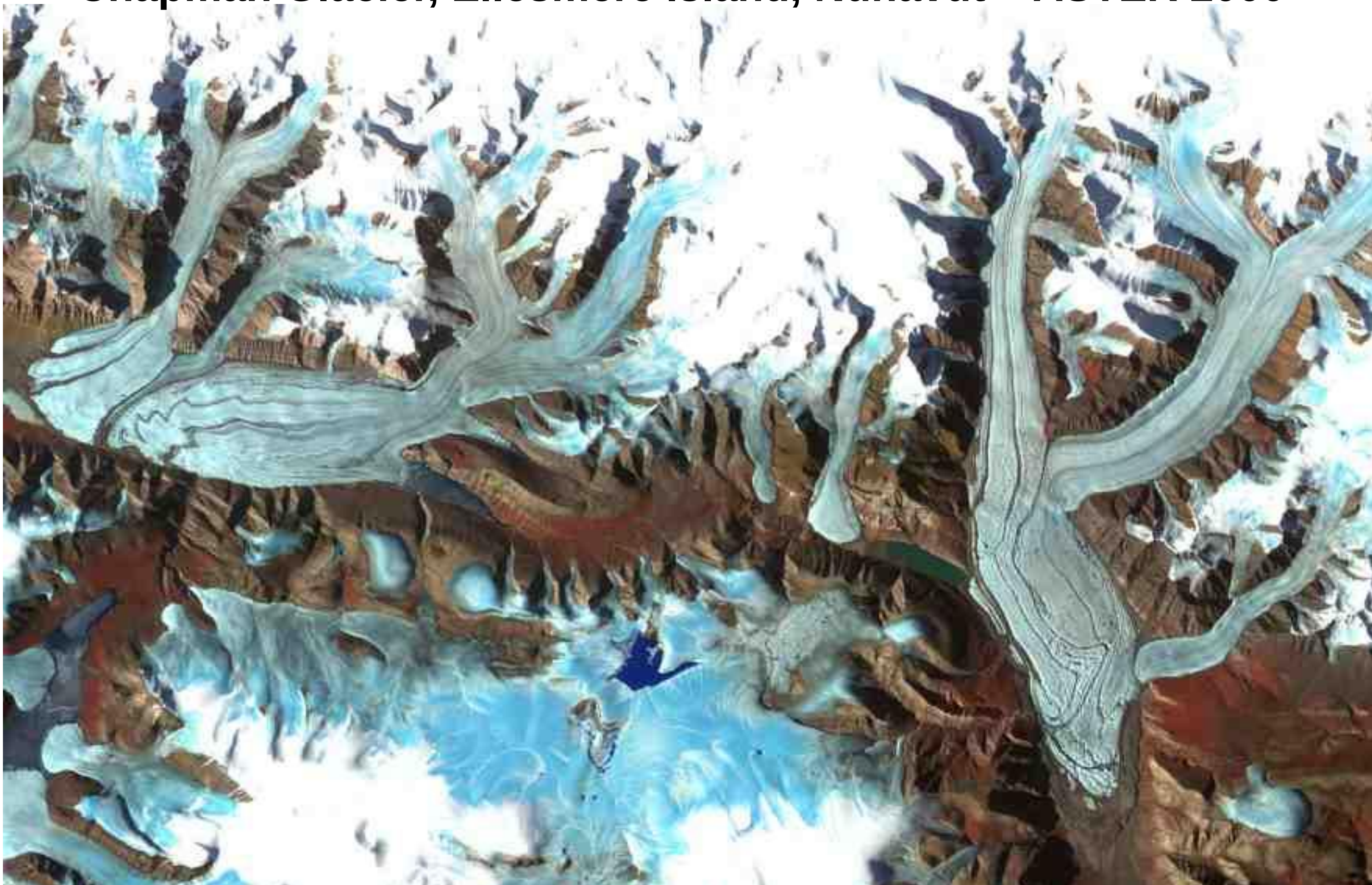
Remote Sensing of Glaciers

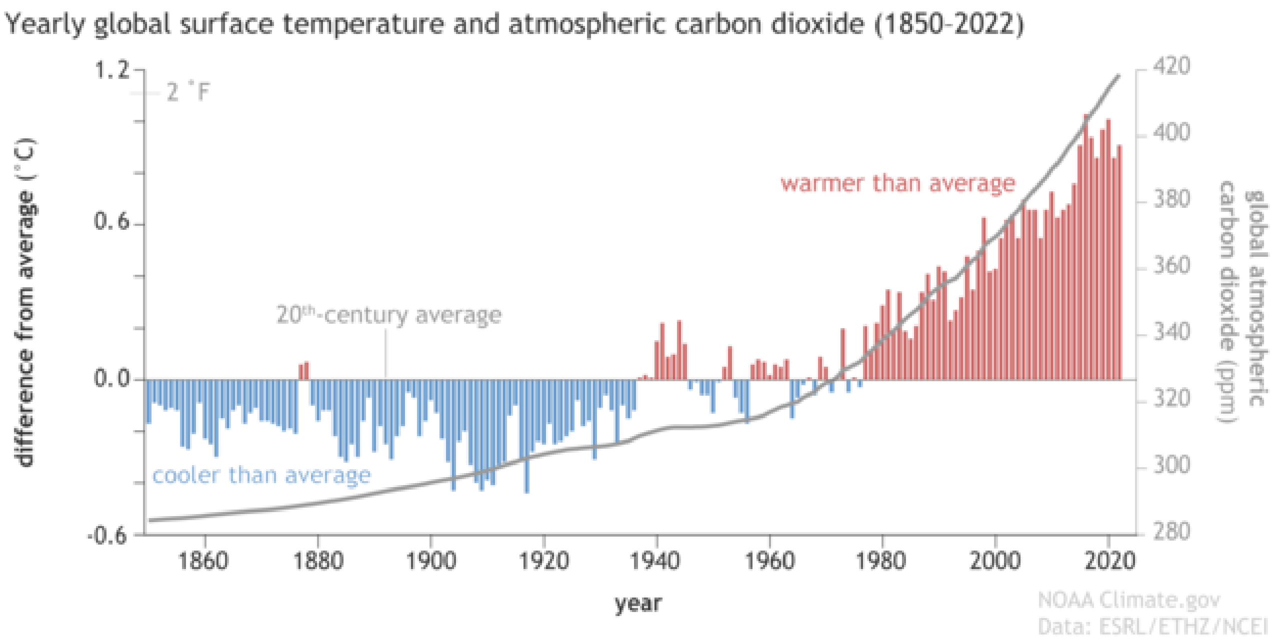
Chapman Glacier, Ellesmere Island, Nunavut – ASTER 2000

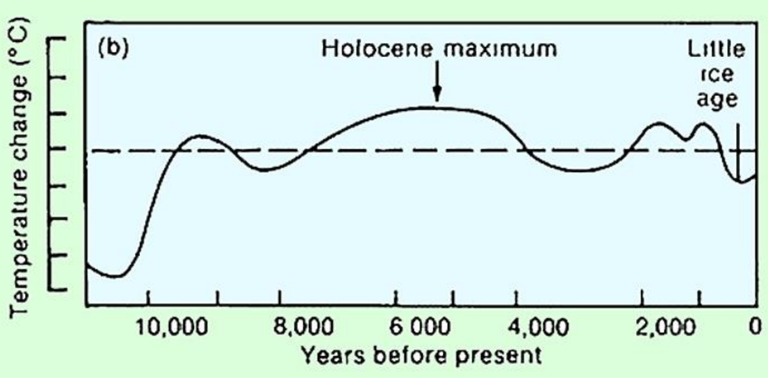


Global Temperatures

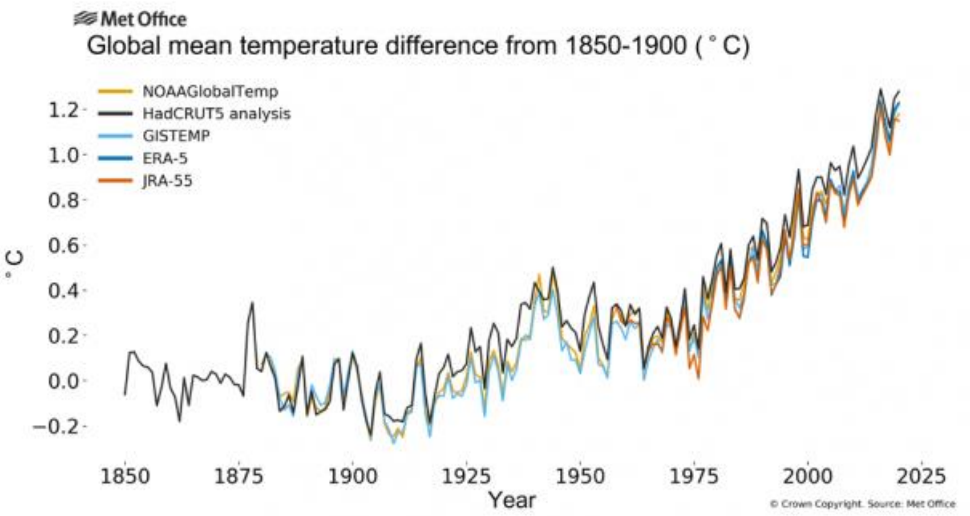
0BC -> / 1850AD->

effect on glaciers …





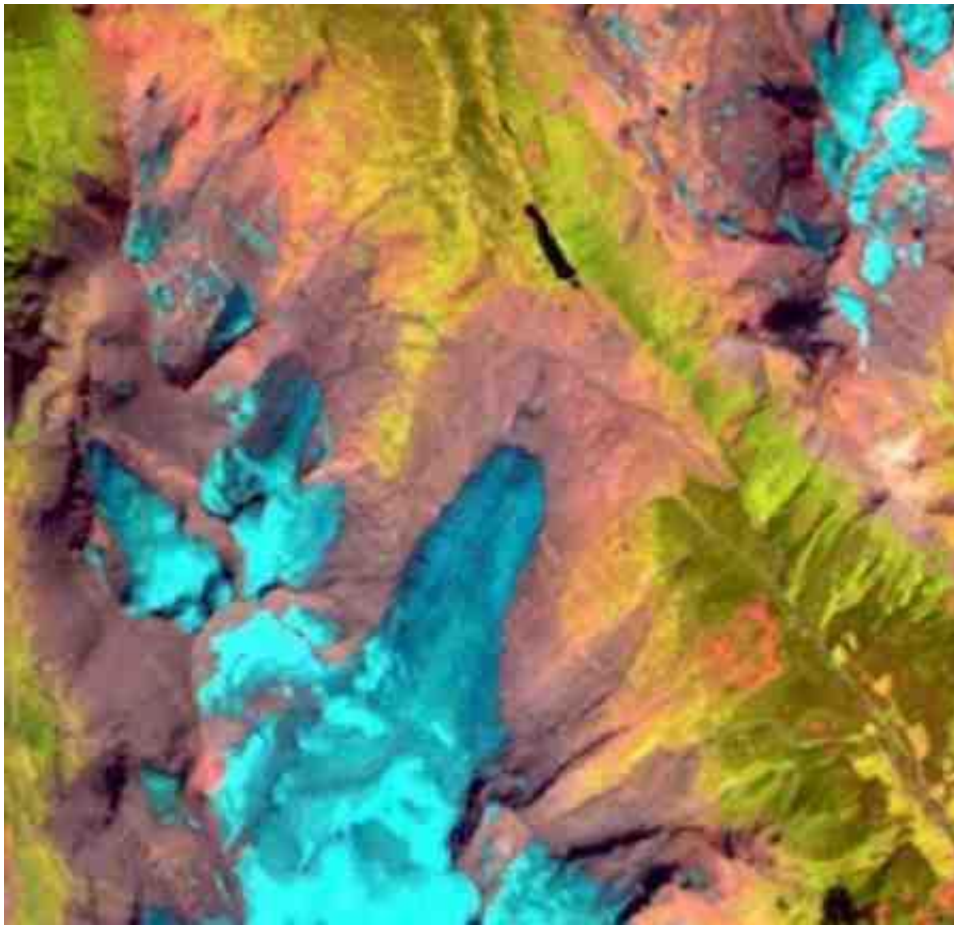
Schematic diagram of global temperature variations during the last ten thousand years



Landsat Images (since 1972 / 1984)
Most glaciers are remote ….

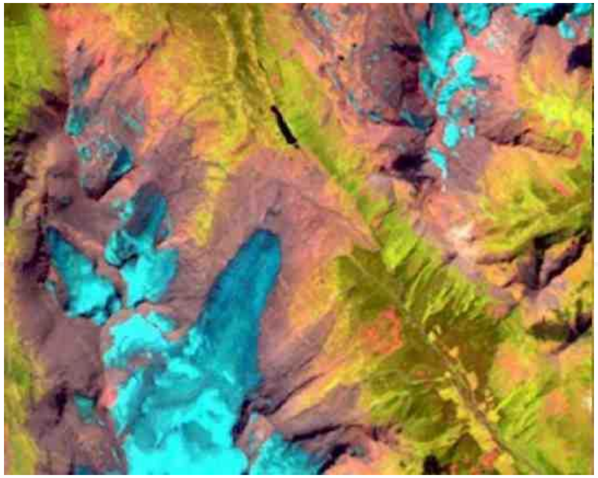
Note mark of Little Ice Age ~ 1850

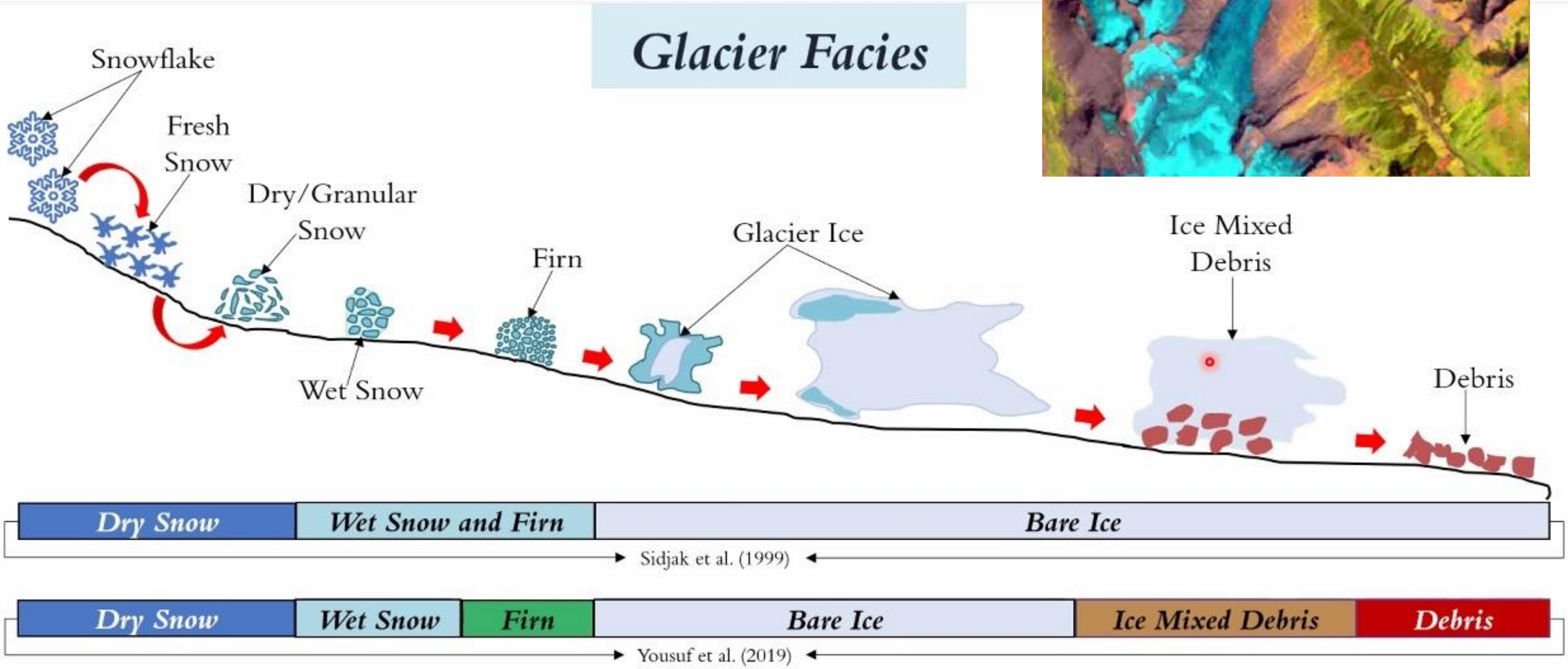
Castle Glacier- SW of McBride



Note late lying snow cover
Muskwa-Kechika-northern BC

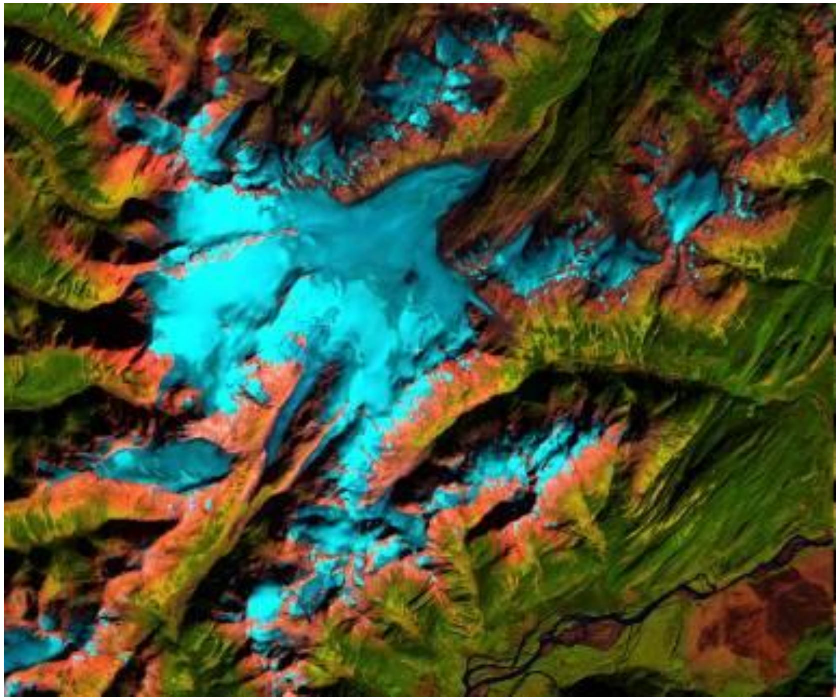
See facies on previous slide



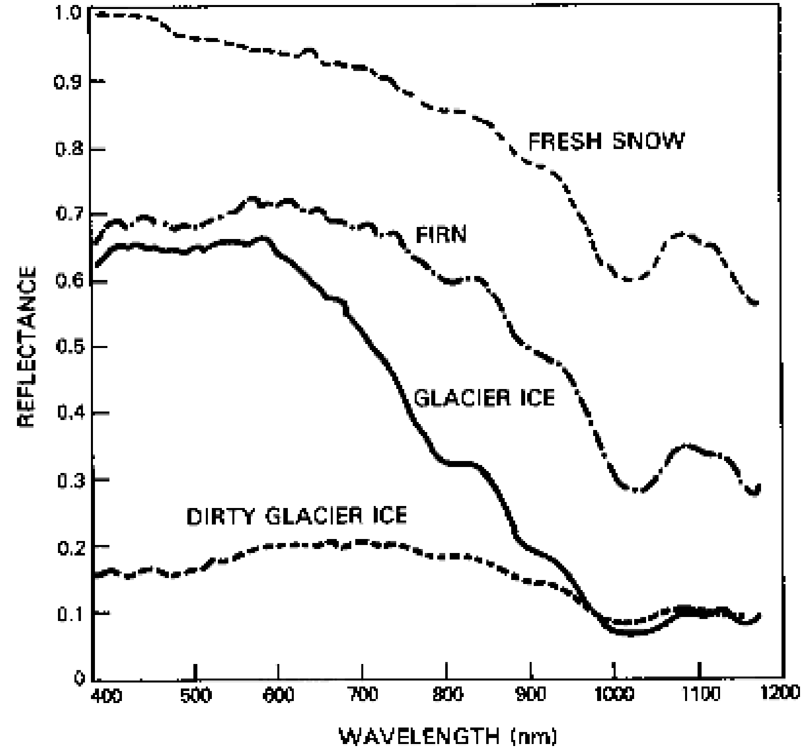


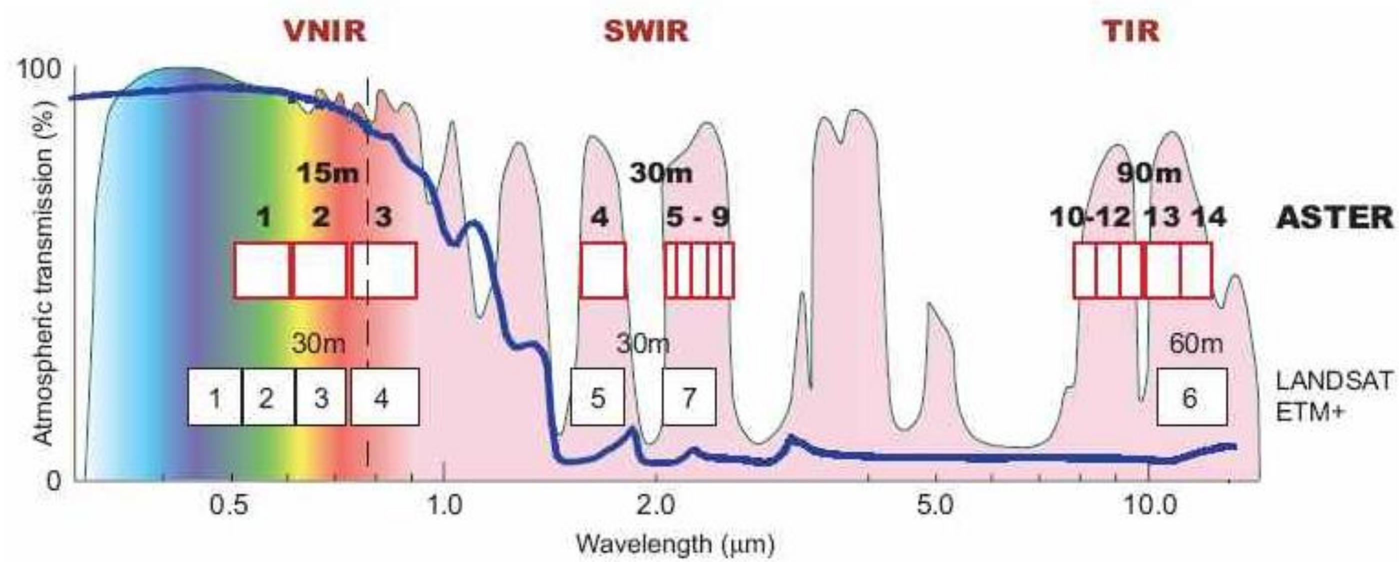
Glacier facies are natural zones of distinct variations of snow and ice which are formed as a result of the evolution of precipitated snow to ice, the cyclic process of ablation, refreezing, and eventually its melt.

Spectral characteristics of snow and ice

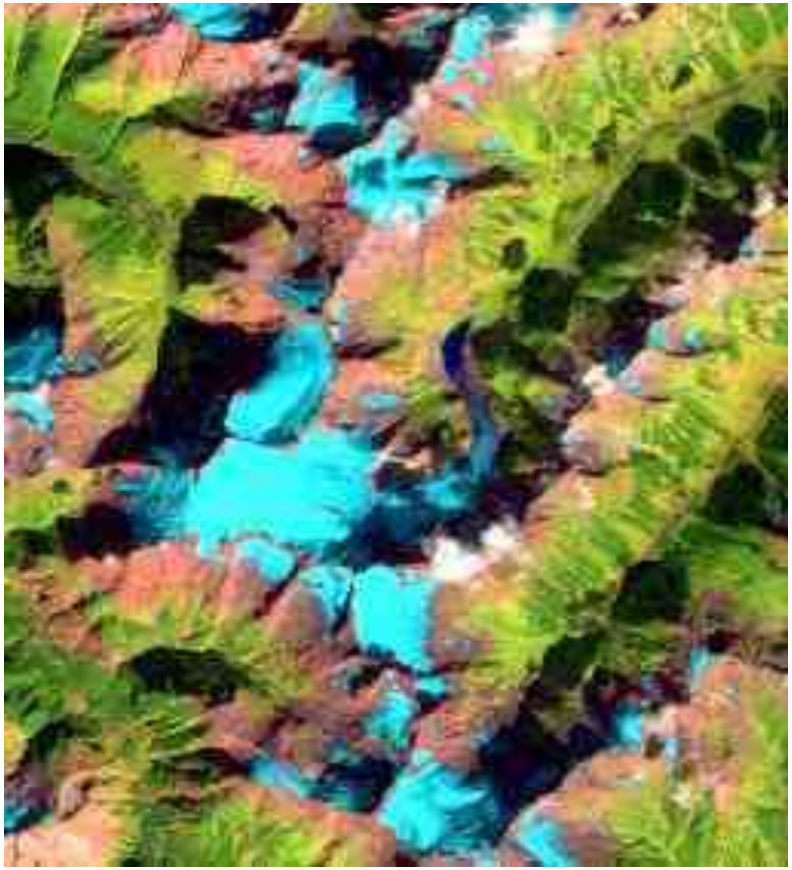


TM543





The spectral curve explains why glaciers look blue-green on a 5-4-3 composite (why?) .. and enables distinguishing snow/ice from clouds compared to a normal composite.. (why?)

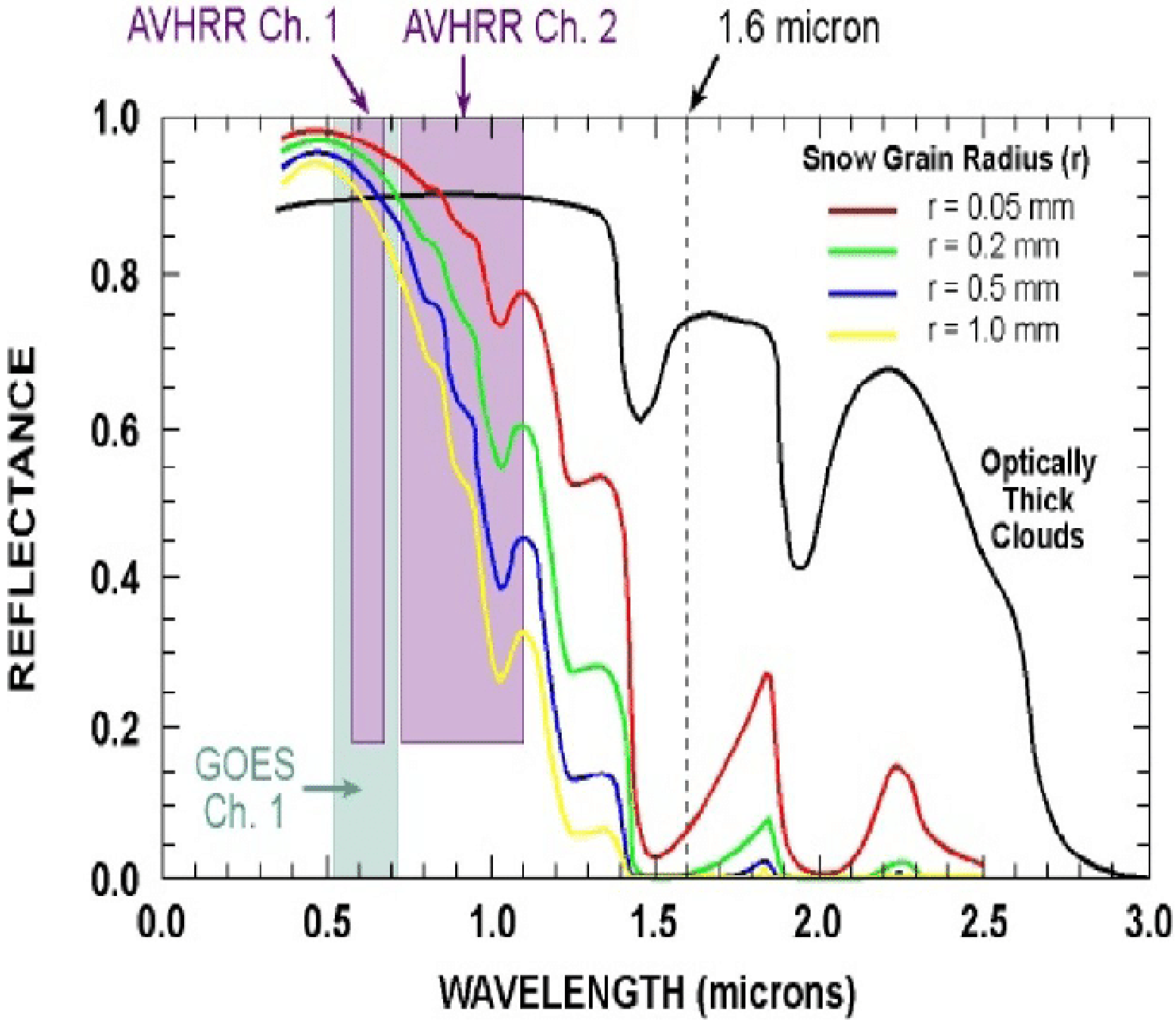


Mid-IR/Near-IR-Red

Red-Green-Blue

http://asterweb.jpl.nasa.gov/gallery-detail.asp?name=Aletsch

Snow versus clouds

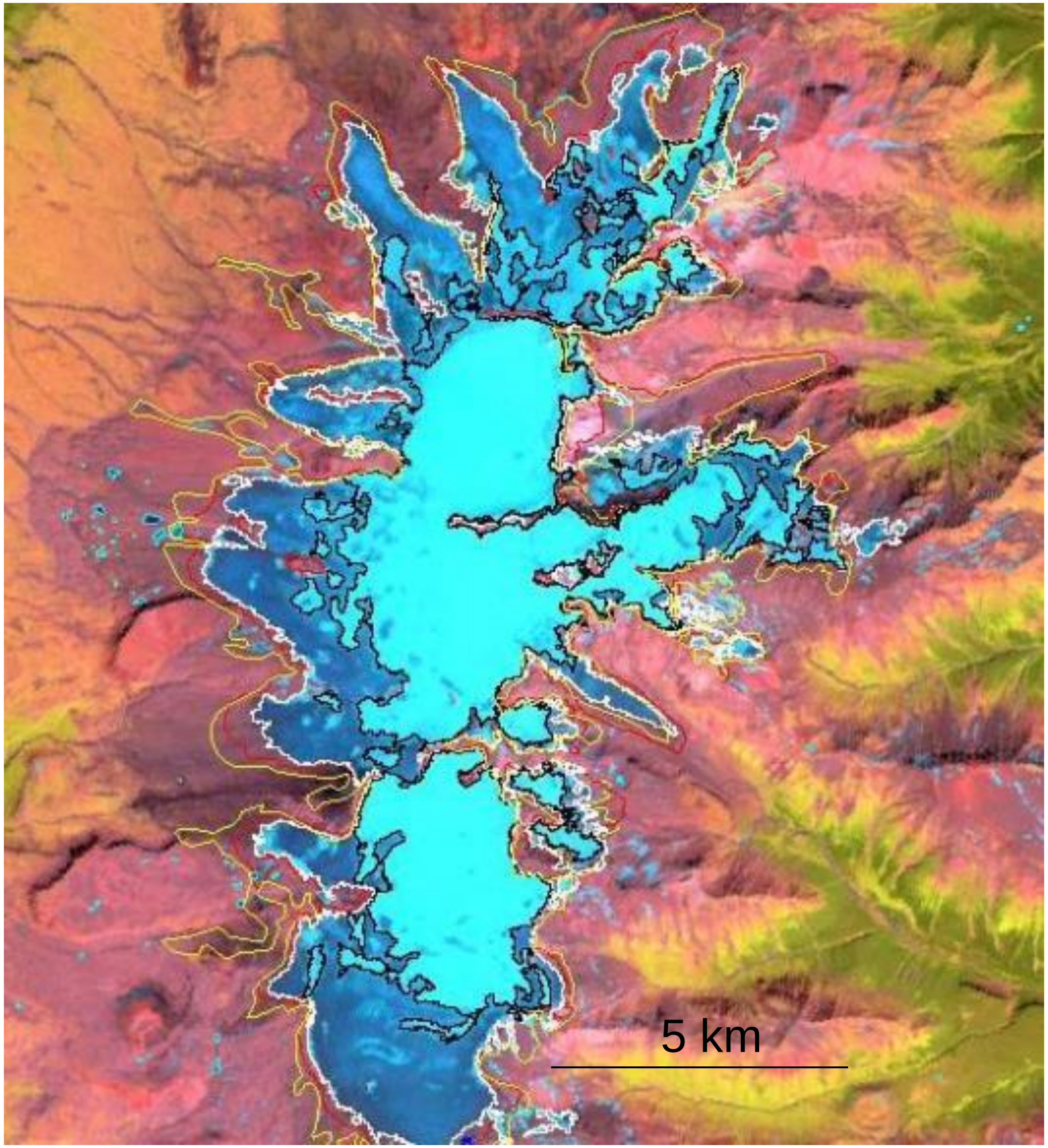


1. Classification: glacier areas 2000 - supervised classification

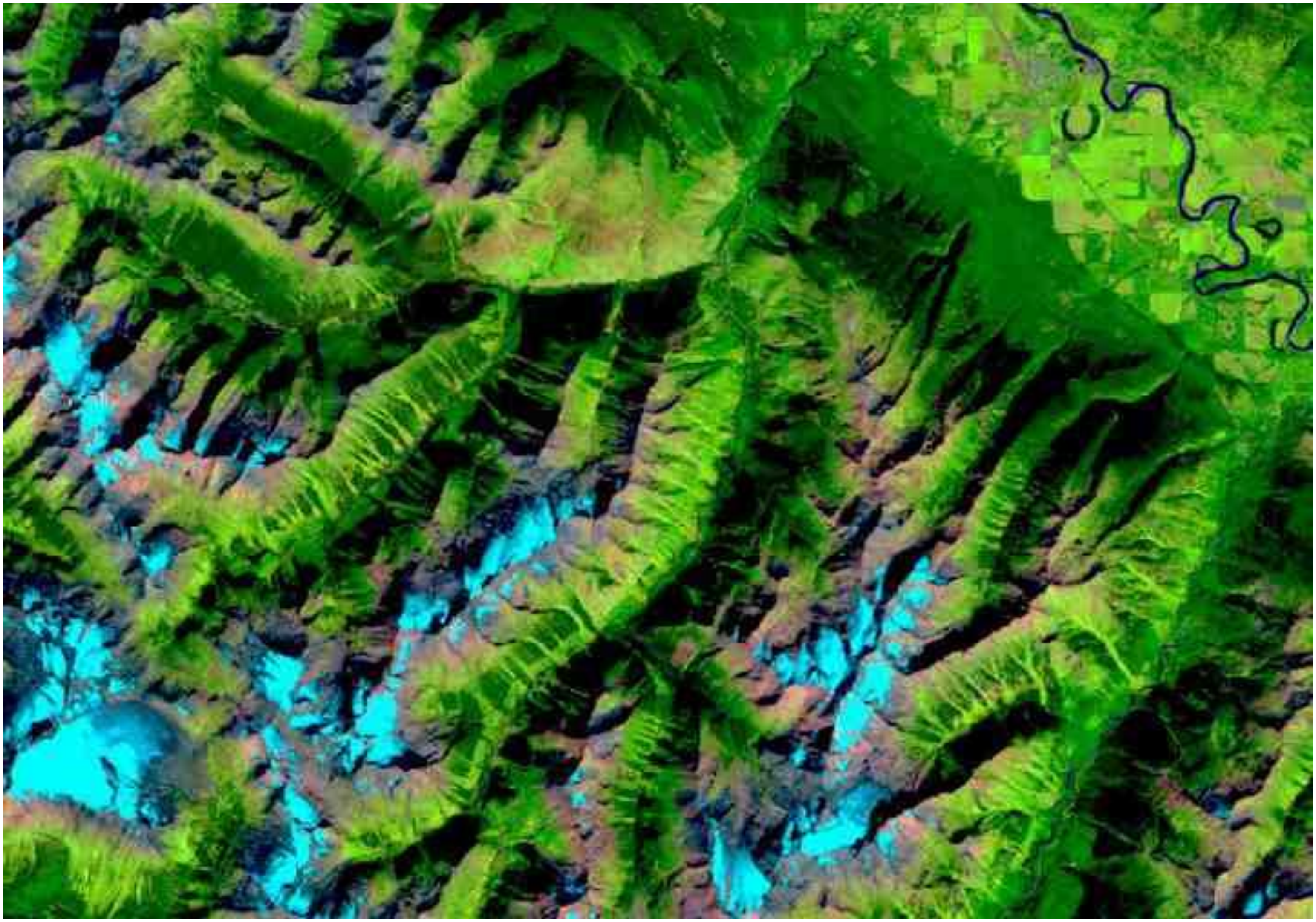
Edziza: extents from Landsat 2000

Training on ablation / accumulation areas

Extra Vectors: NTDB 1966, BC TRIM 1985,

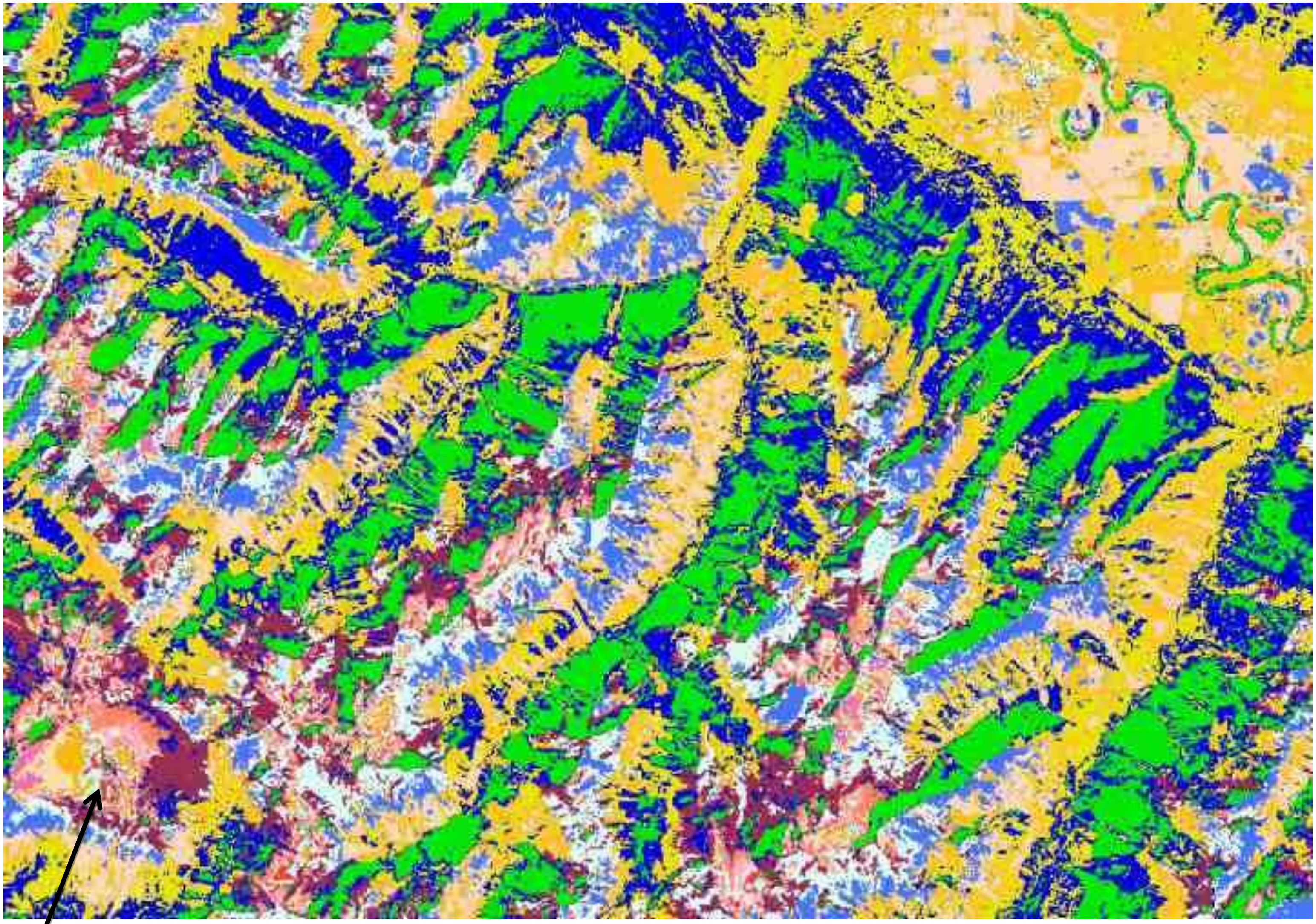


Unsupervised classification: McBride OLI image including Kristi Glacier (SW corner)



Note: its difficult to distinguish between snow covering glaciers and late lying snow on land except by size (sieve) and perhaps modelling from location

Image classification - Unsupervised



These orange-pink clusters, not the brown one (forefield) – why so many - 6?

2. Normalised Difference Snow Index

(NDSI) = (G-SWIR)/(G+SWIR)

NDSI (TM) = (2-5)/(2+5)

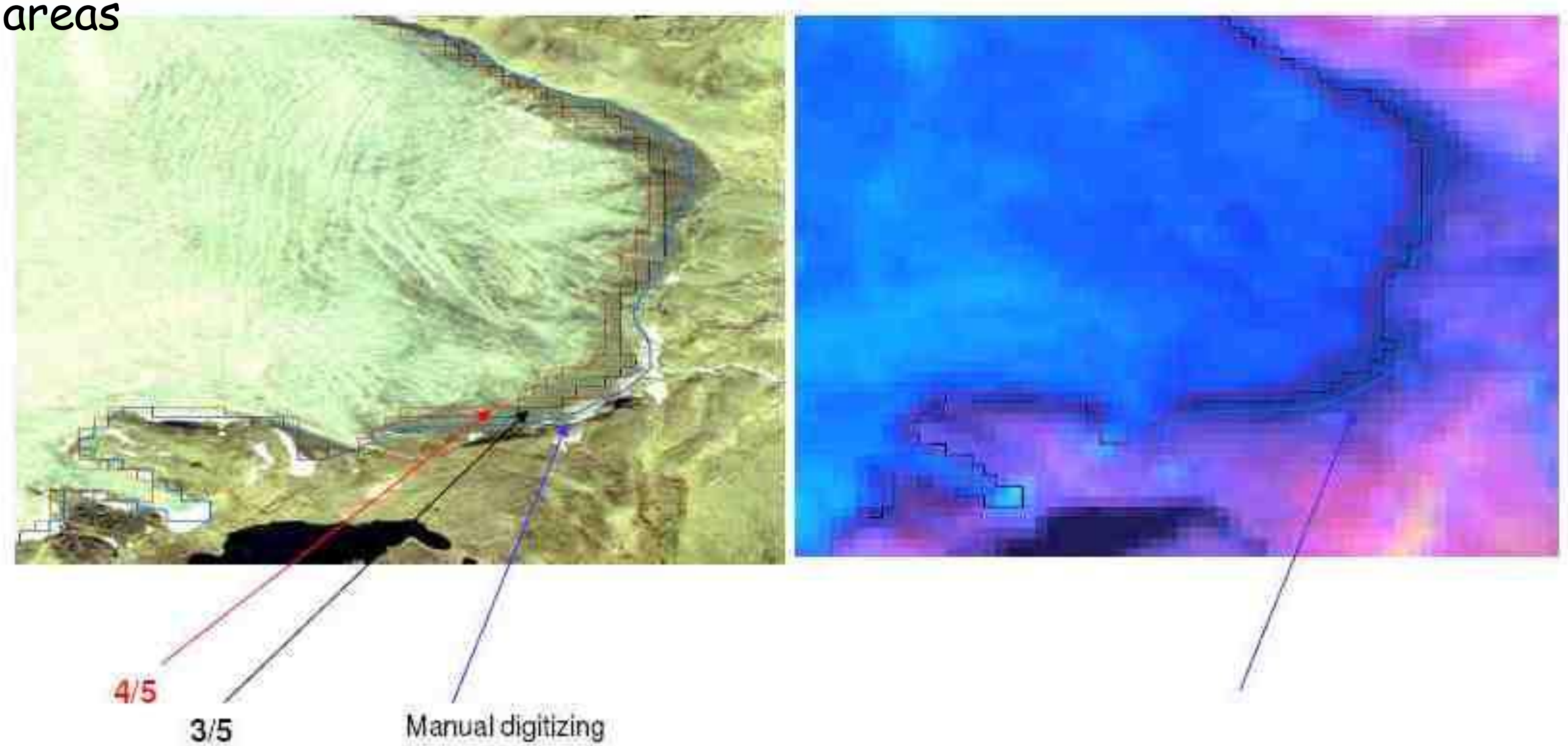
NDSI (OLI) = (3-6)/(3+6)

Method: use as threshold or input in classification

3. Ratio image - thresholding

…. NIR/SWIR band ratio TM 4 / 5 (snow/ice >1.0)

Red/SWIR TM 3/5 (snow/ice > 2.0) … 'better' for shadow areas



Snow and ice: very high in visible, very low in SWIR

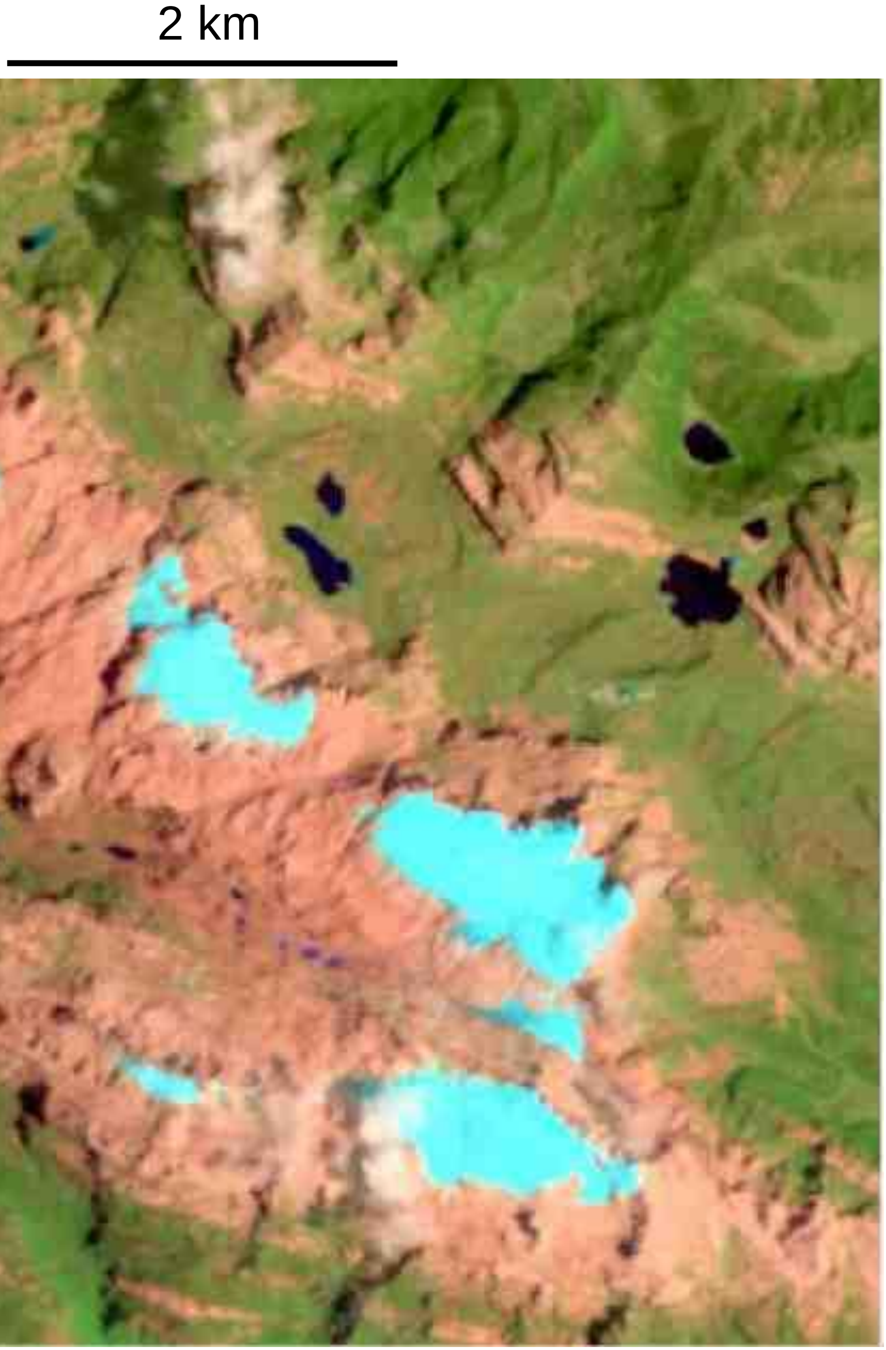
Ratio = Visible (Red) to SWIR captures snow/ice almost exclusively

- Some issues with silt-laden water, shadowed glaciers and debris cover

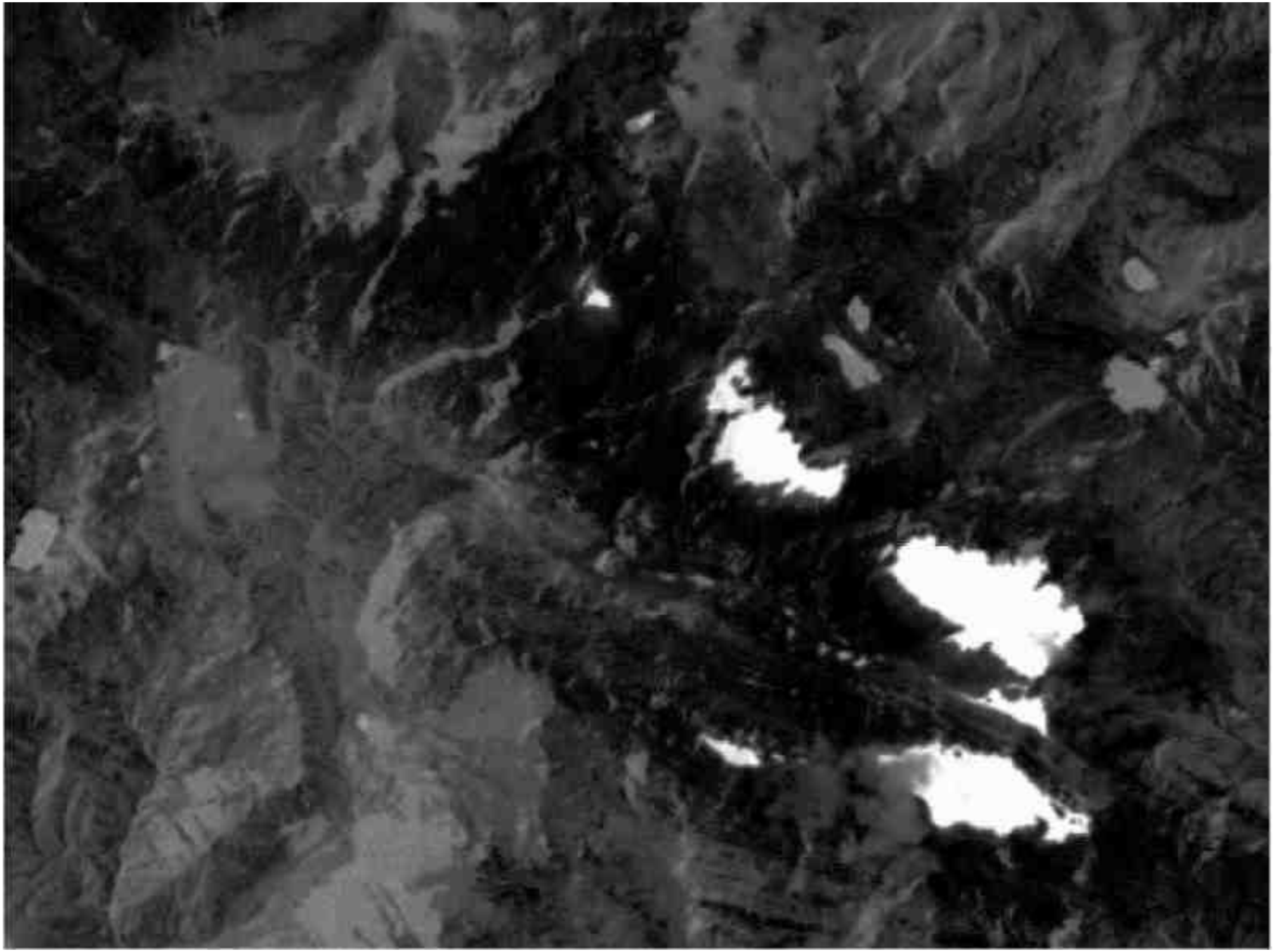
Puncak Jaya, Indonesia 4°S, 137°E elevation m. asl: 4884m

This is the highest peak in Asia, using distance from the centre of the Earth .

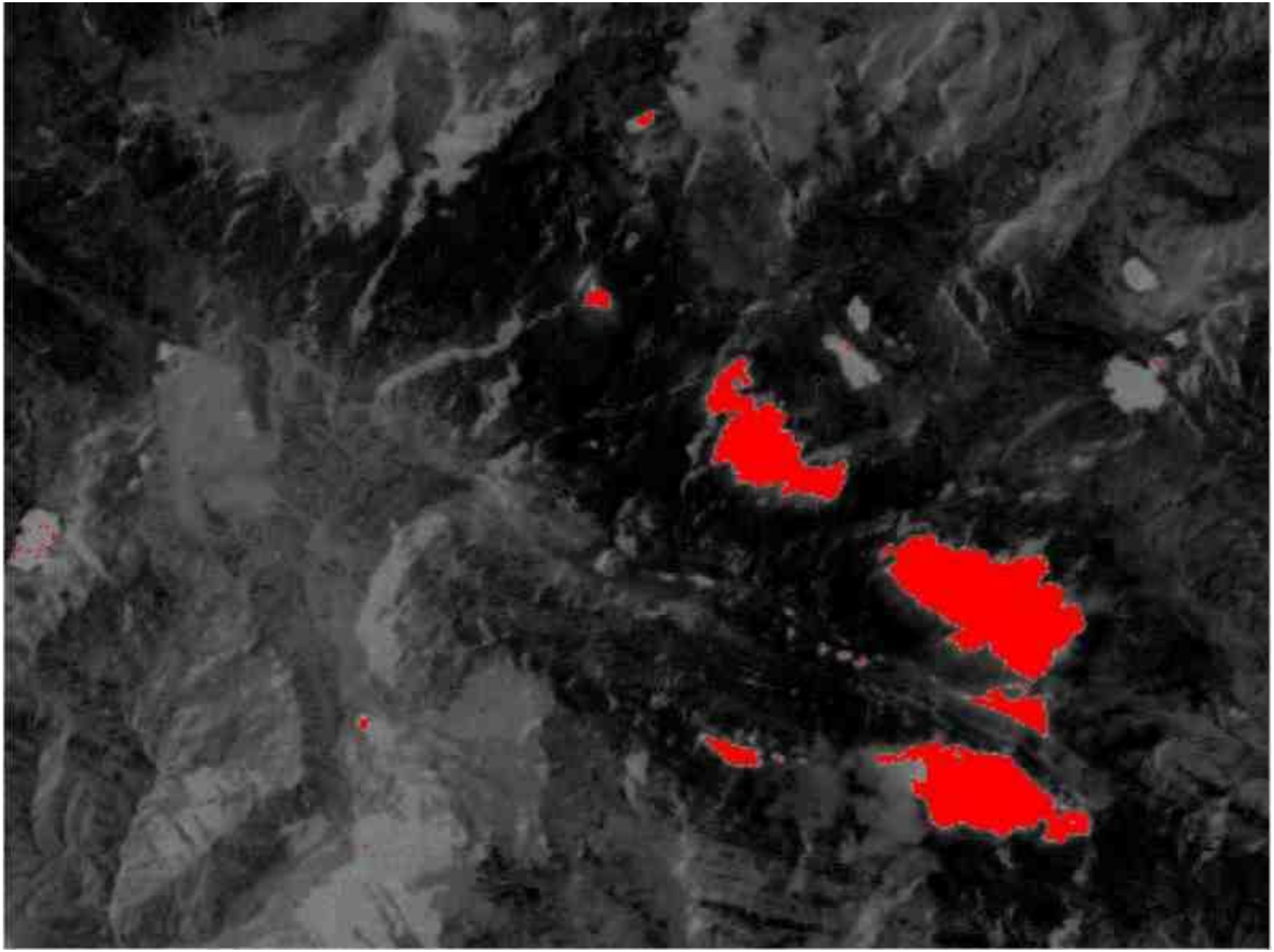
Landsat 1992



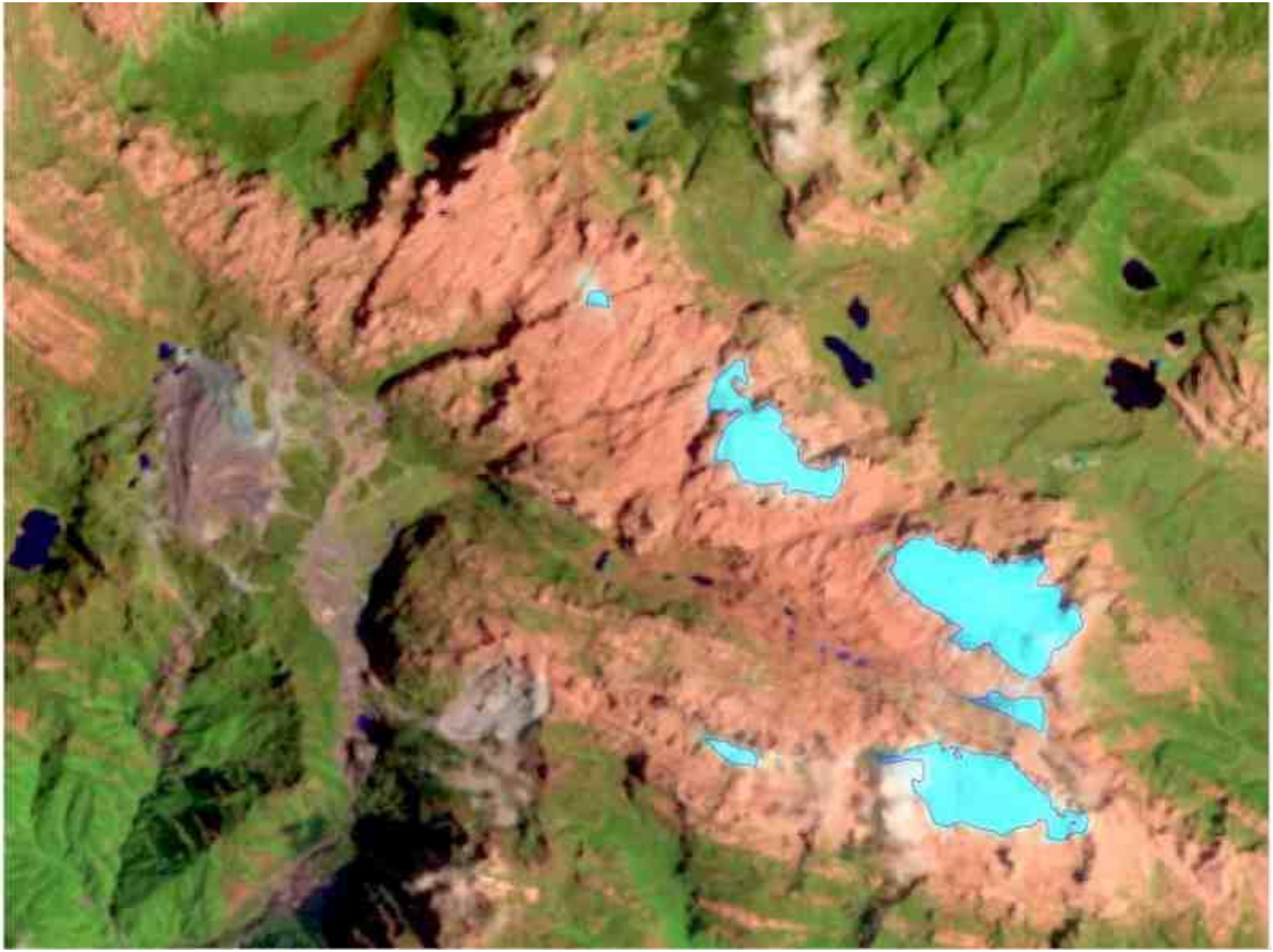
Red/SWIR ratio



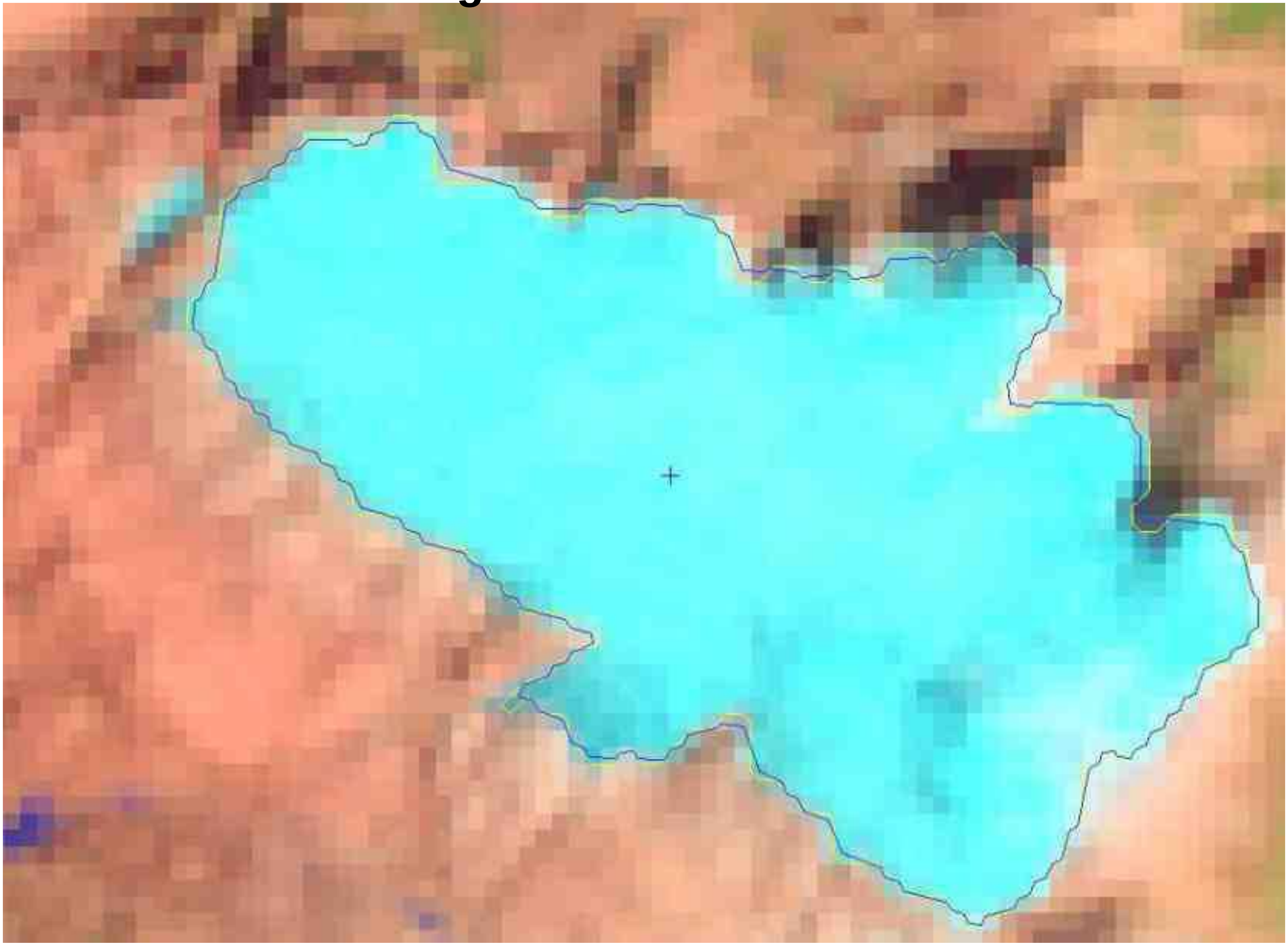
Threshold value 2.0



Convert bitmap to polygon

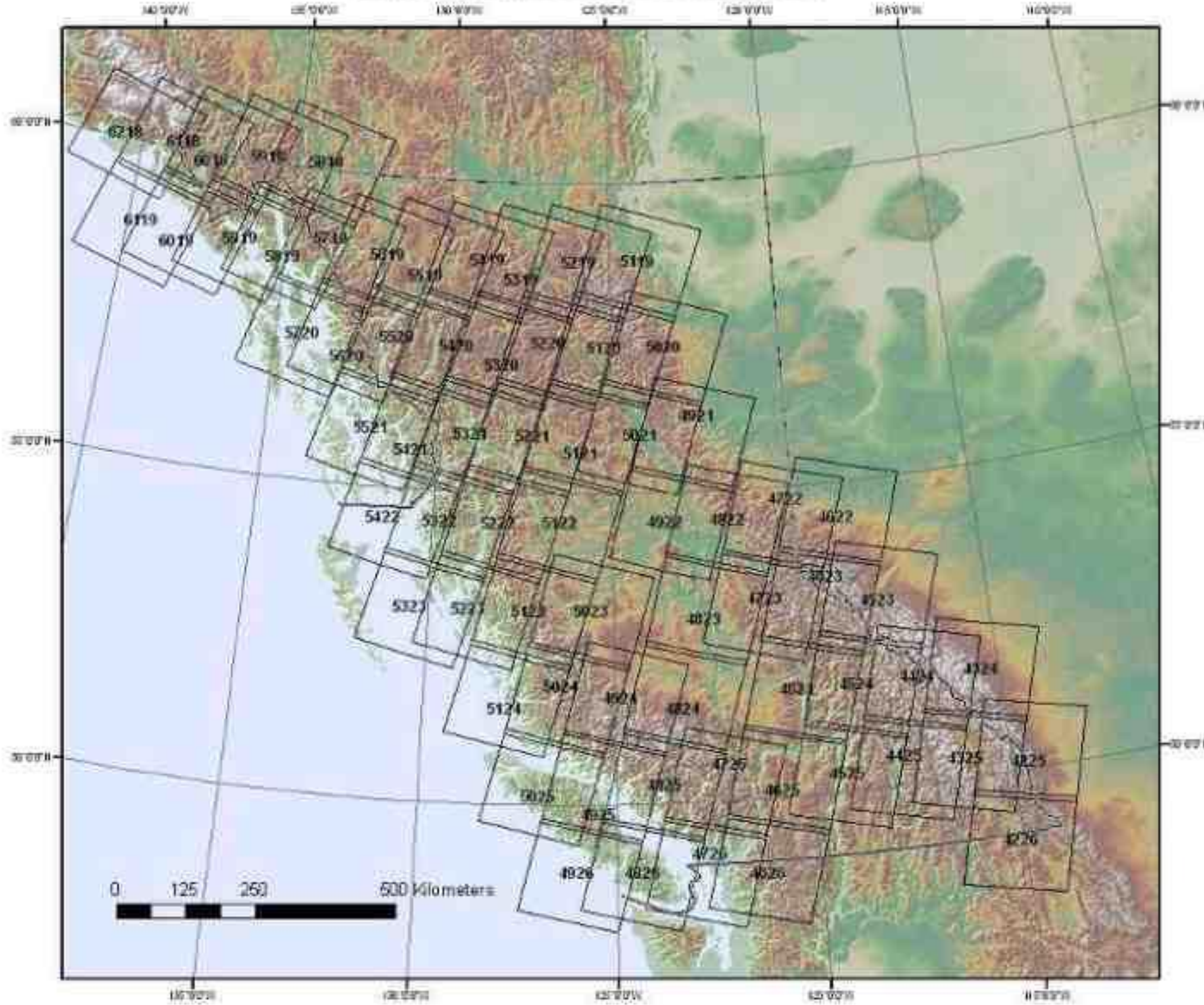


Vector smoothing

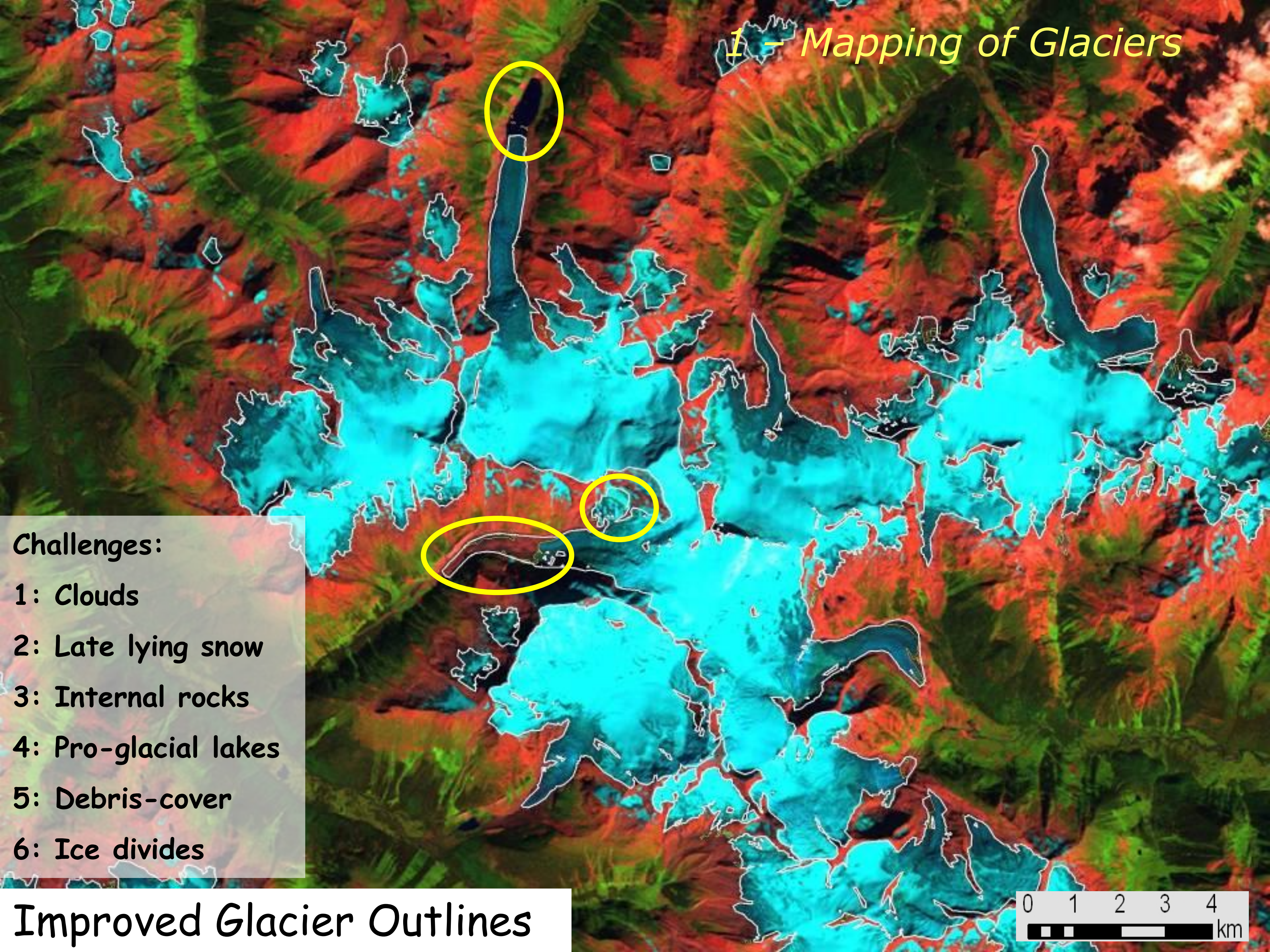


The cordilleran glaciers of western Canada

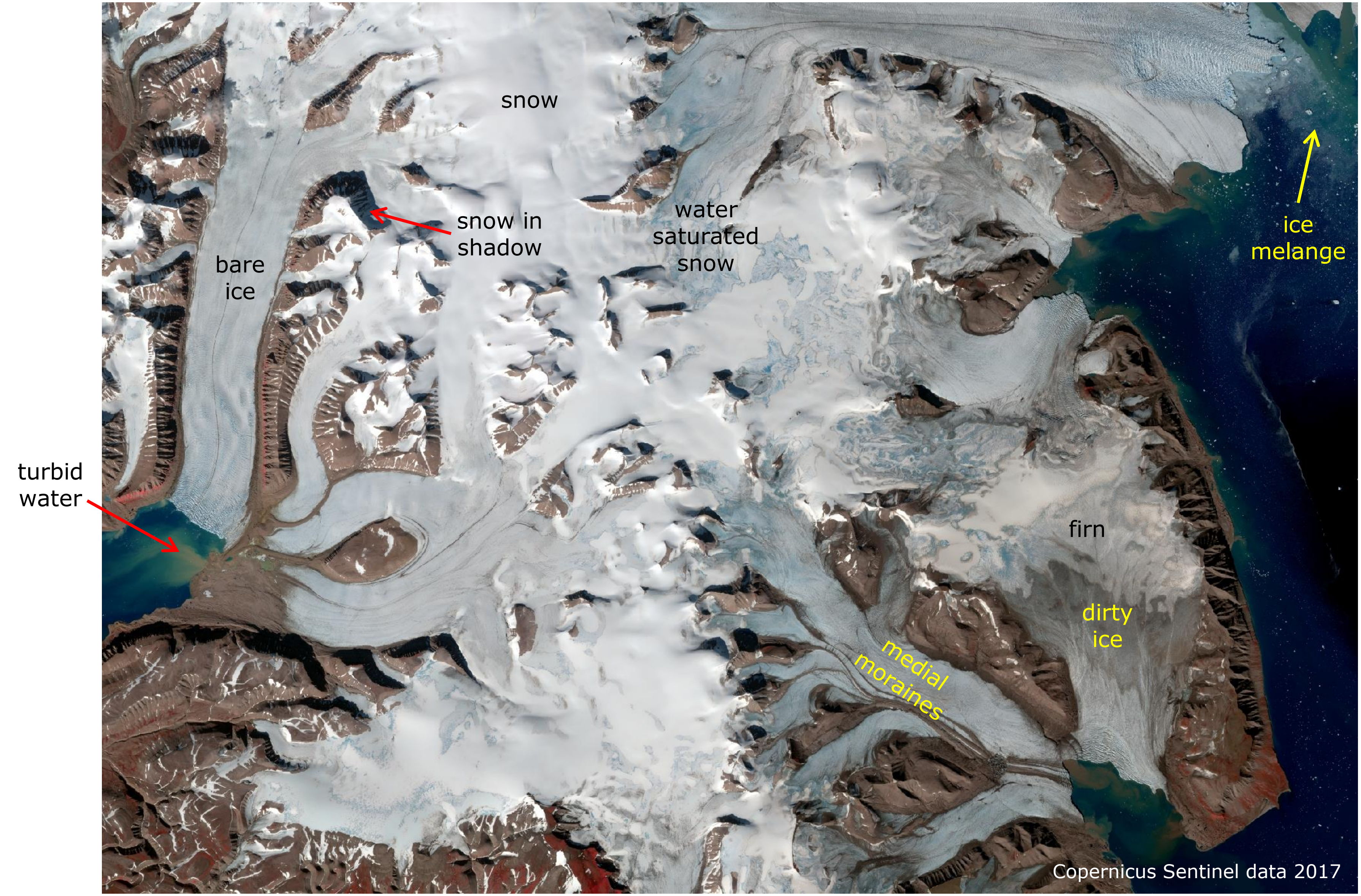
British Columbia: Landsat Path and Row



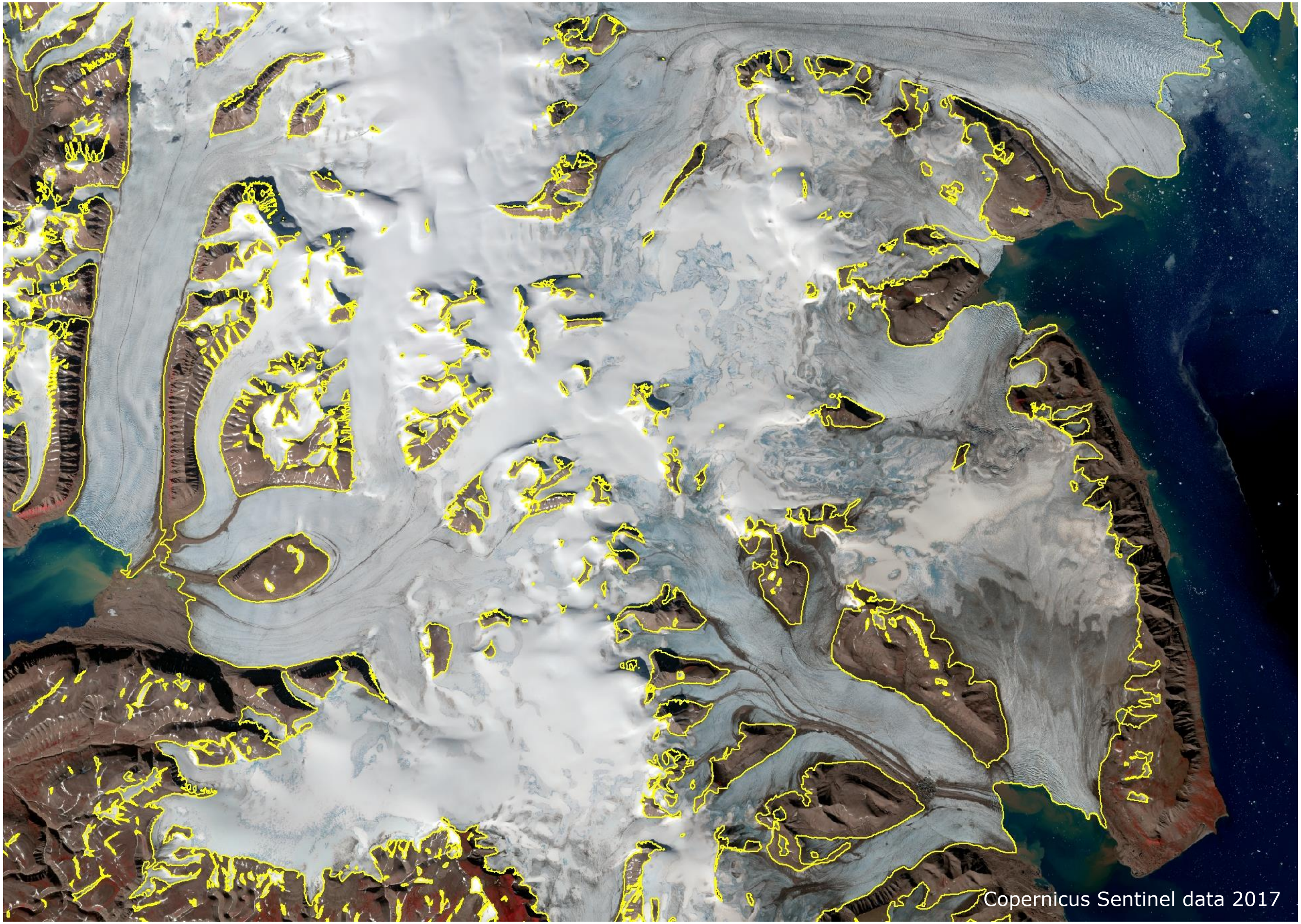
2007-08: We used 50 Landsat scenes and applied the 3/5 ratio, with threshold >2.0
~15,000 glaciers covering ~ 25,000 km²


1 – Mapping of Glaciers
Challenges:
1: Clouds
2: Late lying snow
3: Internal rocks
4: Pro-glacial lakes
5: Debris-cover
6: Ice divides
Improved Glacier Outlines
0 1 2 3 4
km

Glaciers: Svalbard subset Sentinel 2 (bands 8 4 3)



Resulting corrected outlines



Challenges and possible solutions

1. mixed pixels → lower threshold

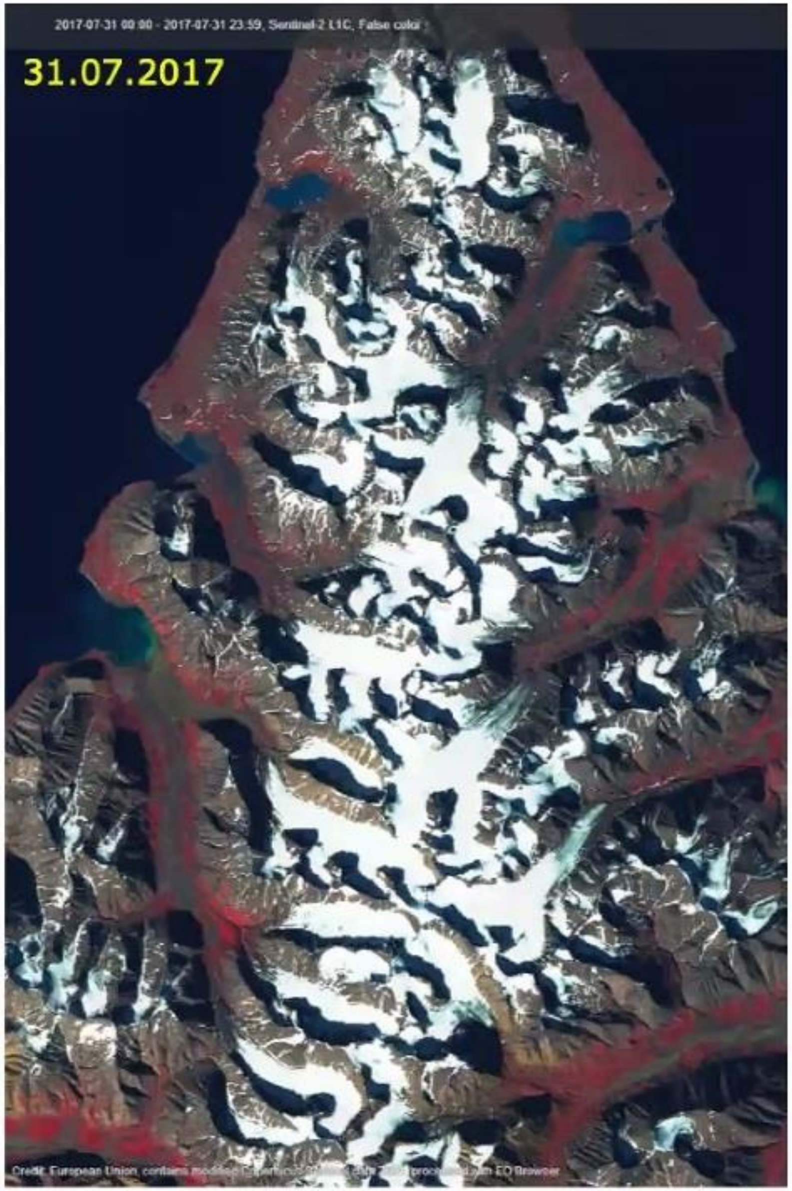
2. shadows → lower threshold, DEM ?

3. Misclassified lakes → higher threshold

4. Debris Cover – thermal ?

5. Late snow – mask ?

Later in the year: less snow, more shadow



Approach:
map with July scene, correct with September

Svalbard: 80 N

Ratio Improvements with Landsat 8/9 (2013) /Sentinel (2015)
- taking advantage of higher spatial resolution layers

- Landsat 5 TM: Red / SWIR 30m (glaciers 1984-2011)

- Landsat 8/9 OLI: PAN 15m VNIR/SWIR 30m

PAN / SWIR – ratio takes on 15m pixels (add SWIR to Pan file)

- Sentinel 2A/B MSI: VNIR: 10m SWIR 20m

Red / SWIR – ratio takes on 10m pixels (add SWIR to VNIR file)

Remote Sensing of Glaciers

Image processing can be used to map:

a. Glacier extents

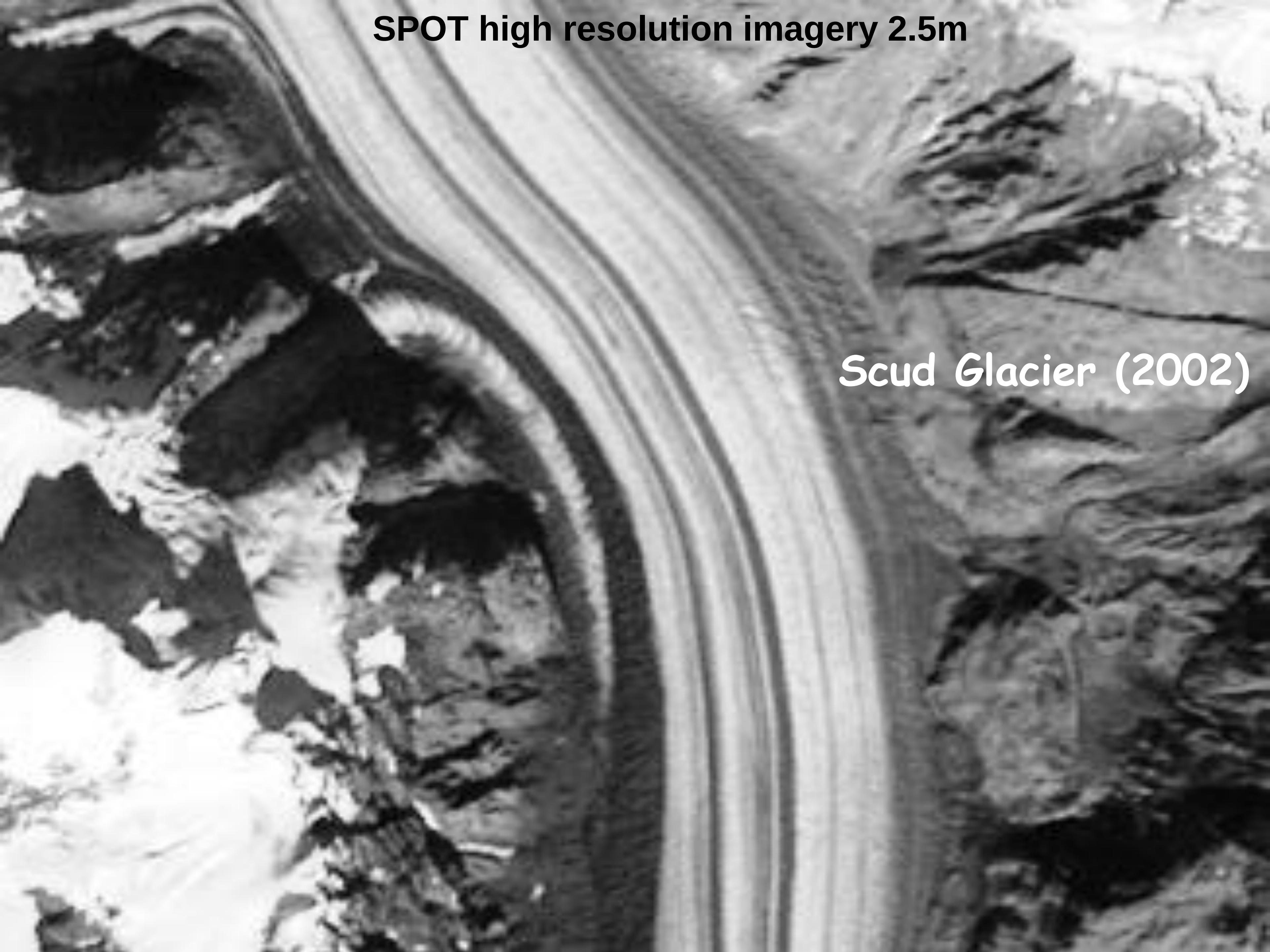
b. Surface characteristics (e.g. accumulation-ablation)

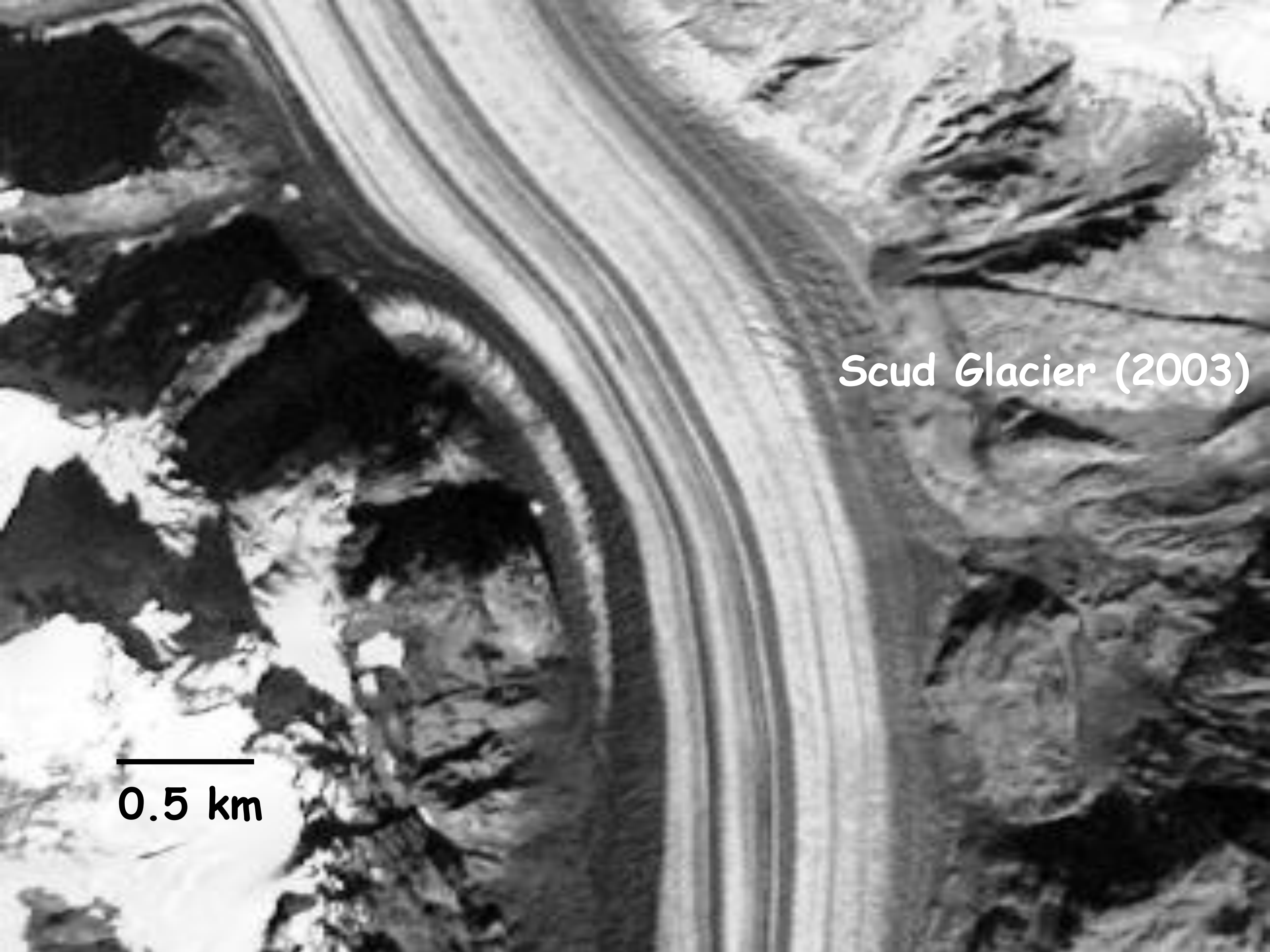
c. Animation – image series

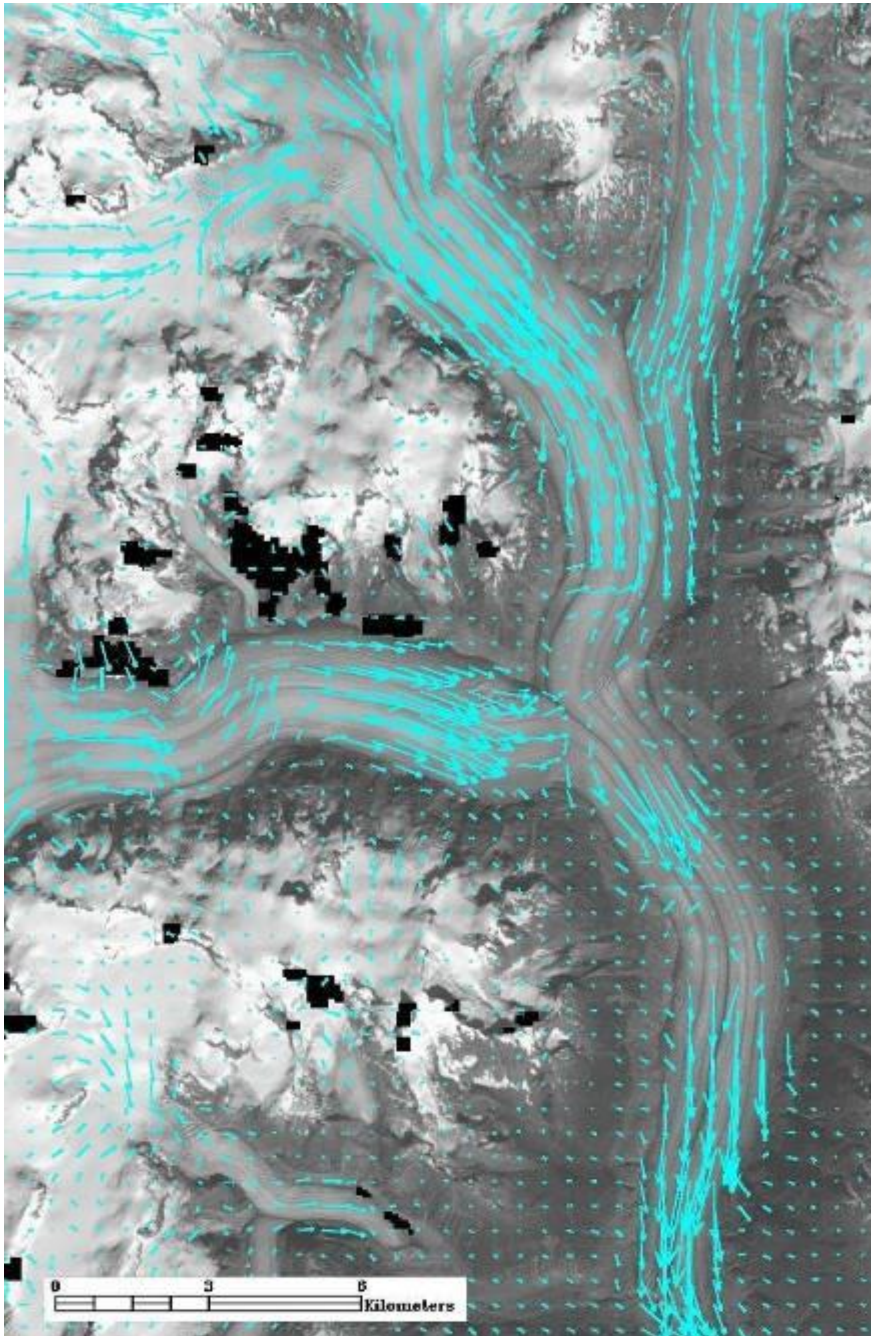
d. Glacier movement /velocity

e. Elevation change / Volume loss from DEMs

SPOT high resolution imagery 2.5m




Scud Glacier (2003)
0.5 km



4. Glacier velocity

Klinaklini Glacier

Annual movement ranges from 30 – 500 m / year mostly in summer)

~1m / day in summer

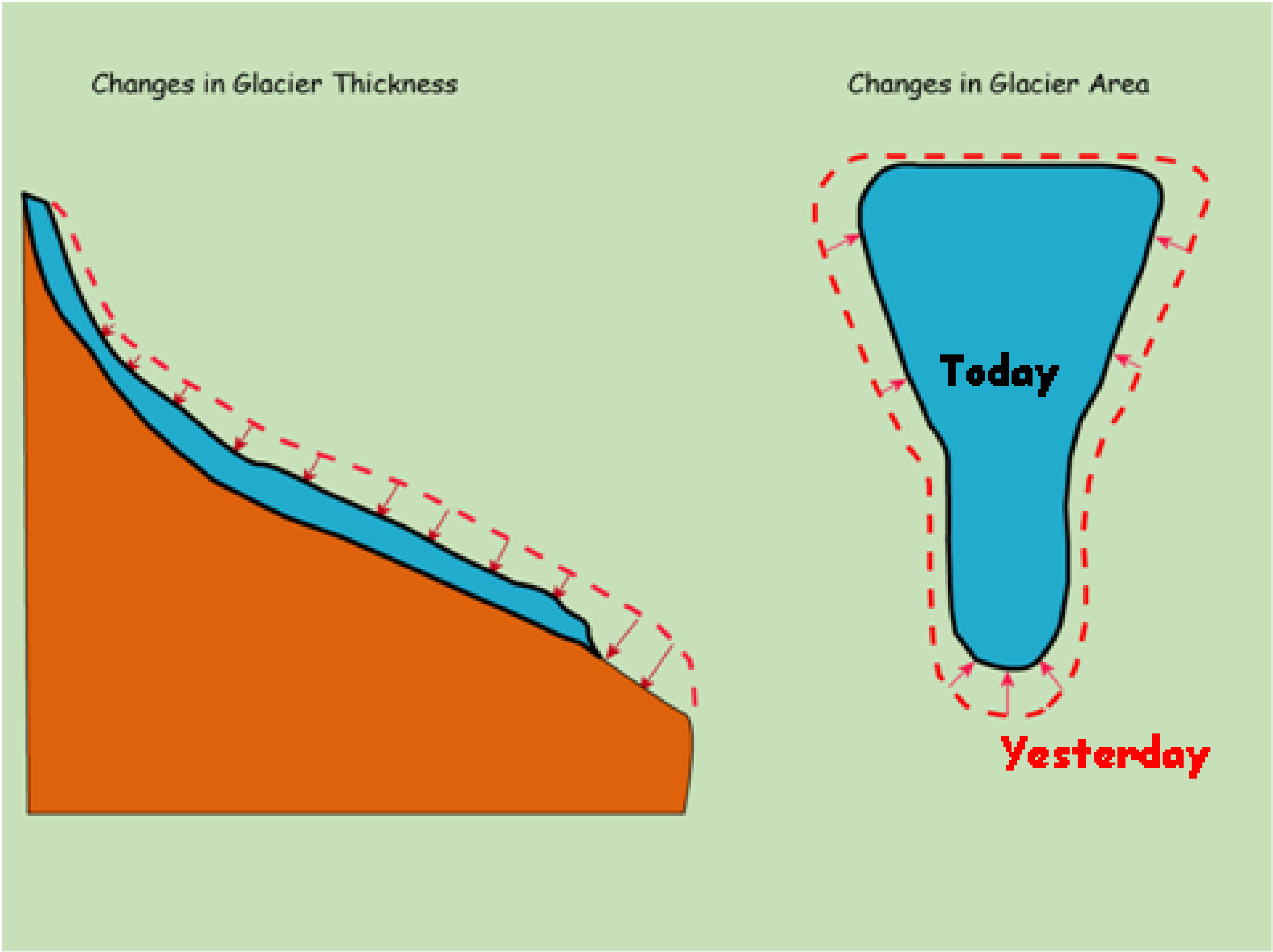
Length of vector is proportional to change between sequential images Oct 2001/Sep 2002

Uses ENVI COSI-CORR

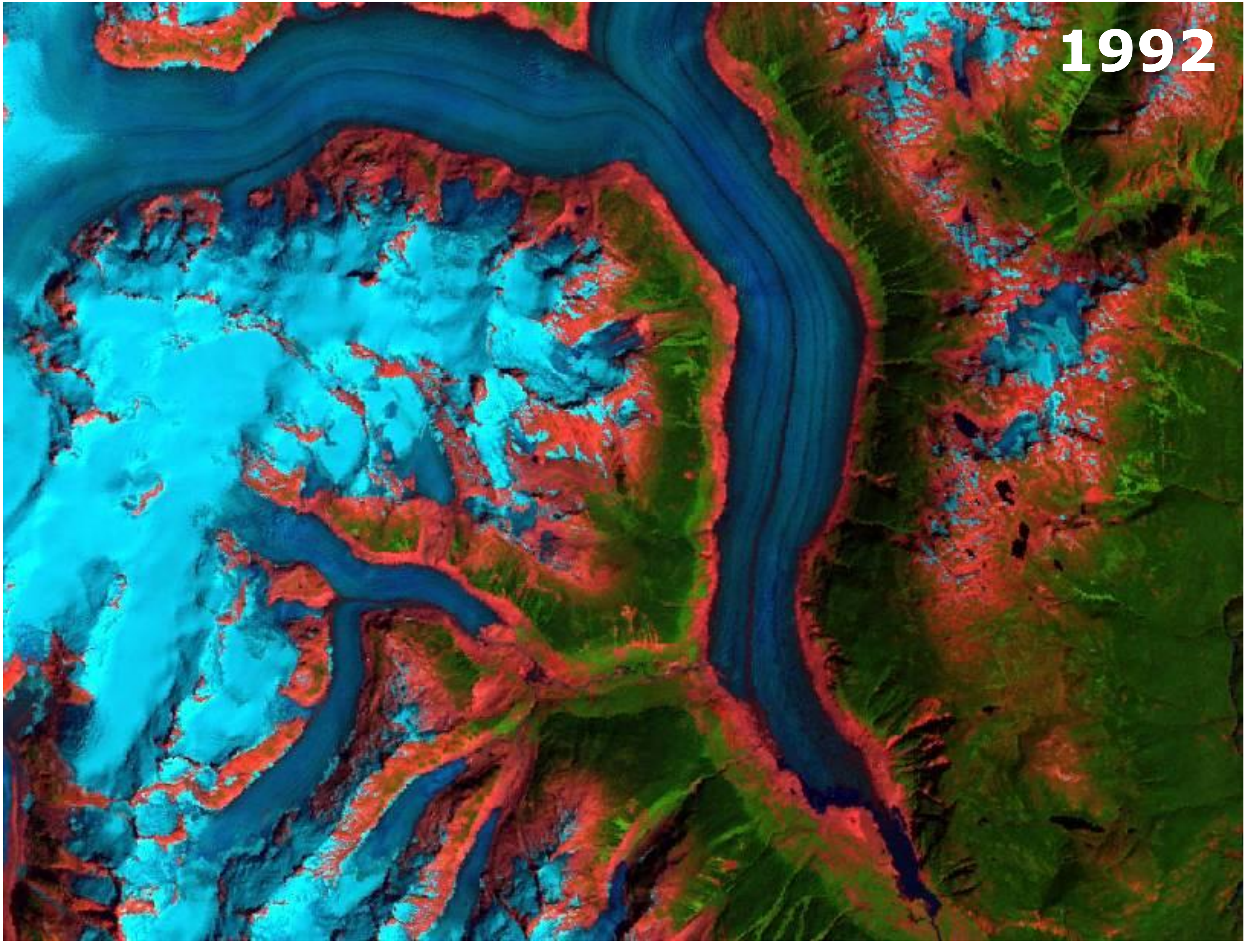
Image processing can be used to map and measure :

e. Elevation change / Volume loss from DEMs

.. See later lectures/labs on changed detection / DEMs



Animation series: Klinaklini Glacier




2006