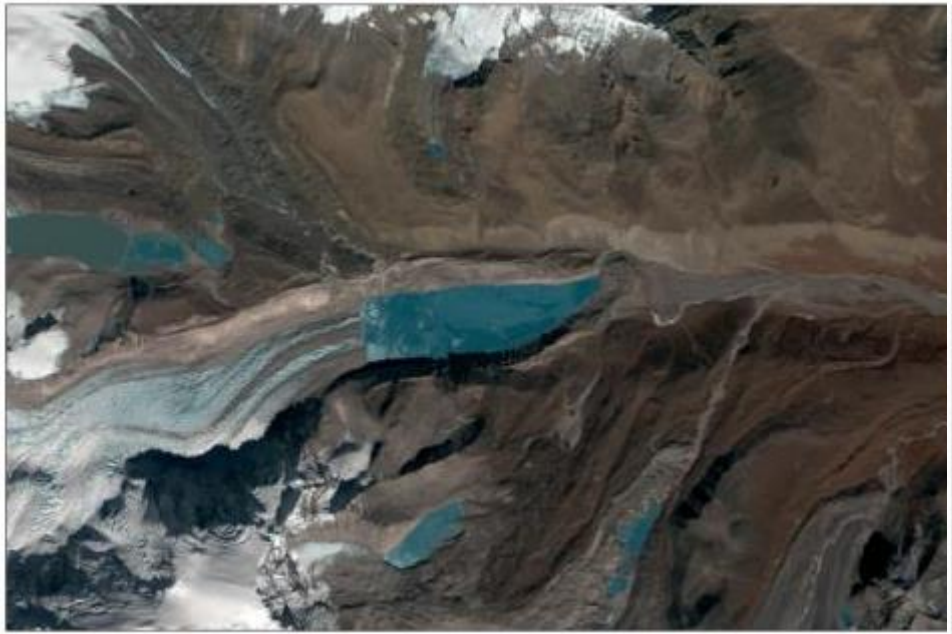
Ghepan Ghat Glacial Lake as seen in EOS-04 FRS-1 SAR Imagery

Resolution = 2.25 m

Polarisation = VV

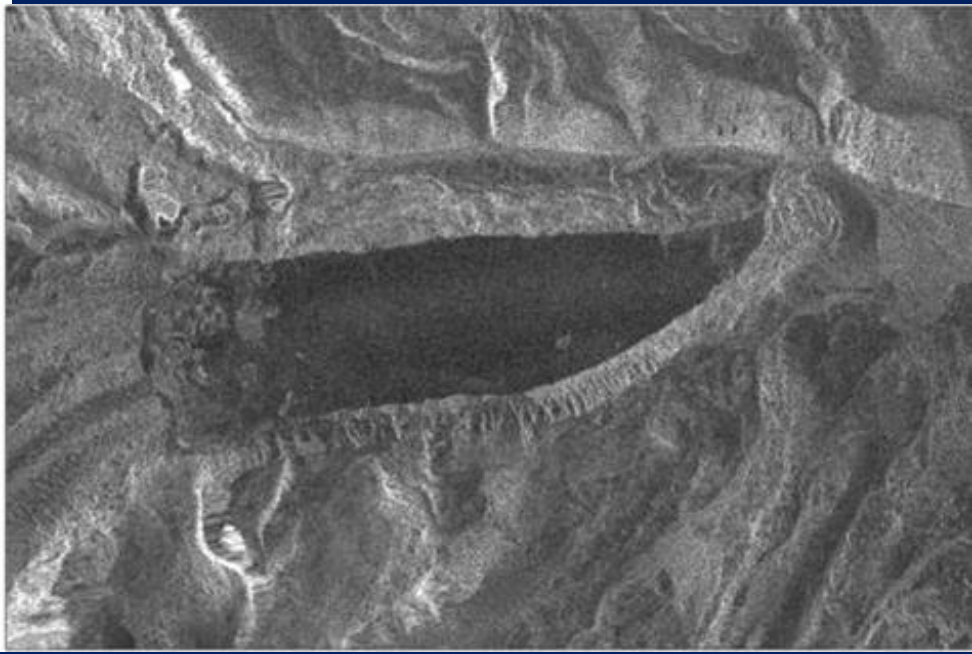
Glacier and Glacier Lake Mapping Using Remote Sensing Data

South Lhonak Glacial Lake as seen on Optical and SAR Image



RS-2 LISS-IV MX FCC Image

Resolution = 5.8 m

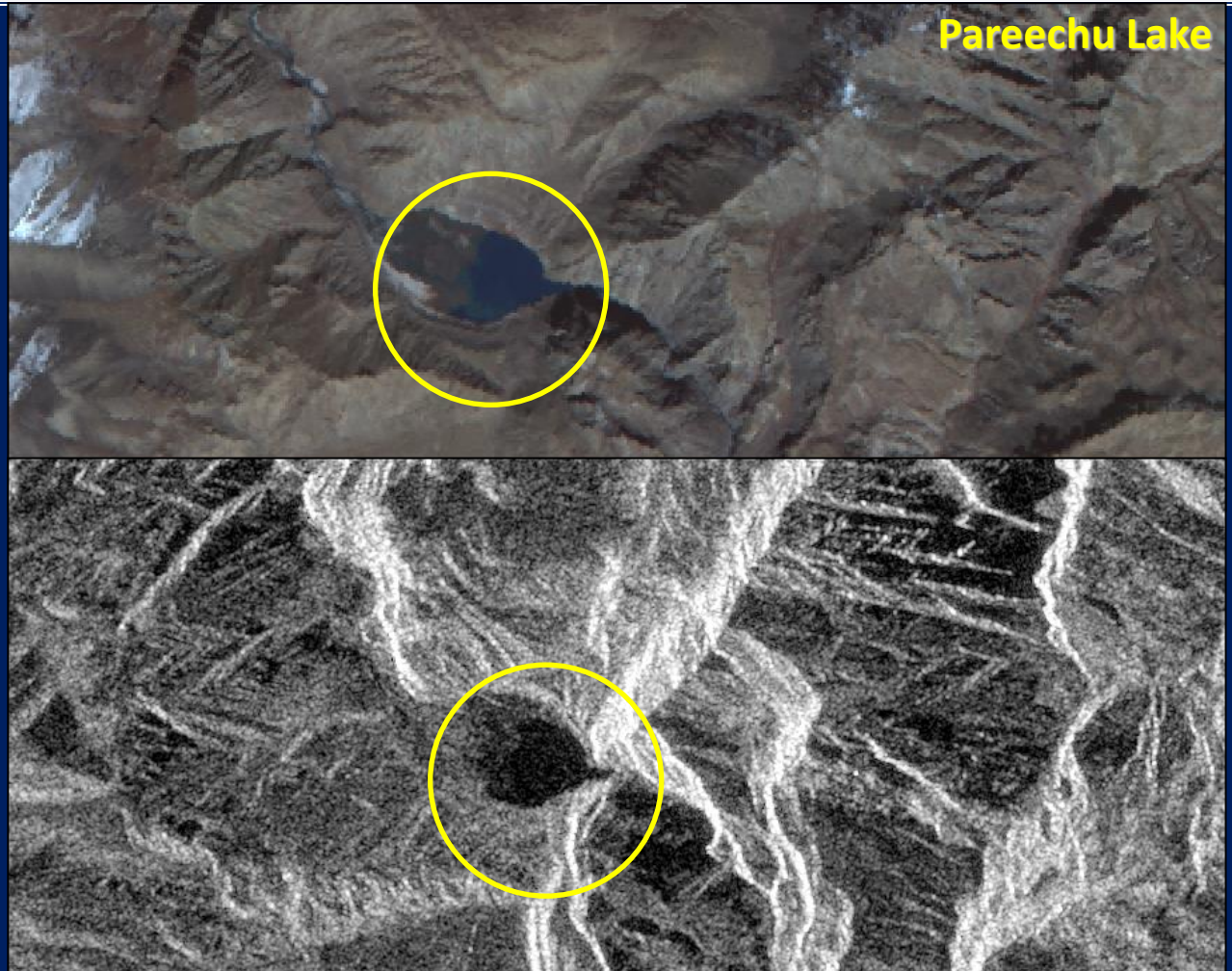


EOS-04 FRS-1 VV Image

Resolution = 2.25 m

Glacier and Glacier Lake Mapping Using Remote Sensing Data

Glacial Lakes under Clear Sky Conditions



IRS-P6
LISS-III
Image of
23Oct2019

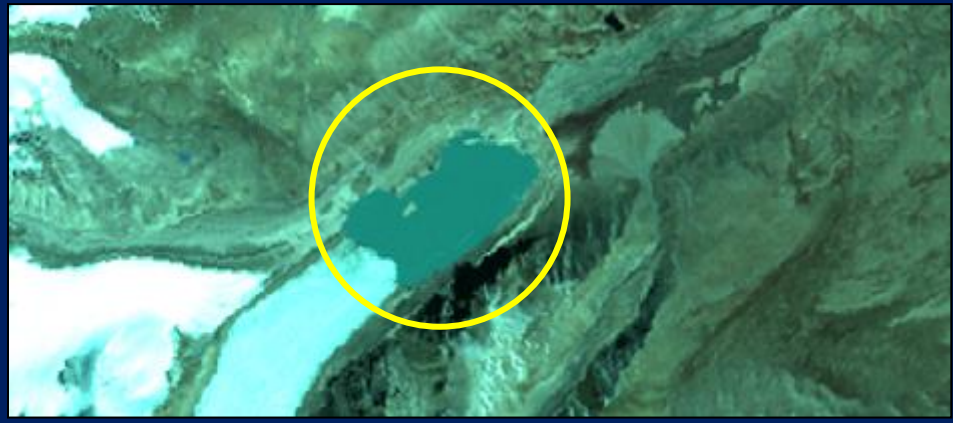
SAR Image
Polarisation:VV

Glacier and Glacier Lake Mapping Using Remote Sensing Data

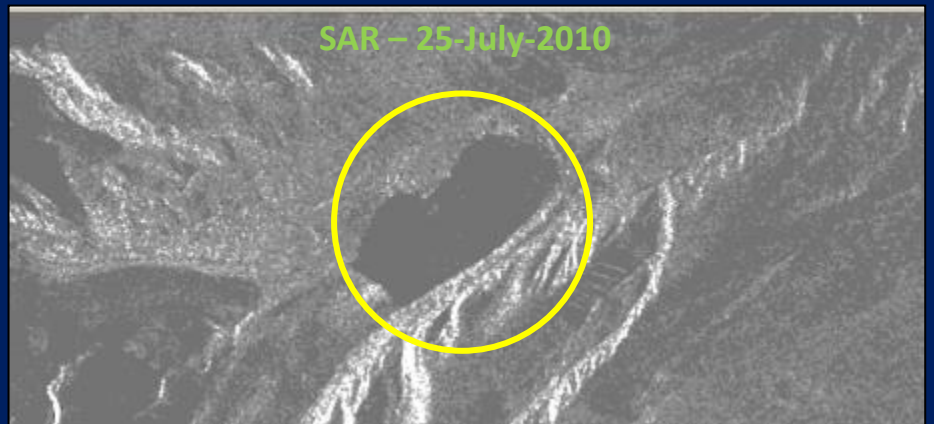
Glacial Lakes under Clear Sky Conditions

IRS-P6 LISS III – 10-July-2010

Landsat ETM - 2000

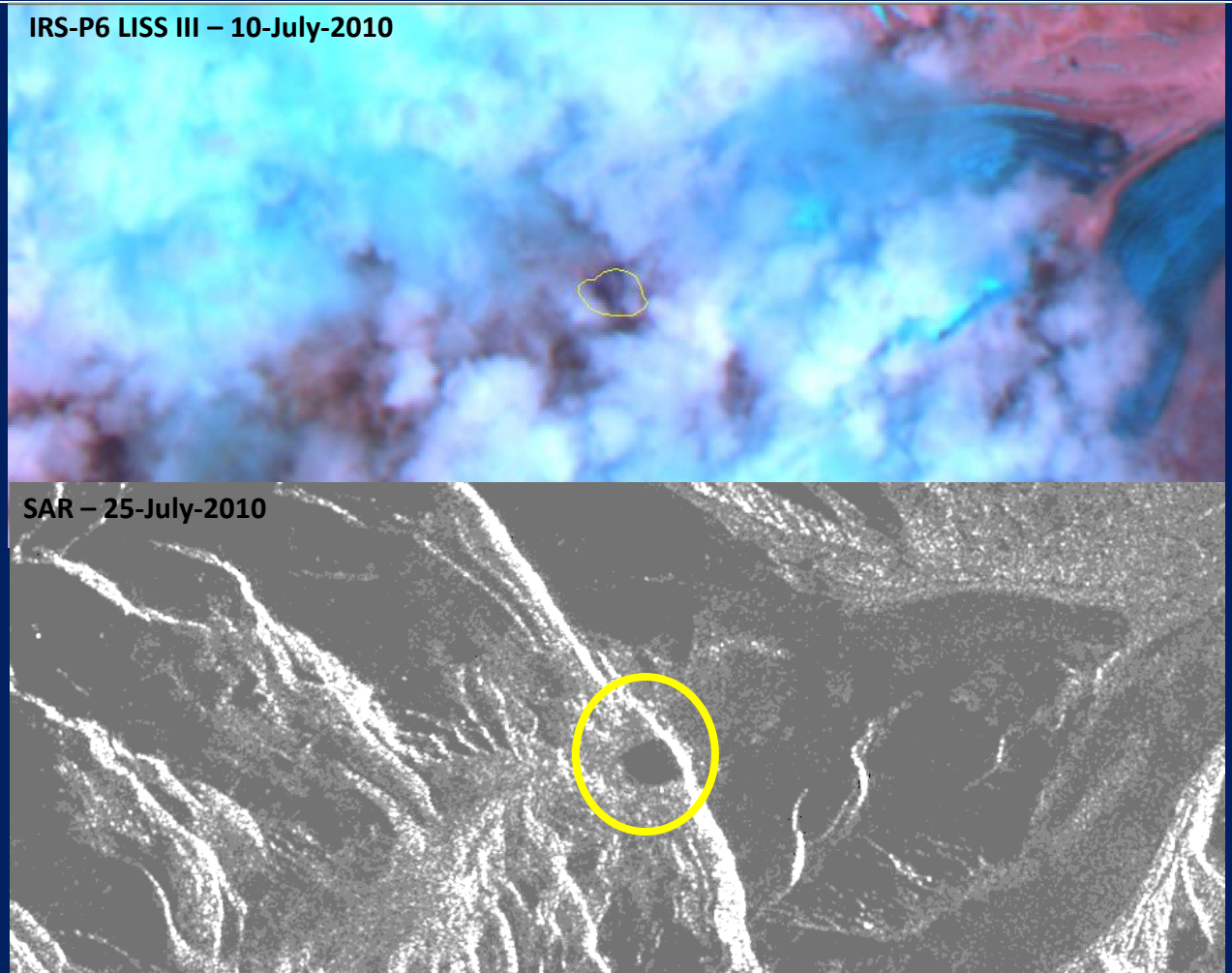


SAR – 25-July-2010



Glacier and Glacier Lake Mapping Using Remote Sensing Data

Glacial Lakes under Fully Cloudy Conditions

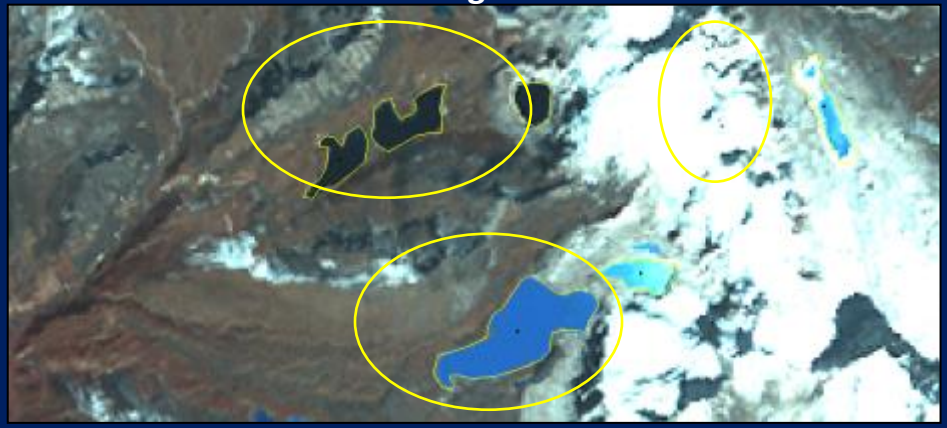


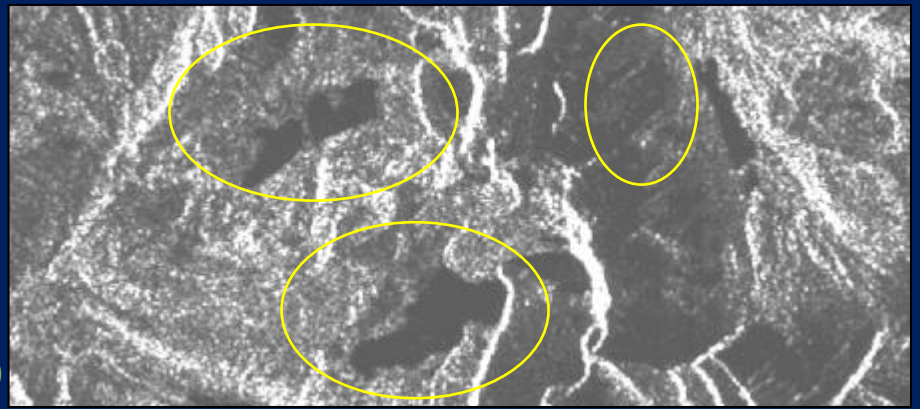
Glacier and Glacier Lake Mapping Using Remote Sensing Data

Glacial Lakes under Fully & Partly Cloudy Conditions

IRS-P6 LISS III – 21-July-2010

Landsat ETM Image of 2010



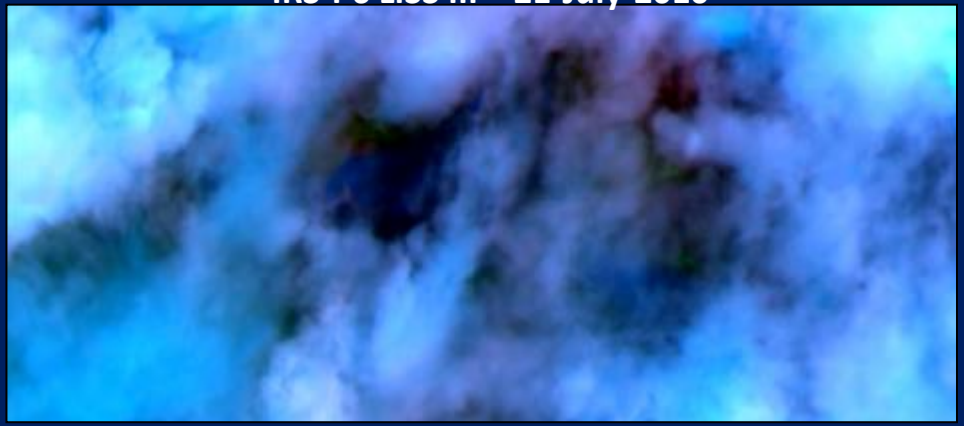


ENVISAT ASAR – 26-July-2010

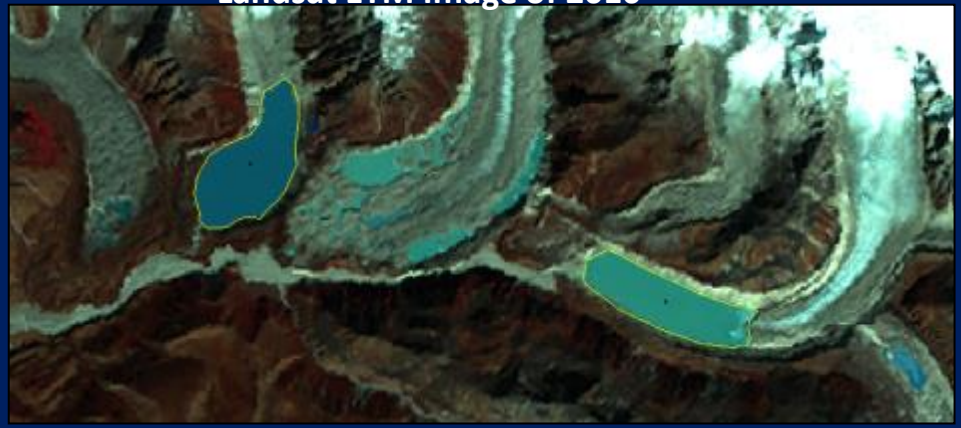
Glacier and Glacier Lake Mapping Using Remote Sensing Data

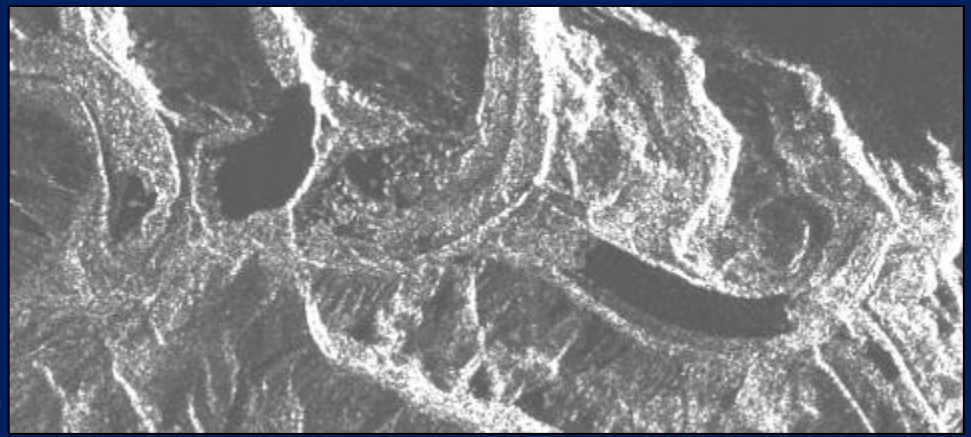
Glacial Lakes under Fully & Partly Cloudy Conditions

IRS-P6 LISS III – 21-July-2010



Landsat ETM Image of 2010

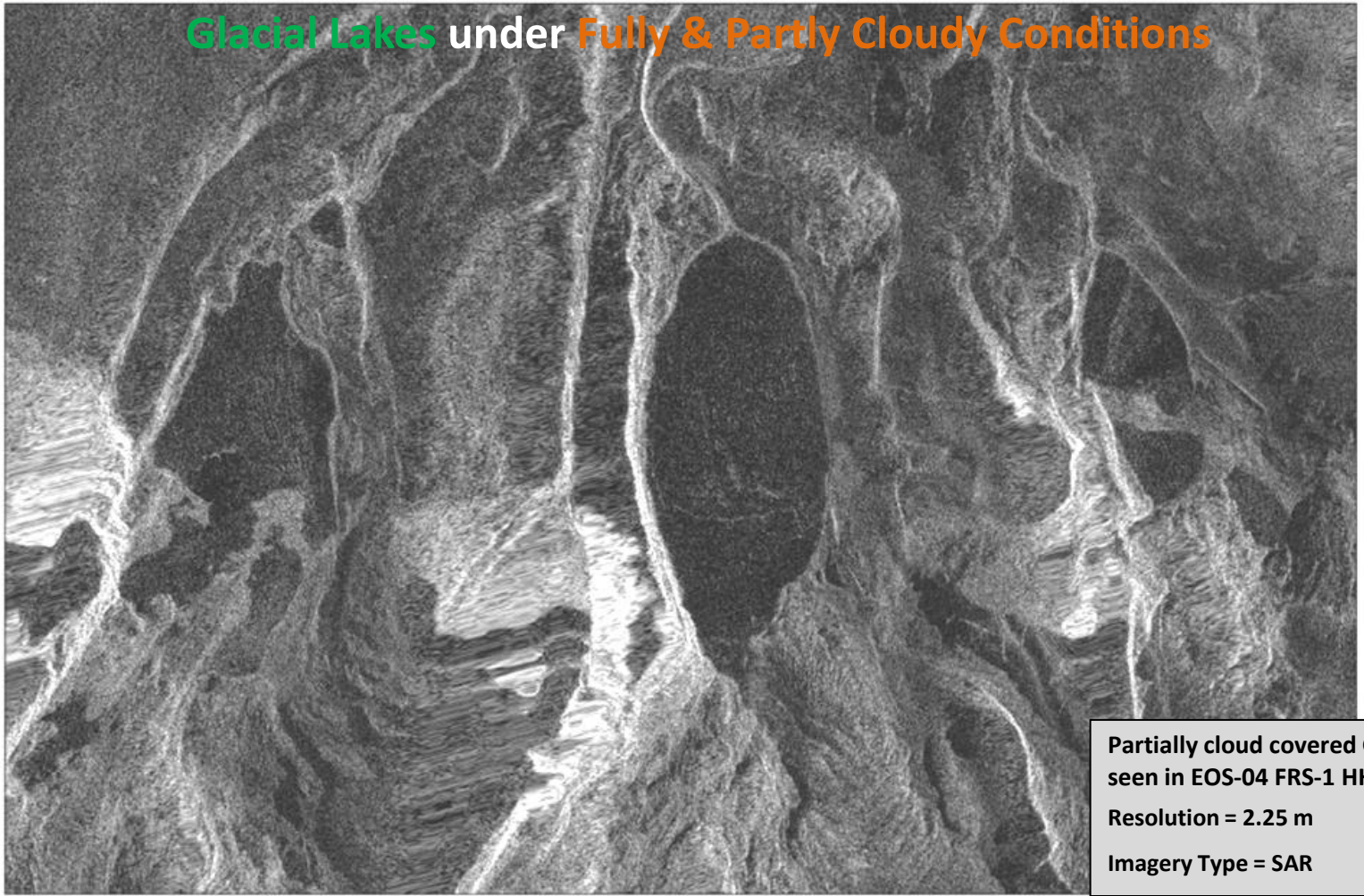




SAR Image of 26-July-2010

Glacier and Glacier Lake Mapping Using Remote Sensing Data

Glacial Lakes under Fully & Partly Cloudy Conditions



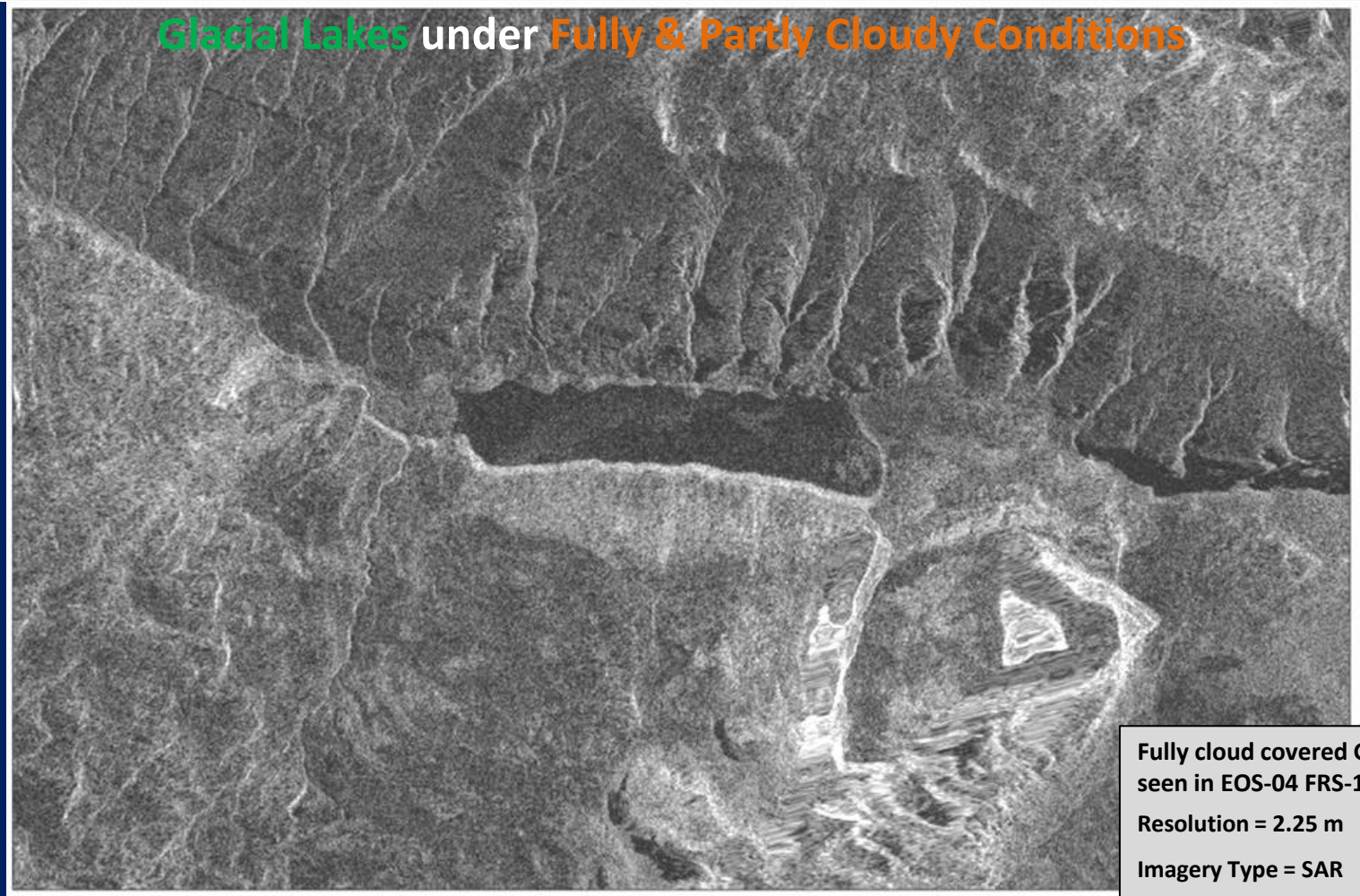
Partially cloud covered Glacial Lakes as seen in EOS-04 FRS-1 HH Imagery

Resolution = 2.25 m

Imagery Type = SAR

Glacier and Glacier Lake Mapping Using Remote Sensing Data

Glacial Lakes under Fully & Partly Cloudy Conditions



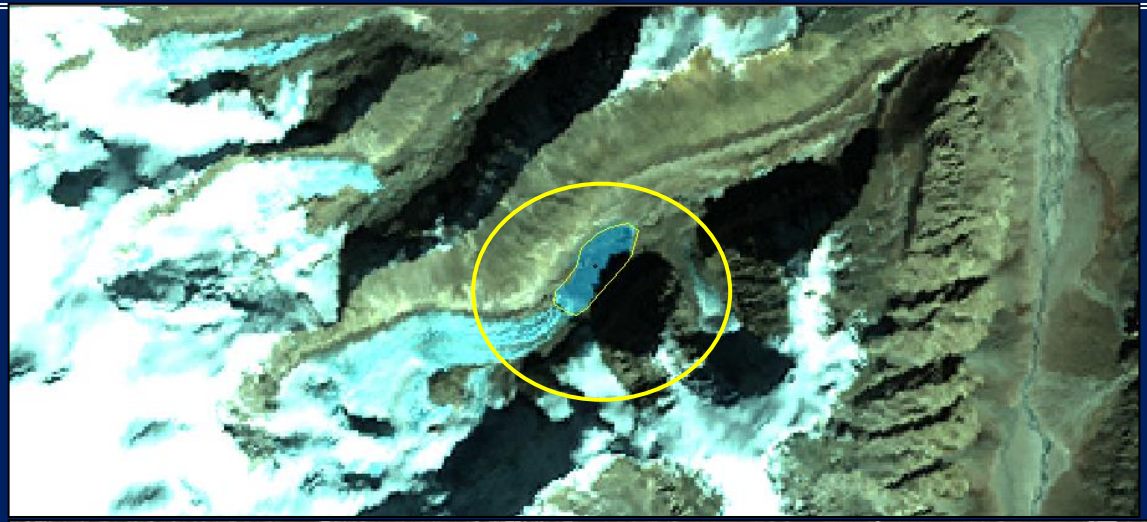
Fully cloud covered Glacial Lake as seen in EOS-04 FRS-1 HH Imagery

Resolution = 2.25 m

Imagery Type = SAR

Glacier and Glacier Lake Mapping Using Remote Sensing Data

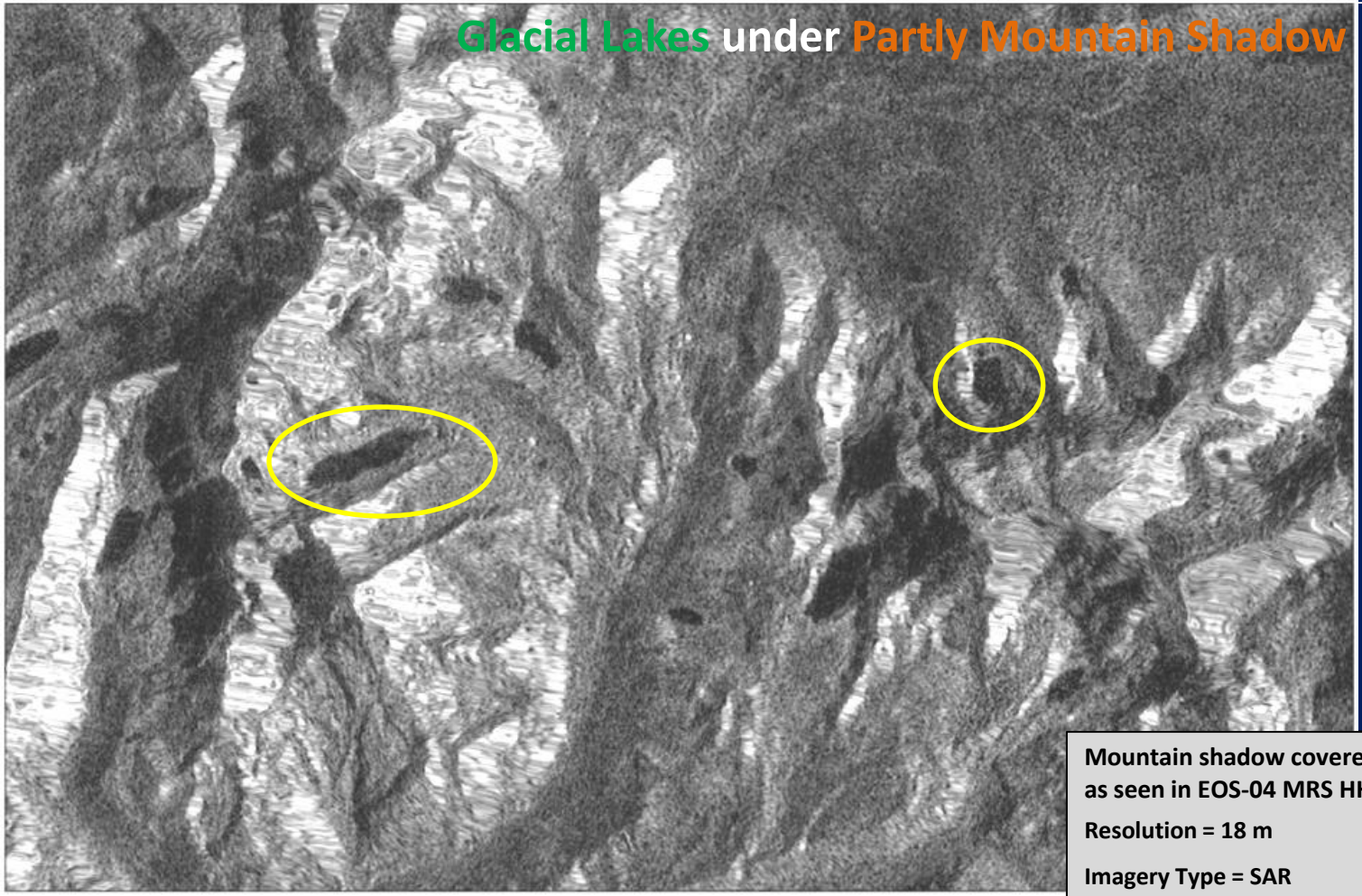
Glacial Lakes under Partly Mountain Shadow



Landsat ETM Image of 2010

SAR Image of 26-July-2010

Glacier and Glacier Lake Mapping Using Remote Sensing Data

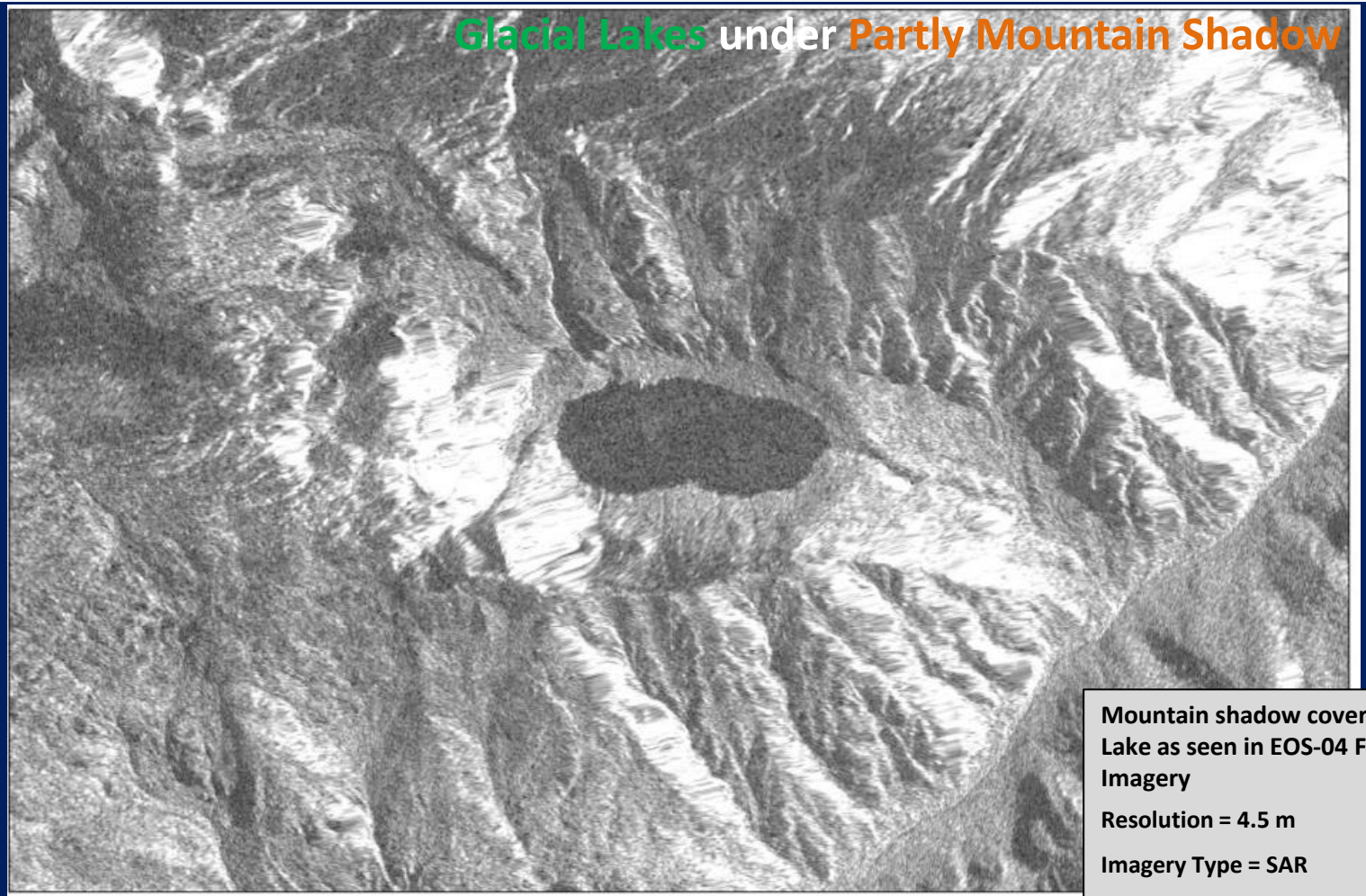


Mountain shadow covered Glacial Lakes as seen in EOS-04 MRS HH Imagery

Resolution = 18 m

Imagery Type = SAR

Glacier and Glacier Lake Mapping Using Remote Sensing Data



Mountain shadow covered Glacial Lake as seen in EOS-04 FRS-2 VV Imagery

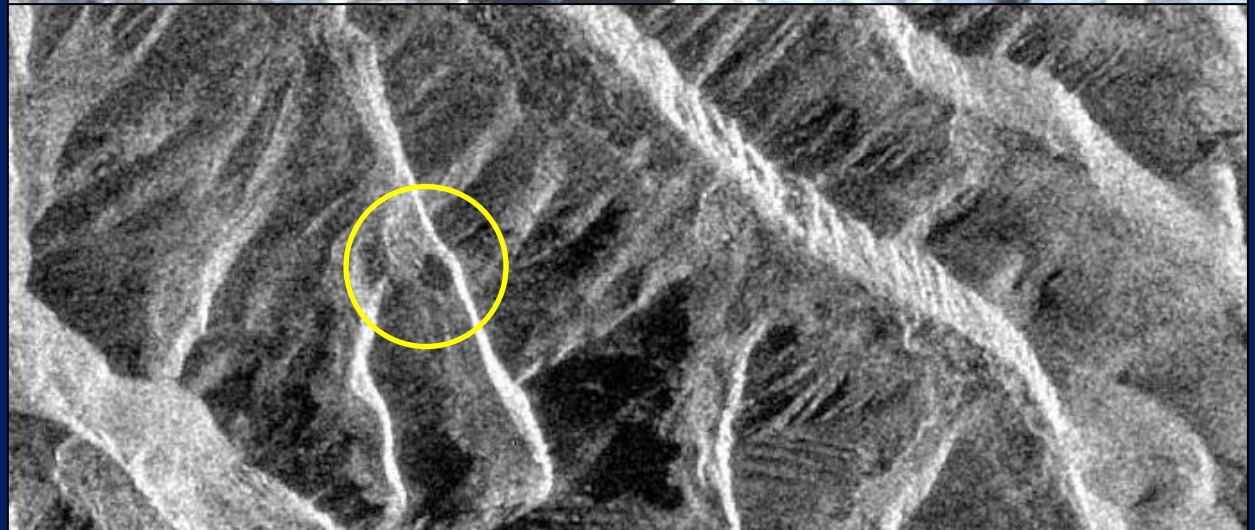
Resolution = 4.5 m

Imagery Type = SAR

Glacier and Glacier Lake Mapping Using Remote Sensing Data

Glacial Lakes under Frozen Conditions

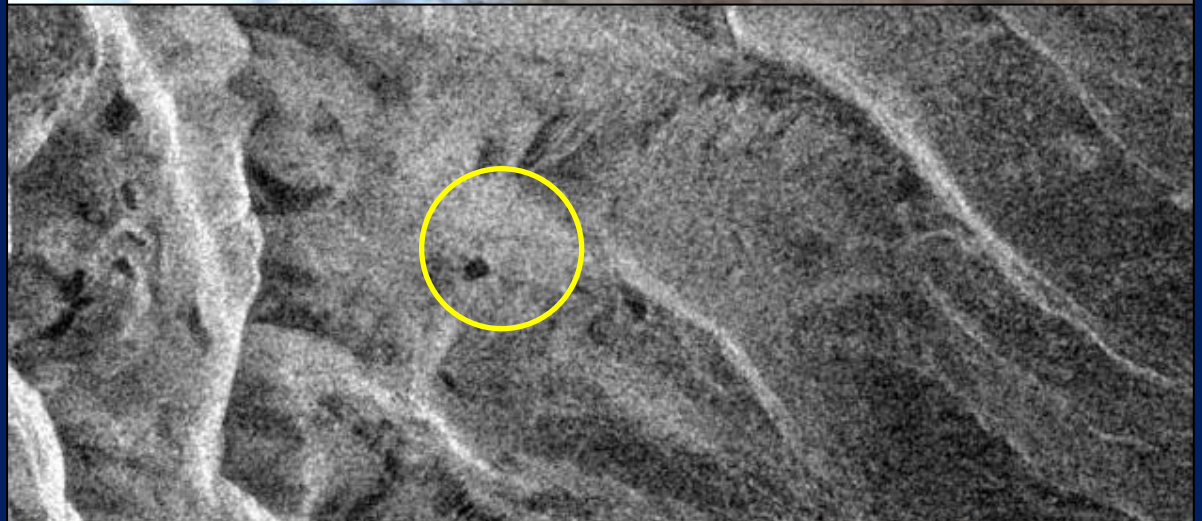
IRS-P6 LISS-III Image of 23Oct2019



SAR Image
Polarisation:VV

Glacier and Glacier Lake Mapping Using Remote Sensing Data

Glacial Lakes under Frozen Conditions



IRS-P6 LISS-III Image of 23Oct2019

SAR Image Polarisation:VV

Glacier and Glacier Lake Mapping Using Remote Sensing Data

Glacial Lakes under Frozen Conditions

Samudra Tapu Glacial Lake as seen in EOS-04 FRS-1 VV Imagery

Resolution = 2.25 m

Imagery Type = SAR

Glacier and Glacier Lake Mapping Using Remote Sensing Data

Glacial Lakes under Frozen Conditions

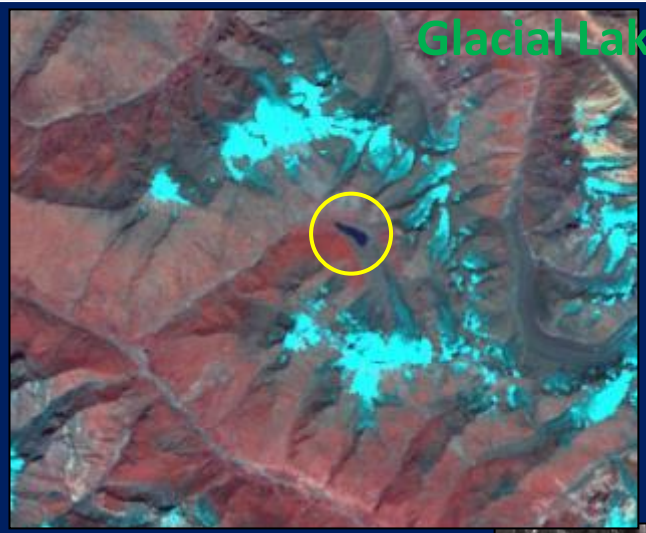
Ice covered Glacial Lakes as seen in EOS-04 FRS-2 VV Imagery

Resolution = 4.5 m

Imagery Type = SAR

Glacier and Glacier Lake Mapping Using Remote Sensing Data

Glacial Lakes under Snow Cover



AWiFS data of 07 Sep 2004

AWiFS data of 17 Feb 2006

SAR data of 24 Feb 2006

Glacier and Glacier Lake Mapping Using Remote Sensing Data

Problems in Glacial Lake Identification with SAR data

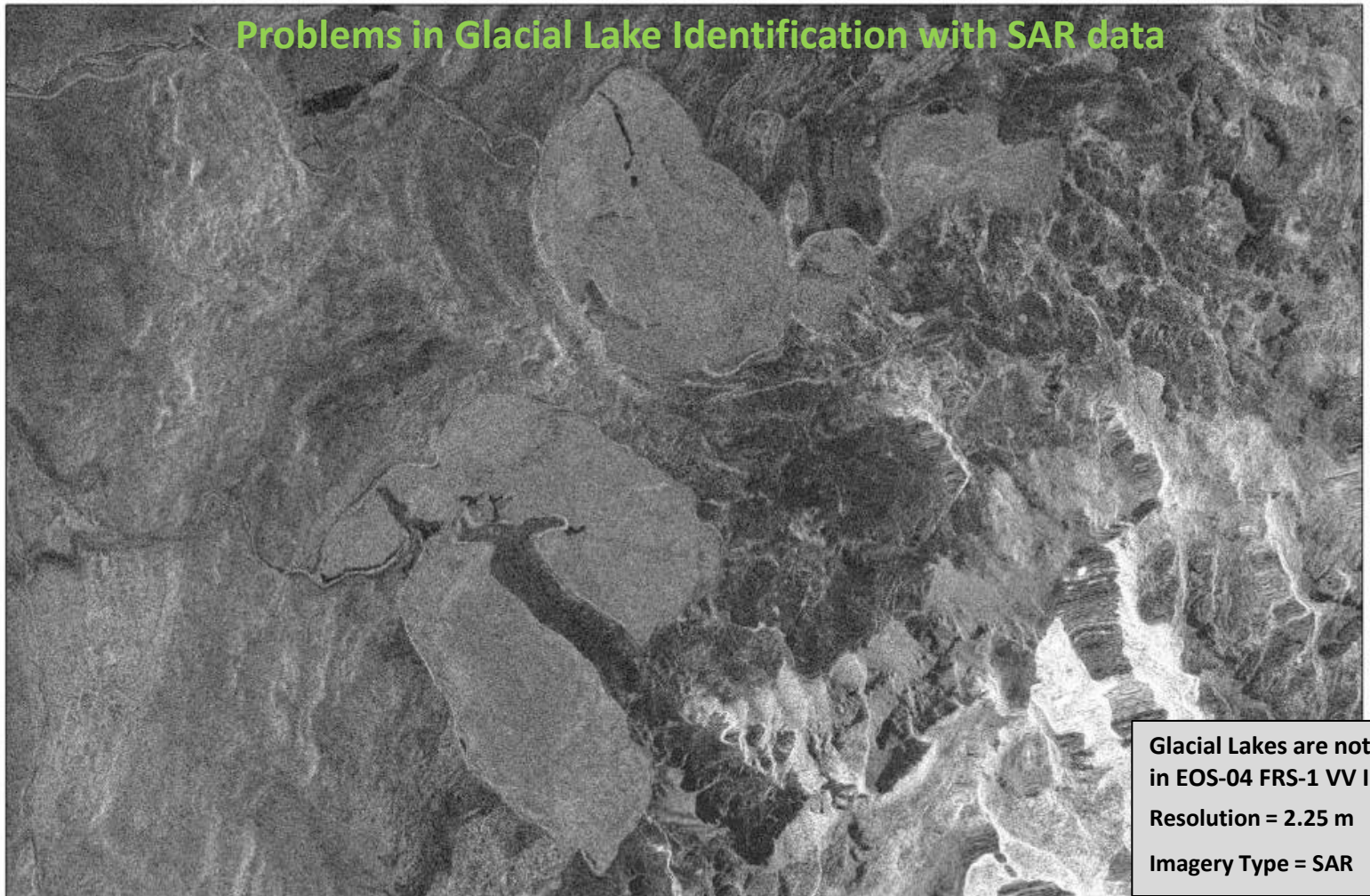
Layover effect on Glacial Lakes as seen in EOS-04 FRS-1 VV Imagery

Resolution = 2.25 m

Imagery Type = SAR

Glacier and Glacier Lake Mapping Using Remote Sensing Data

Problems in Glacial Lake Identification with SAR data



Glacial Lakes are not clearly visible in EOS-04 FRS-1 VV Imagery

Resolution = 2.25 m

Imagery Type = SAR

Glacier and Glacier Lake Mapping Using Remote Sensing Data

Problems in Glacial Lake Identification with SAR data

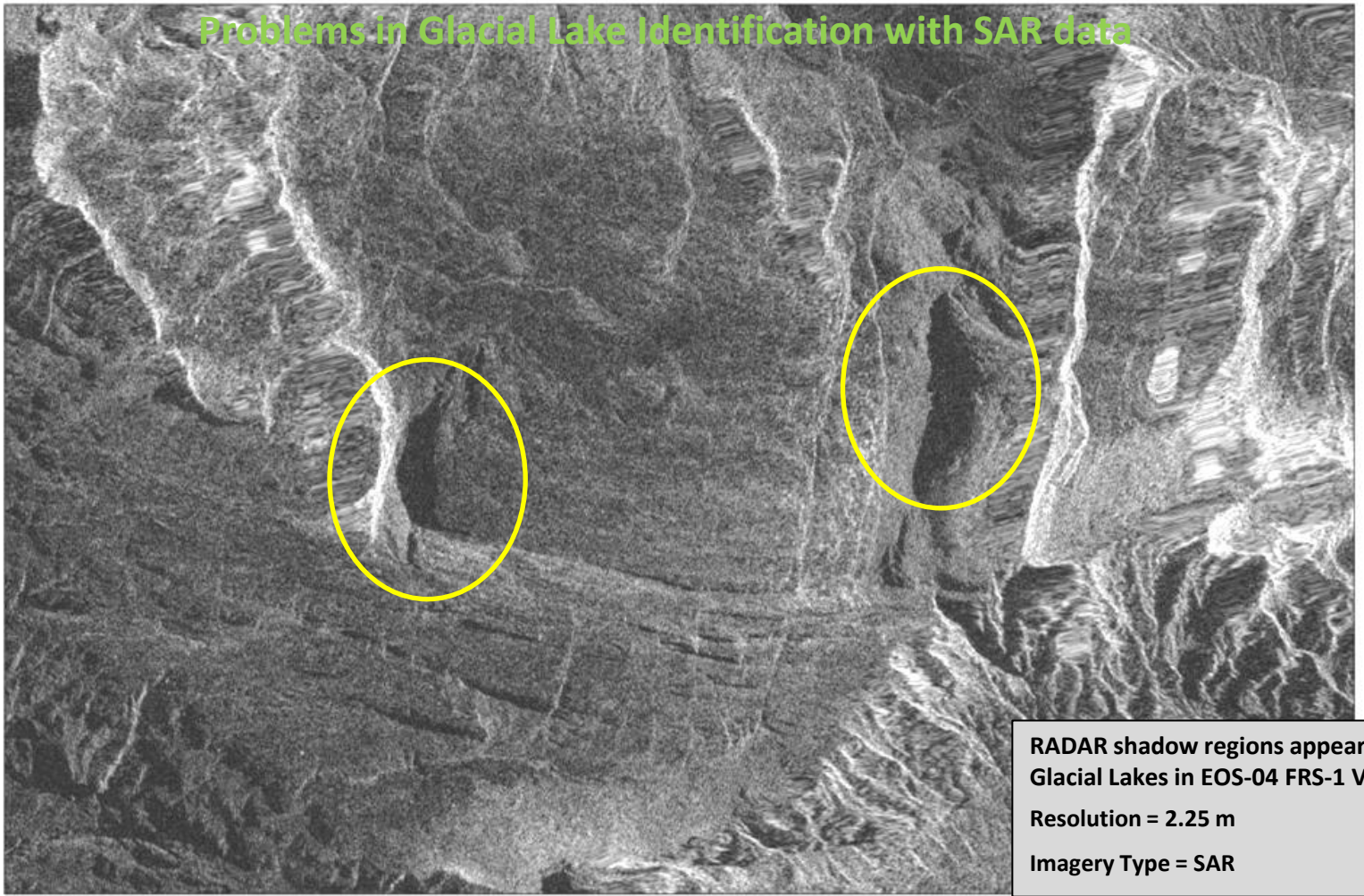
Ghepan Ghat Glacial Lake is clearly visible in EOS-04 FRS-1 VV Imagery

Resolution = 2.25 m

Imagery Type = SAR

Glacier and Glacier Lake Mapping Using Remote Sensing Data

Problems in Glacial Lake Identification with SAR data



RADAR shadow regions appearing as Glacial Lakes in EOS-04 FRS-1 VV Imagery

Resolution = 2.25 m

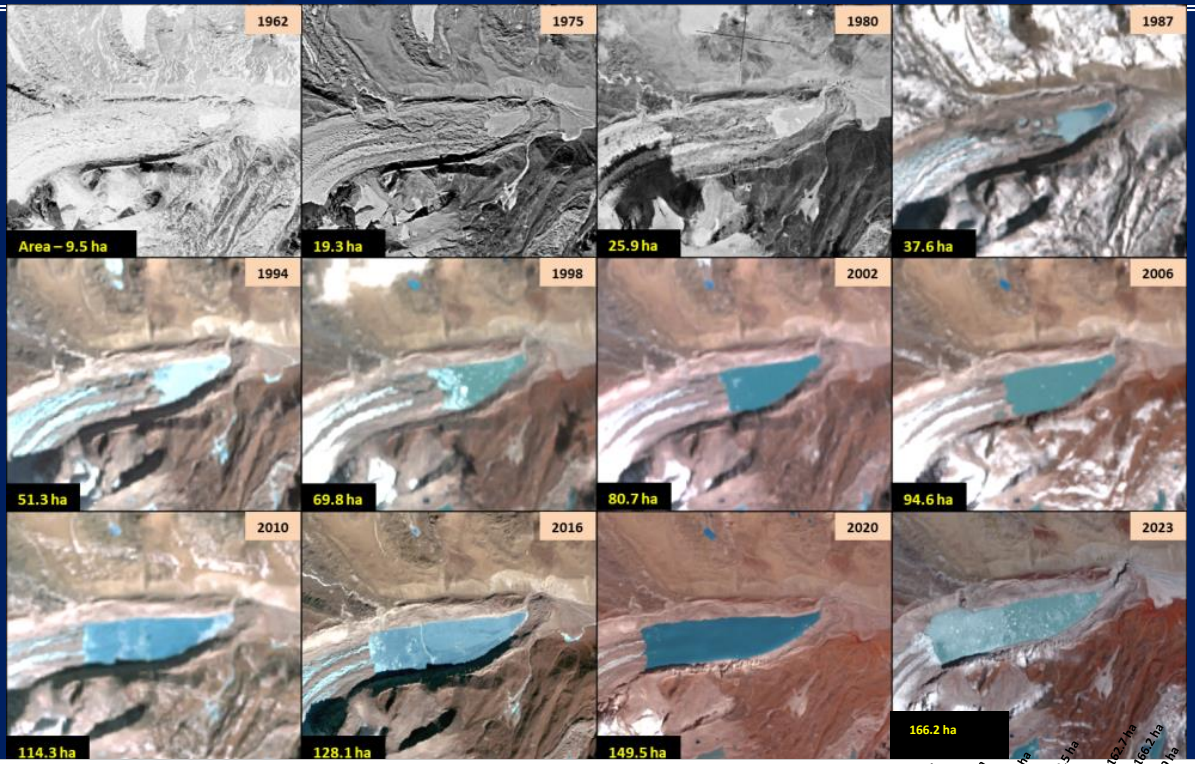
Imagery Type = SAR

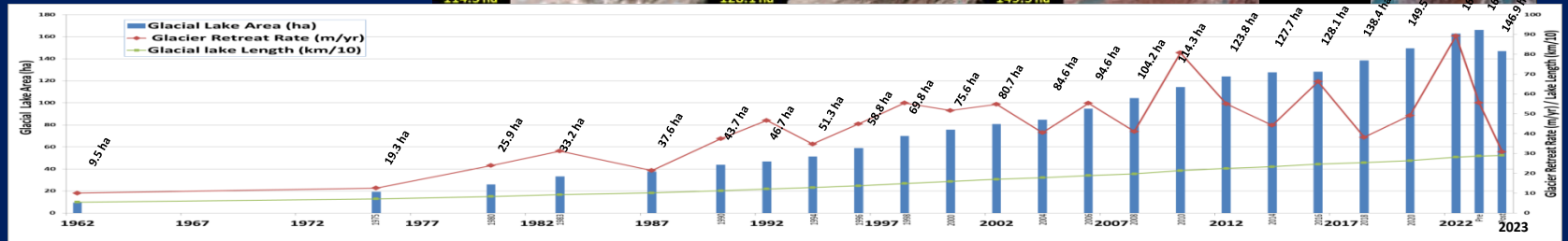
Monitoring of Glacier Lakes

Glacier and Glacier Lake Mapping Using Remote Sensing Data

Monitoring of Glacial Lakes

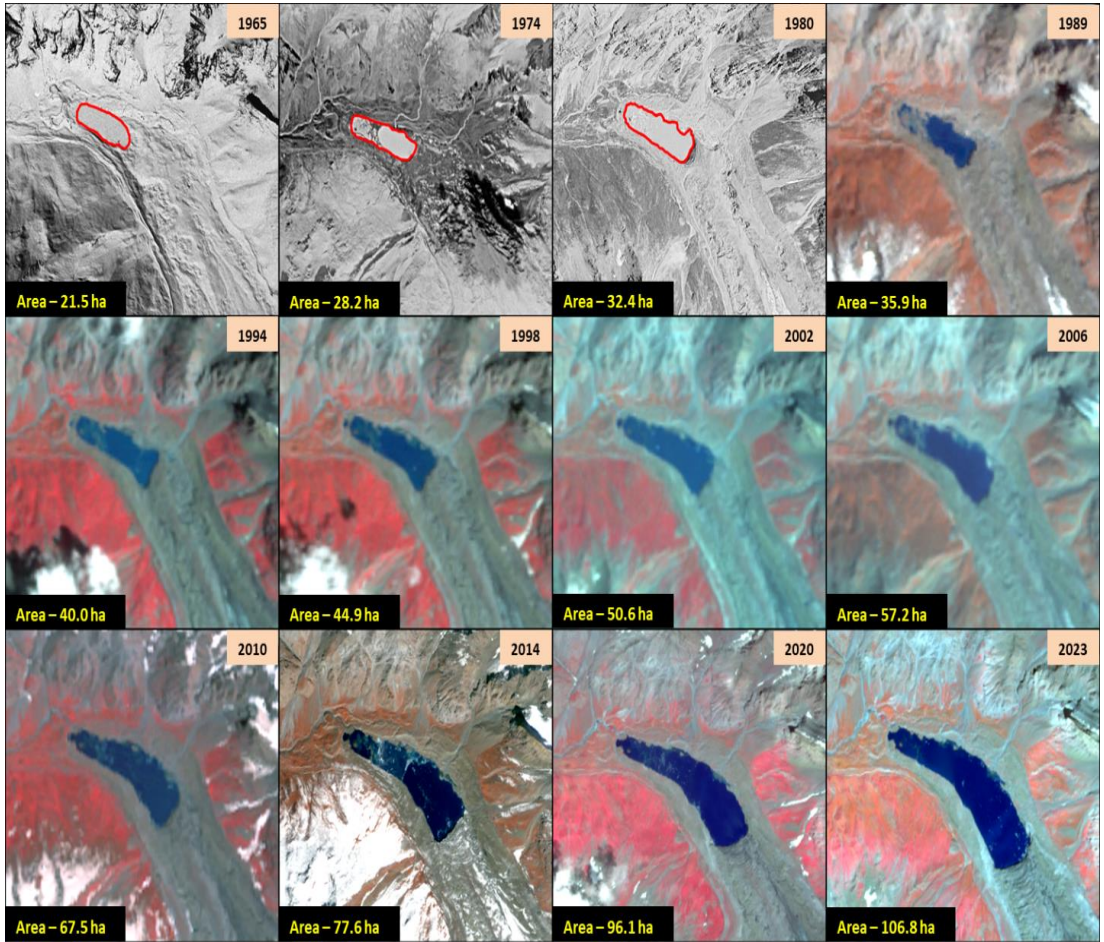
- Long term monitoring of South Lhonak glacial lake in Sikkim Sate,India



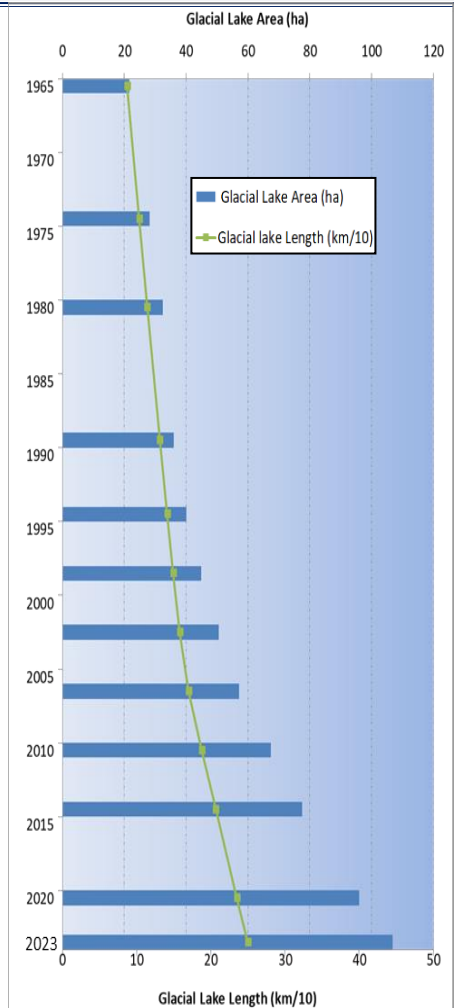


Glacier and Glacier Lake Mapping Using Remote Sensing Data

Ghepang Ghat Glacial Lake, India



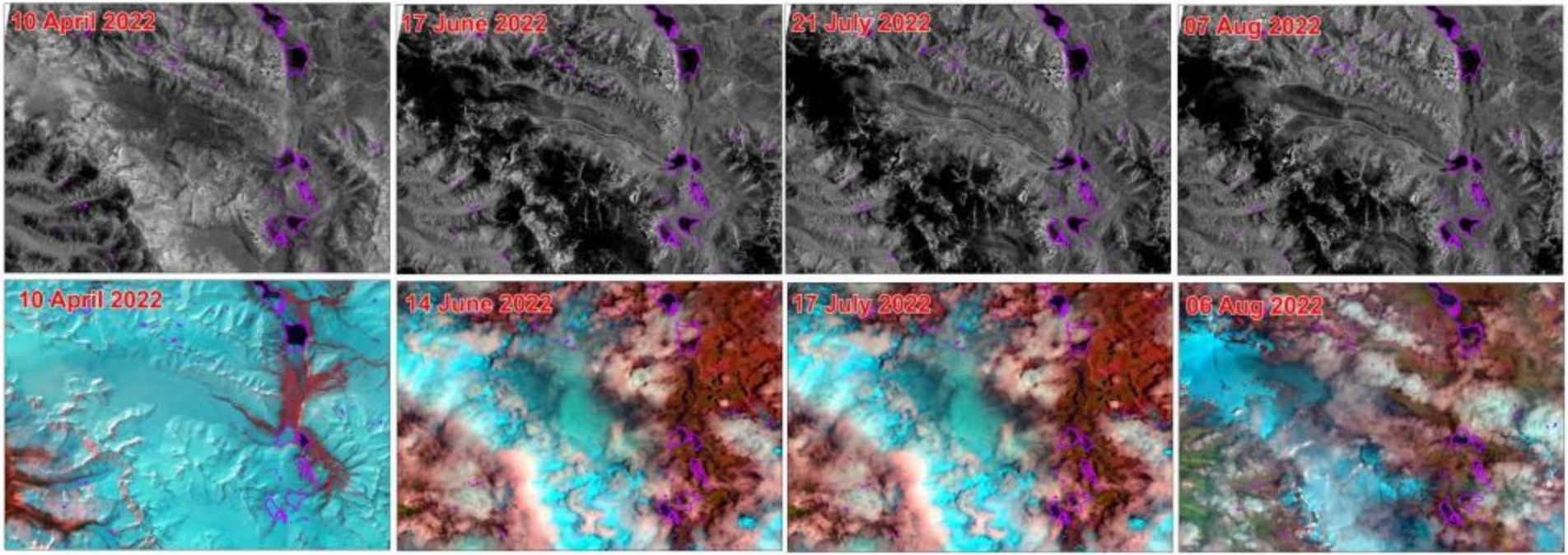
Glacier Retreat Rate: 30m/yr;
Lake Expansion Rate: 400%



Glacier and Glacier Lake Mapping Using Remote Sensing Data

Glacial Lake (GL) monitoring using EOS-04 satellite data

EOS-04 MRS data Time series with corresponding Sen-2 imagery



EOS-04 Multi-temporal SAR imagery corresponding optical imagery showing Glacial Lakes in part of Lohit Sub-basin in Brahmaputra basin.

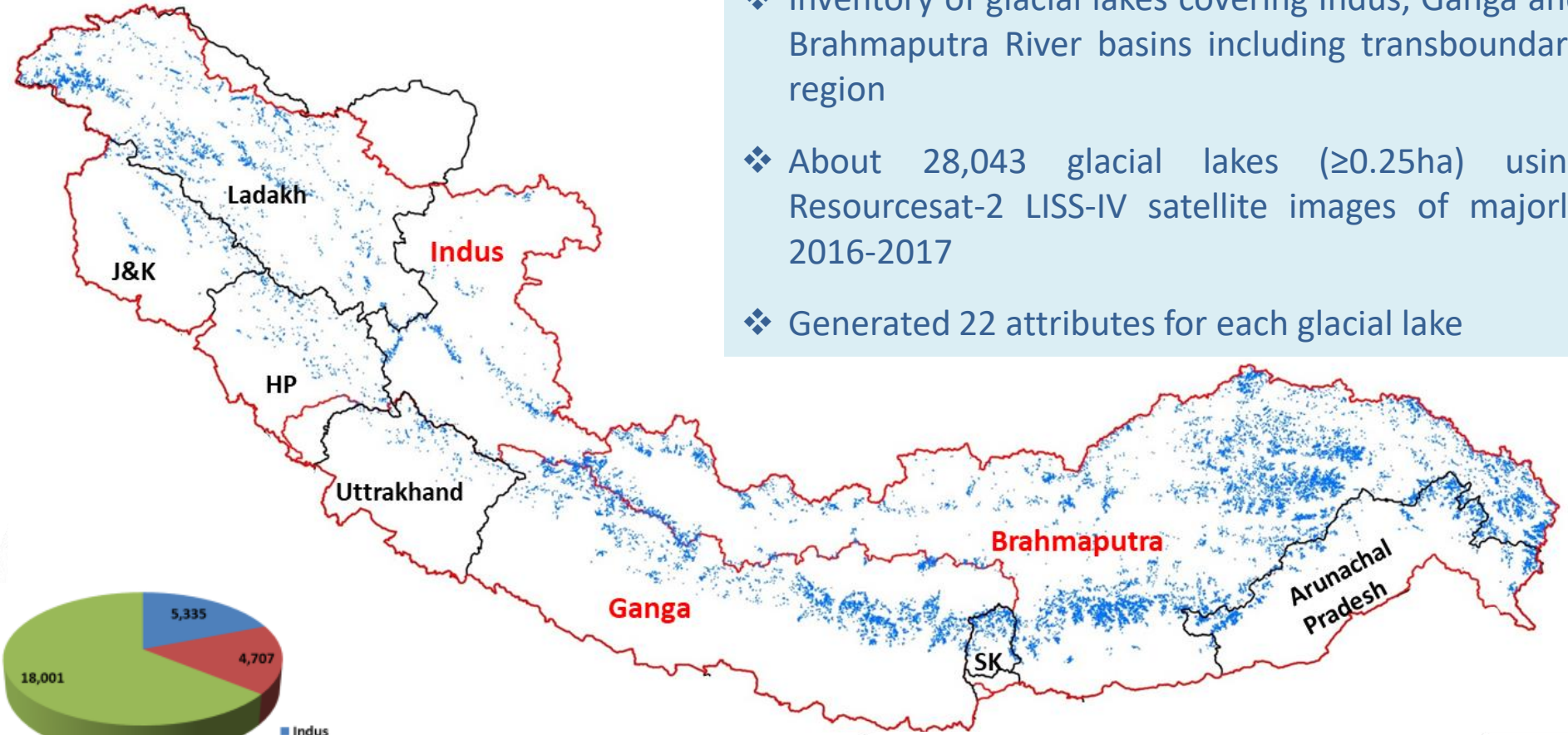
Updated Database of Himalayan Glacier Lakes

Glacier and Glacier Lake Mapping Using Remote Sensing Data

- Recent GLOF events like Pareechu(2005), Kedarnath(2013) created havoc for the people living in the downstream reaches
- These events indicate even small glacial lakes can have devastating effect when combined with extreme rainfall events
- It is important to have inventory of small glacial lakes in entire Himalayas

Glacier and Glacier Lake Mapping Using Remote Sensing Data

- Inventory of glacial lakes covering Indus, Ganga and Brahmaputra River basins including transboundary region
- About 28,043 glacial lakes (≥0.25ha) using Resourcesat-2 LISS-IV satellite images of majorly 2016-2017
- Generated 22 attributes for each glacial lake



Glacier and Glacier Lake Mapping Using Remote Sensing Data

Attribute Data

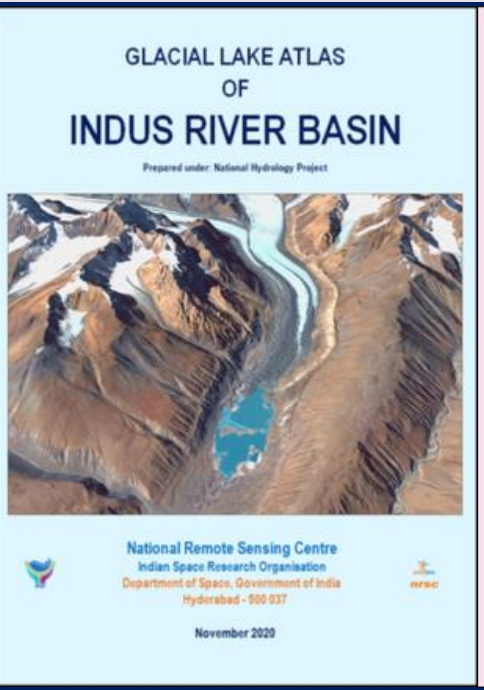
Hydrological, Topographical and other attributes for Glacial Lakes

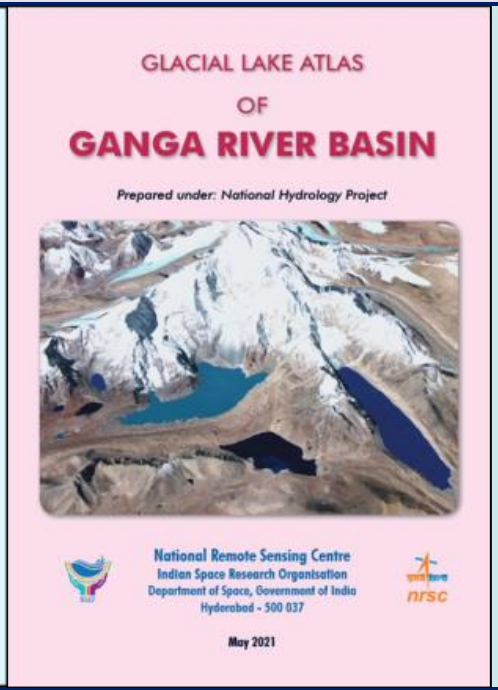
S.No	Database Fields	Type	Format / Unit	Lake Attribute
1	ID No	String	Text	0152H1103771
2	Toposheet 250K	String	Text	52H
3	Toposheet 50K	String	Text	52H11
4	Latitude*	Float	Decimal Degree	32.499
5	Longitude*	Float	Decimal Degree	77.547
6	Basin	String	Text	Indus
7	Subbasin	String	Text	Chenab
8	River	String	Text	Chandra River
9	Type (GL/WB)	String	Text	Glacial Lake
10	Name	String	Text	Samudra Tapu Lake
11	Glacial Lake Type	String	Text	M(e): End-moraine Dammed Lake
12	Surface Area	Float	ha	128.69
13	Length	Float	Km	2.381
14	Mean Width	Float	Km	0.821
15	Elevation	Integer	m (amsl)	4150
16	Aspect	String	Text	SE
17	Source of Database	String	Text	RS-2 LISS-IV
18	Date of Pass	Date	DDMMYYYY	05112016
19	Source of Elevation	String	Text	Cartosat DEM
20	Region	String	Text	India
21	State	String	Text	Himachal Pradesh
22	District	String	Text	Lahul & Spiti

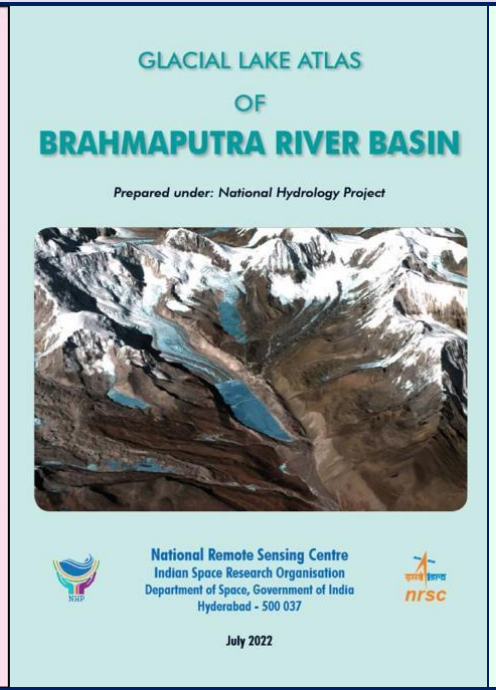
Glacier and Glacier Lake Mapping Using Remote Sensing Data

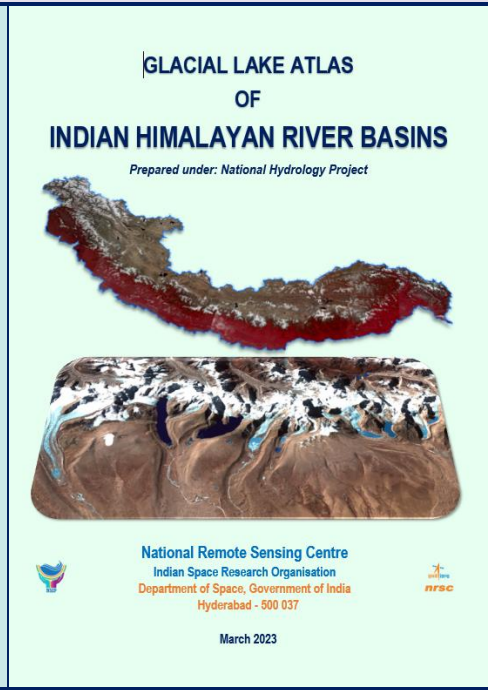
- **Using inventory of glacial lakes database, Glacial Atlases were released**
  - ✓ **Indus on 02-Dec-2020**
  - ✓ **Ganga on 29-Jun-2021 and**
  - ✓ **Brahmaputra on 05-Jul-2022**
  - ✓ **IHR on 16-Mar-2023**

Downloadable from
https://www.nrsc.gov.in/Atlas_Glacial_Lake
https://nhp.mowr.gov.in/HomeNew/NHPIndexnew.aspx#

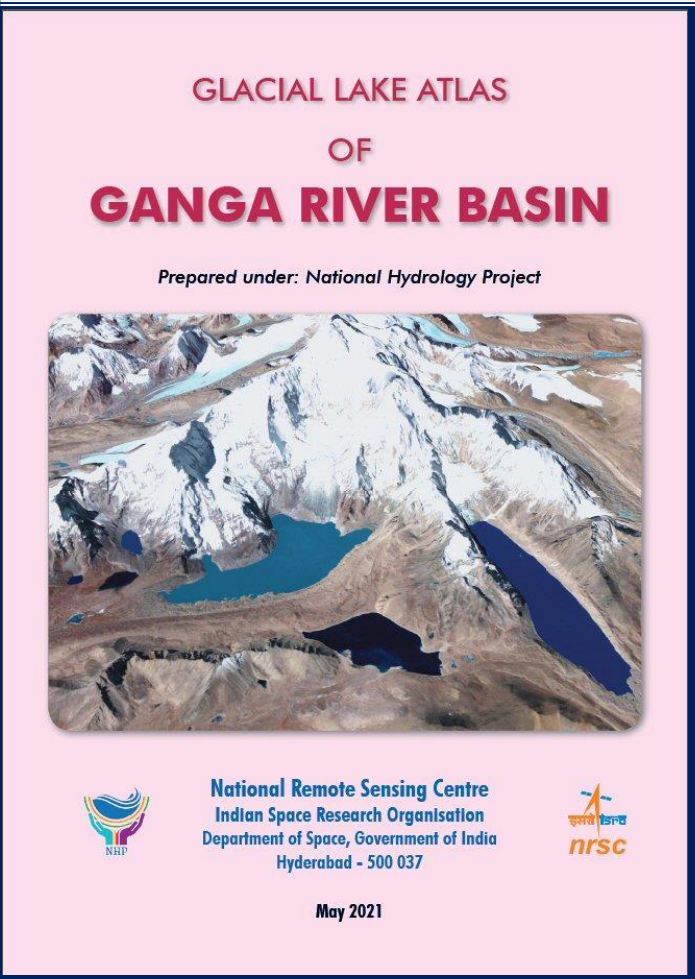








Glacier and Glacier Lake Mapping Using Remote Sensing Data



Glacial Lake Atlas of Ganga River Basin

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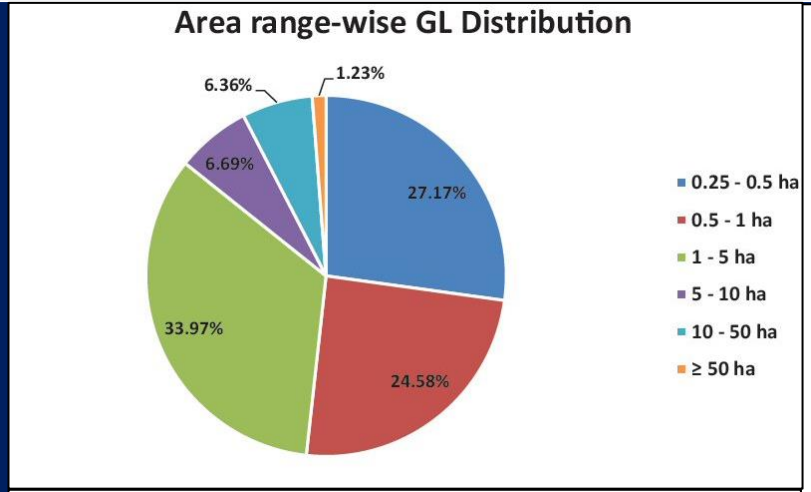
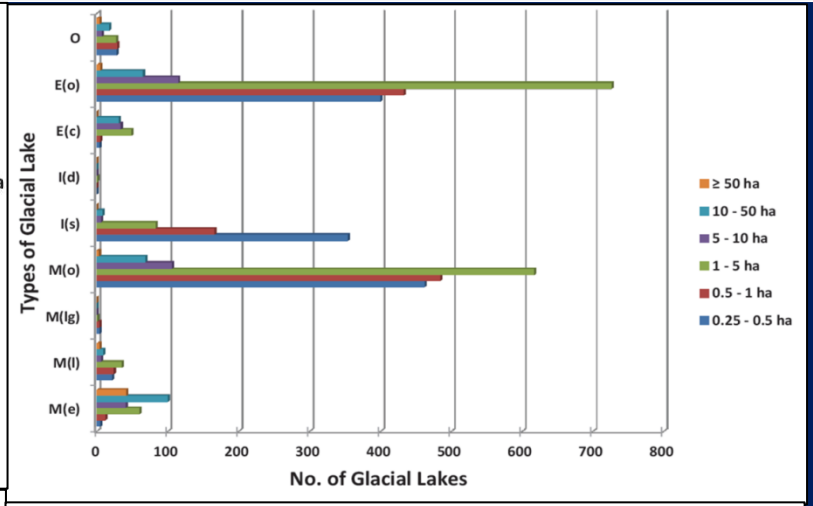
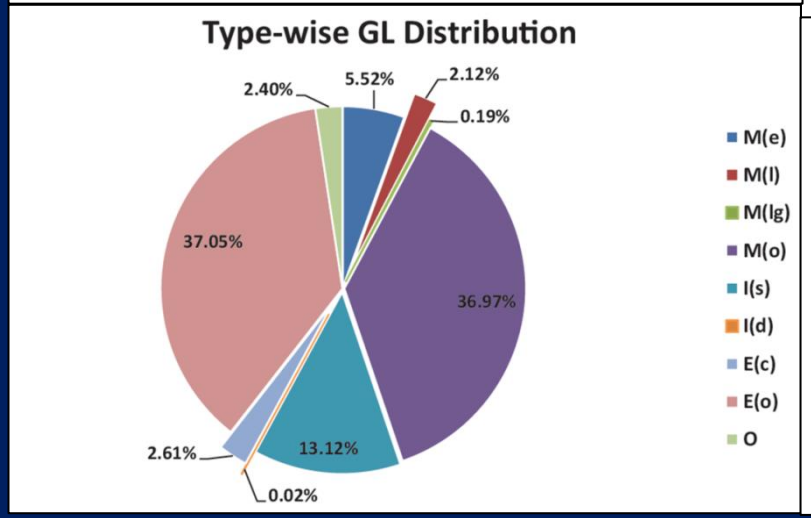
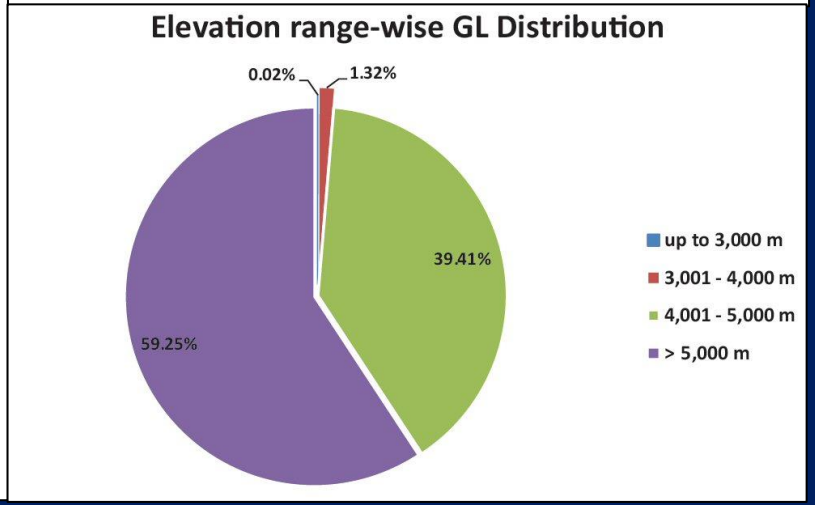
Glacier and Glacier Lake Mapping Using Remote Sensing Data

Glacial Lake Atlas of Ganga River Basin

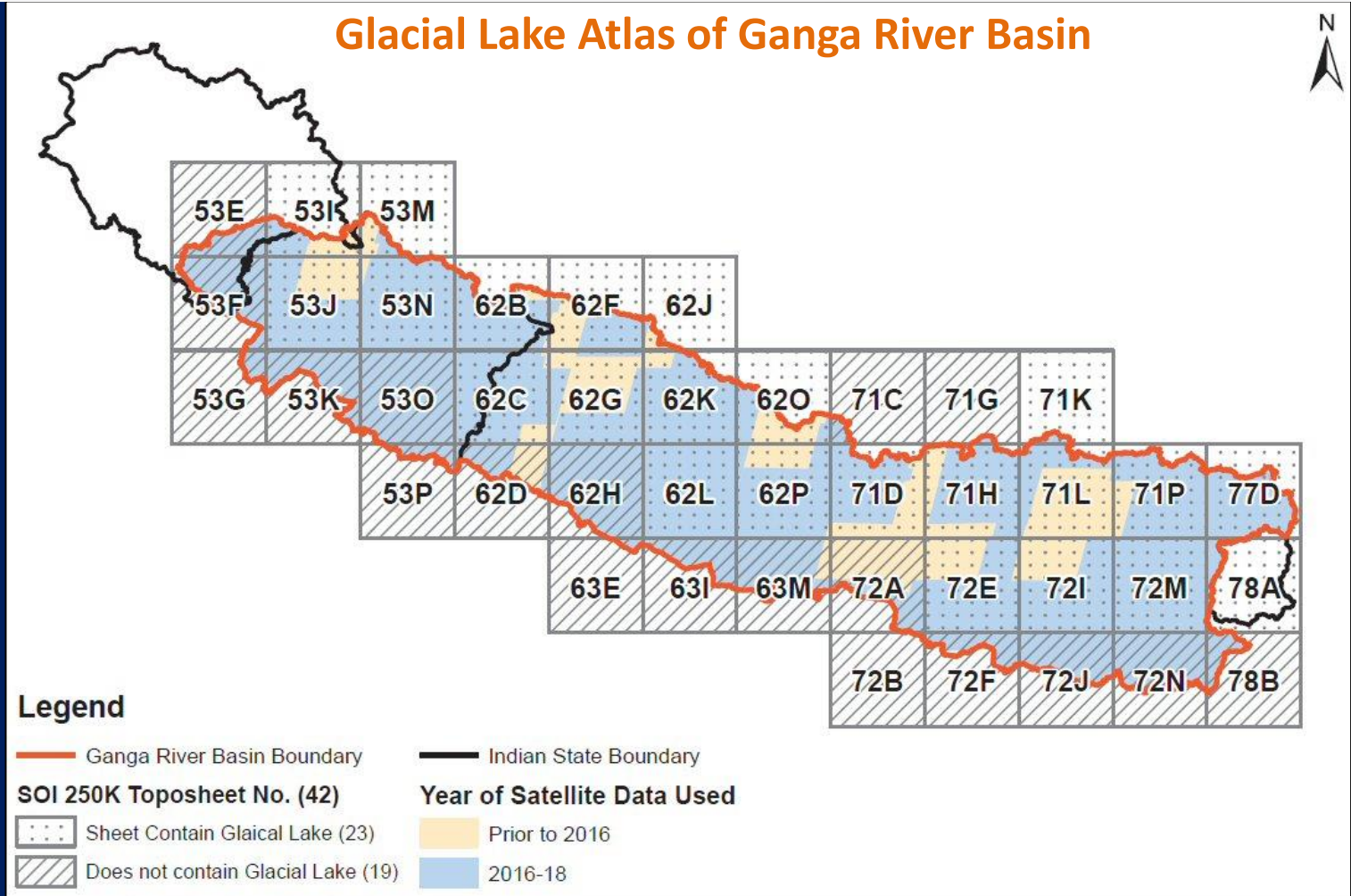






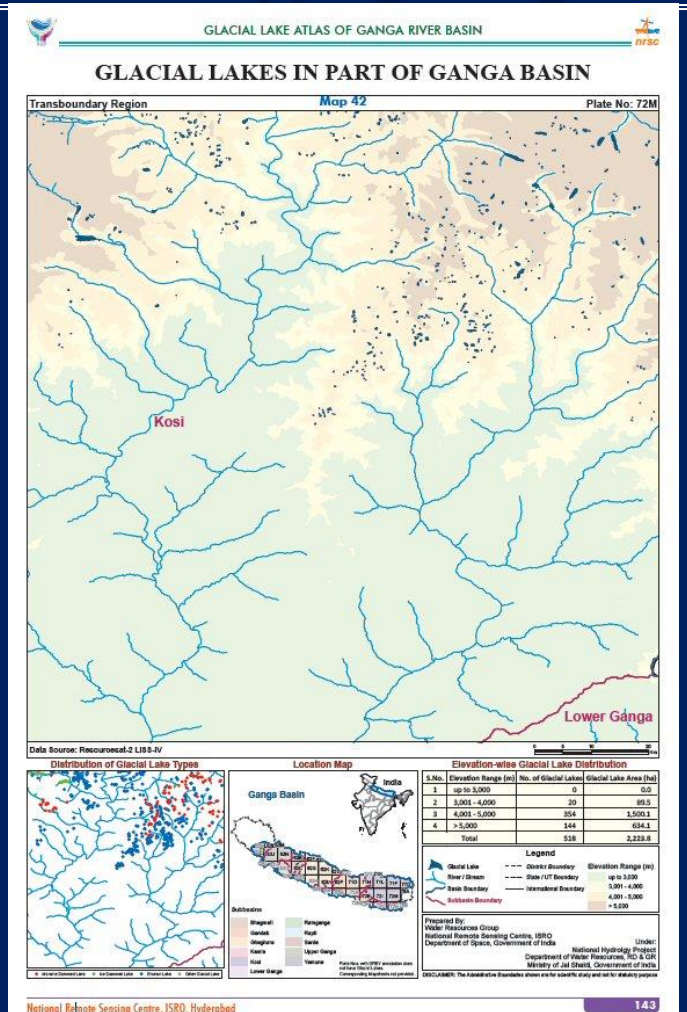


Glacier and Glacier Lake Mapping Using Remote Sensing Data



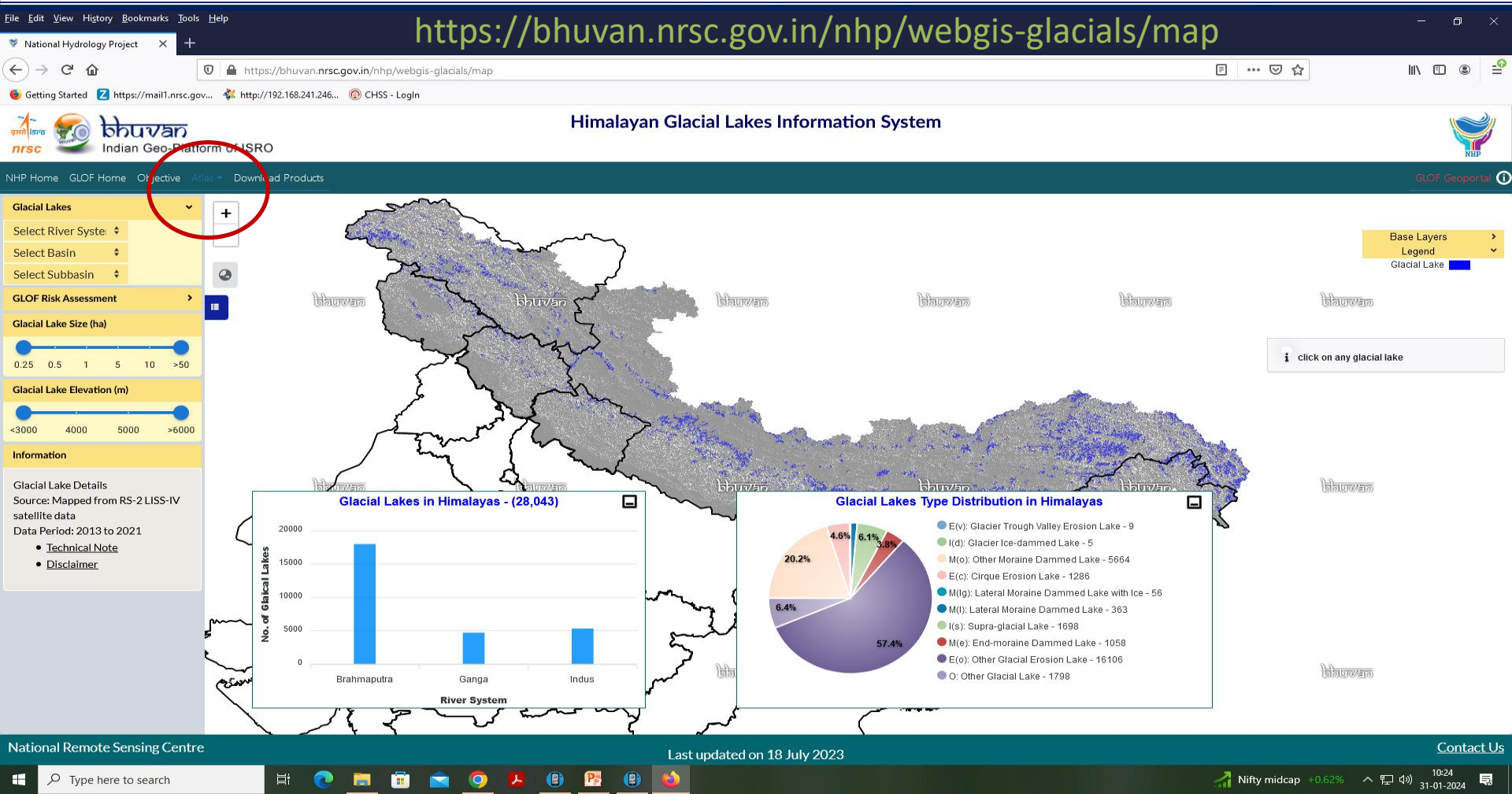
Glacier and Glacier Lake Mapping Using Remote Sensing Data

Glacial Lake Atlas of Ganga River Basin



Glacier and Glacier Lake Mapping Using Remote Sensing Data

https://bhuvan.nrsc.gov.in/nhp/webgis-glacials/map



https://bhuvan.nrsc.gov.in/nhp/webgis-glacials/map

Himalayan Glacial Lakes Information System

bhuvan Indian Geo-Platform of ISRO

NHP Home | GLOF Home | Objective | Atlas | Reports | Download Products | GLOF Geoportal

Glacial Lakes

Ganga

Select Basin

Select Subbasin

GLOF Risk Assessment

Glacial Lake Size (ha)

0.25 0.5 1 5 10 >50

Glacial Lake Elevation (m)

<3000 4000 5000 >6000

Information

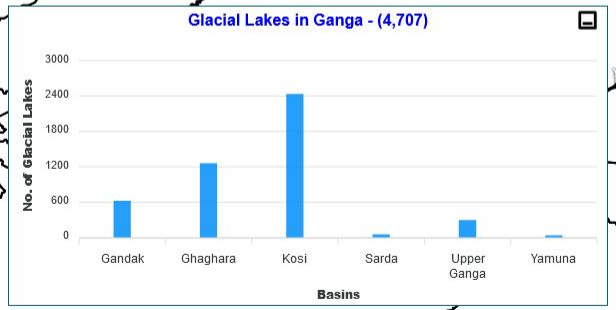
Glacial Lake Details
Source: Mapped from RS-2 LISS-IV satellite data
Data Period: 2013 to 2021

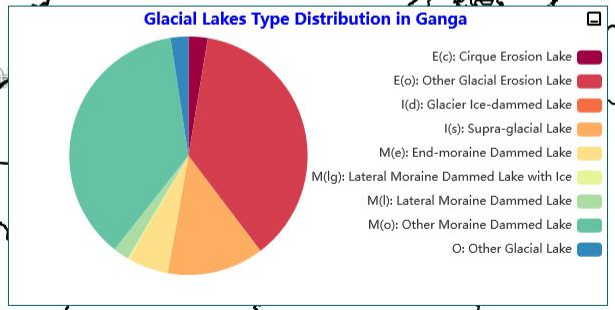
- Technical Note
- Disclaimer

Ganga

click on any glacial lake

Base Layers
Legend
Glacial Lake





National Remote Sensing Centre

Contact Us

28°C Haze 12:41 28-07-2025


THANK YOU