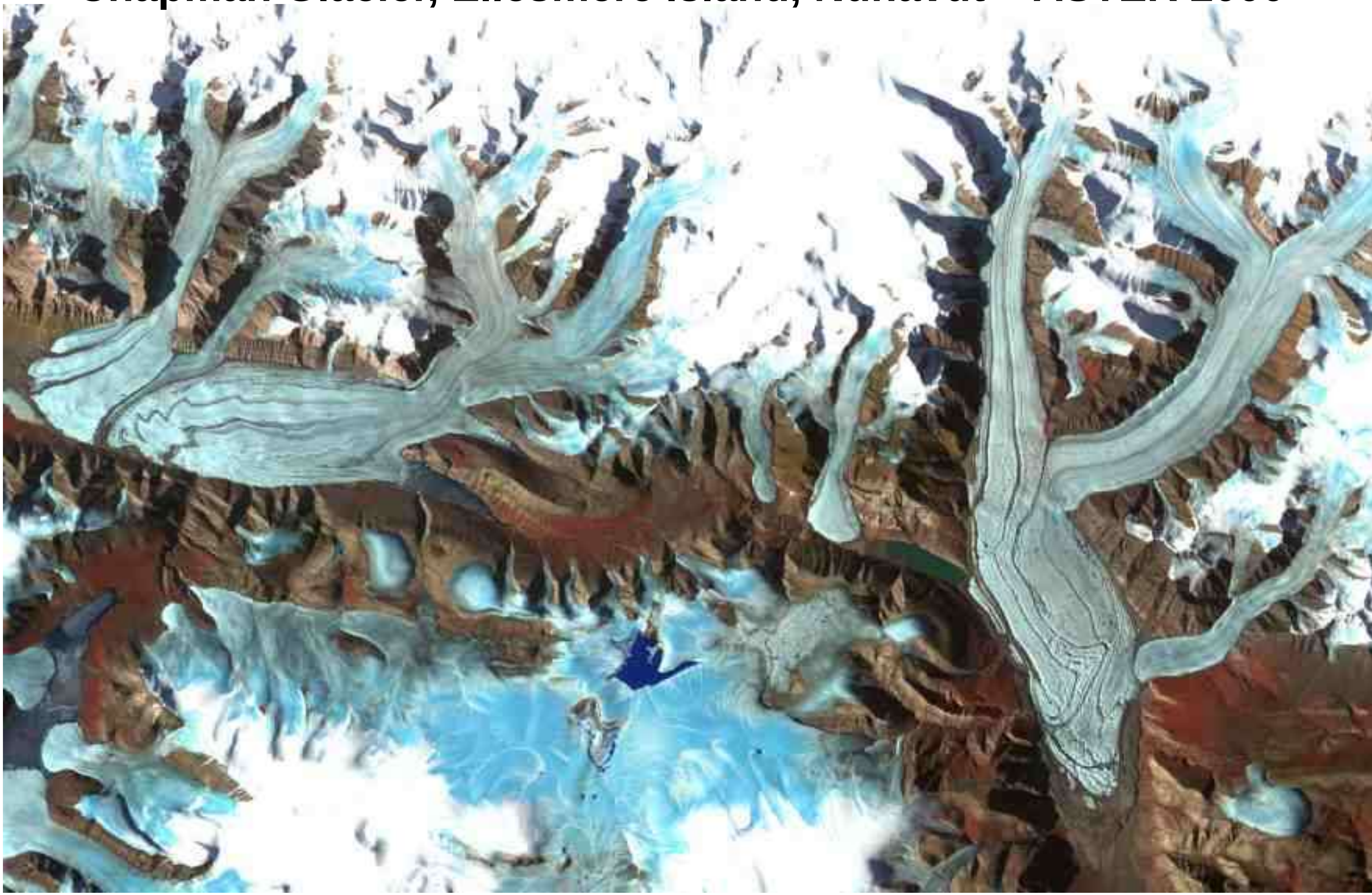
Remote Sensing of Glaciers

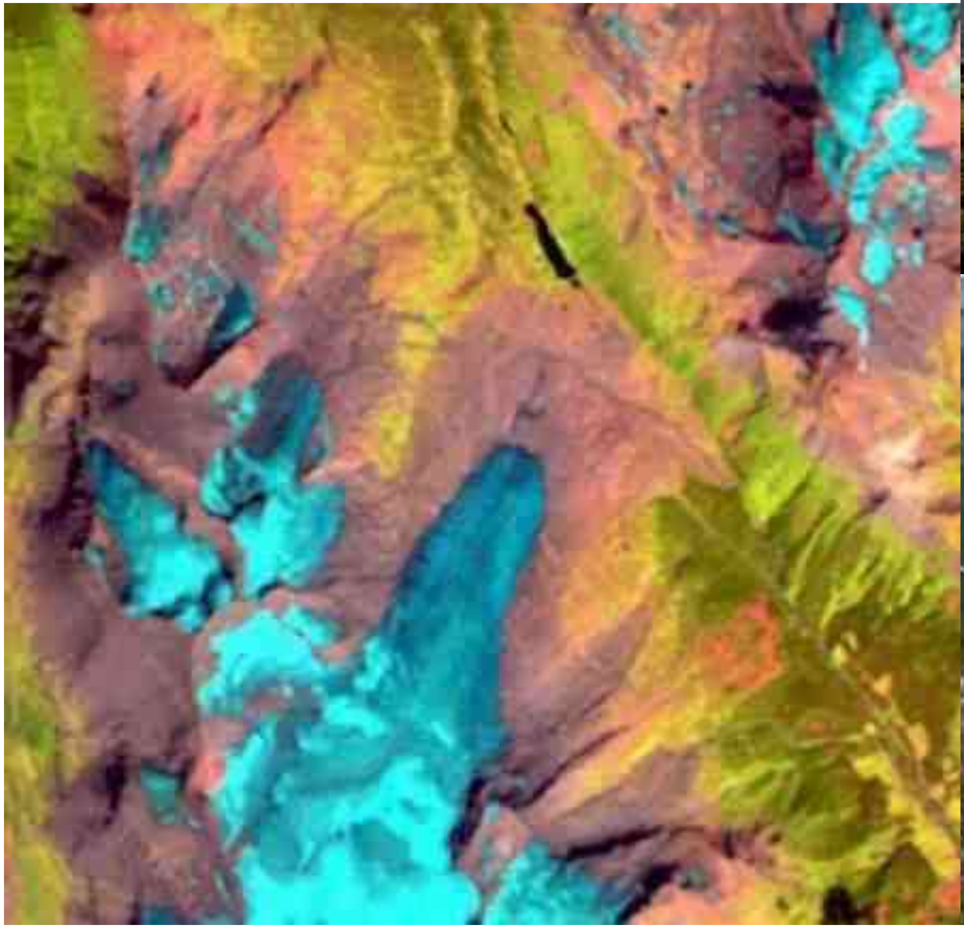
Chapman Glacier, Ellesmere Island, Nunavut – ASTER 2000



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

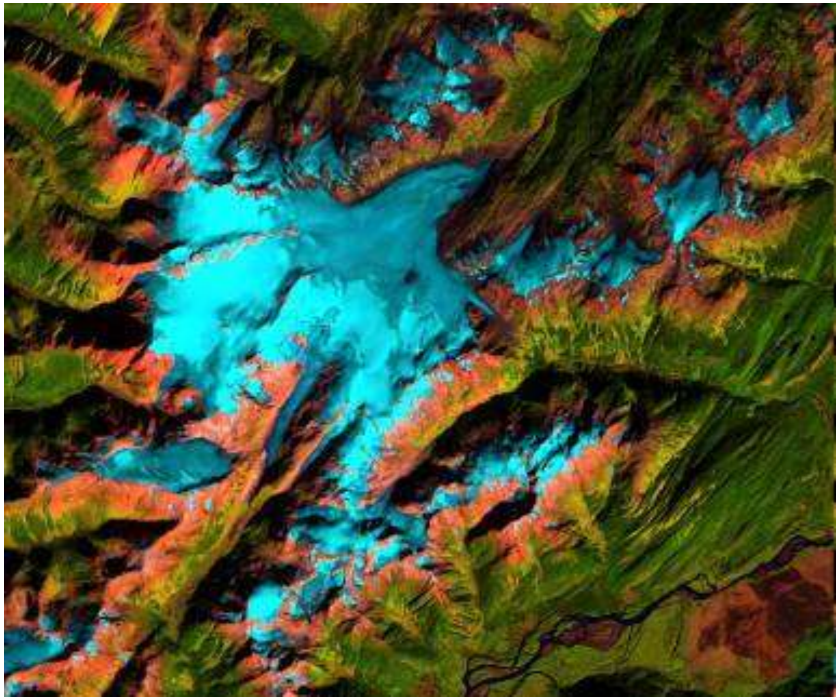
Note mark of Little Ice Age (LIA) ~ 1850

Castle Glacier- SW of McBride

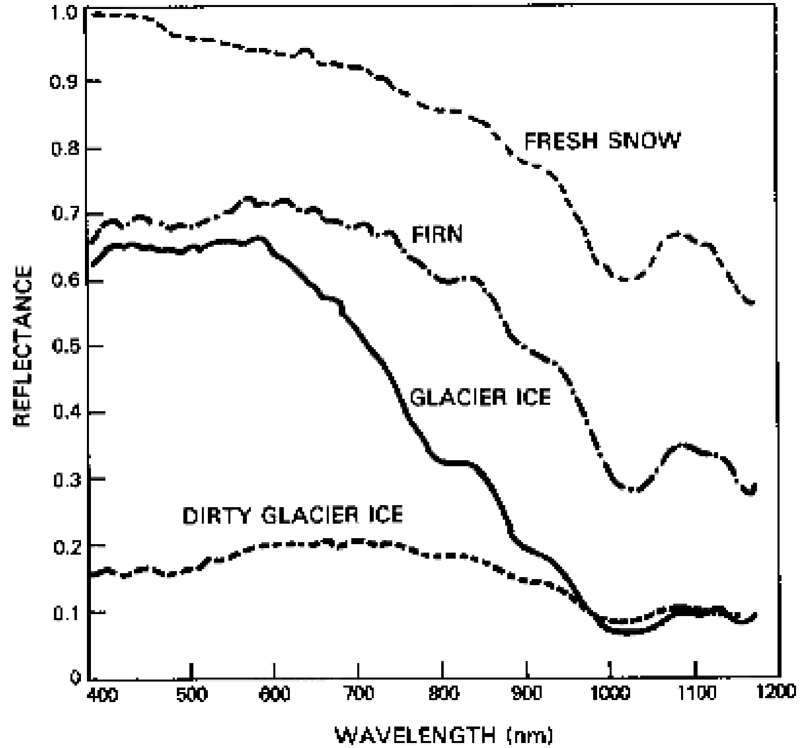


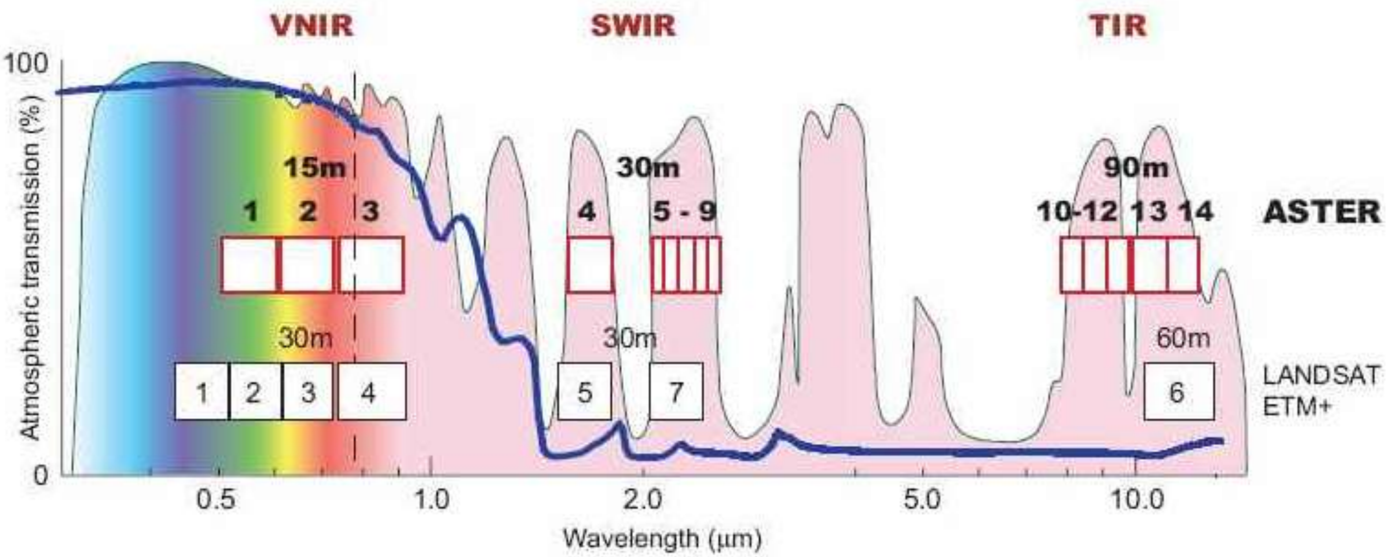
Note late lying snow cover
Muskwa-Kechika-northern BC

Spectral characteristics of snow and ice

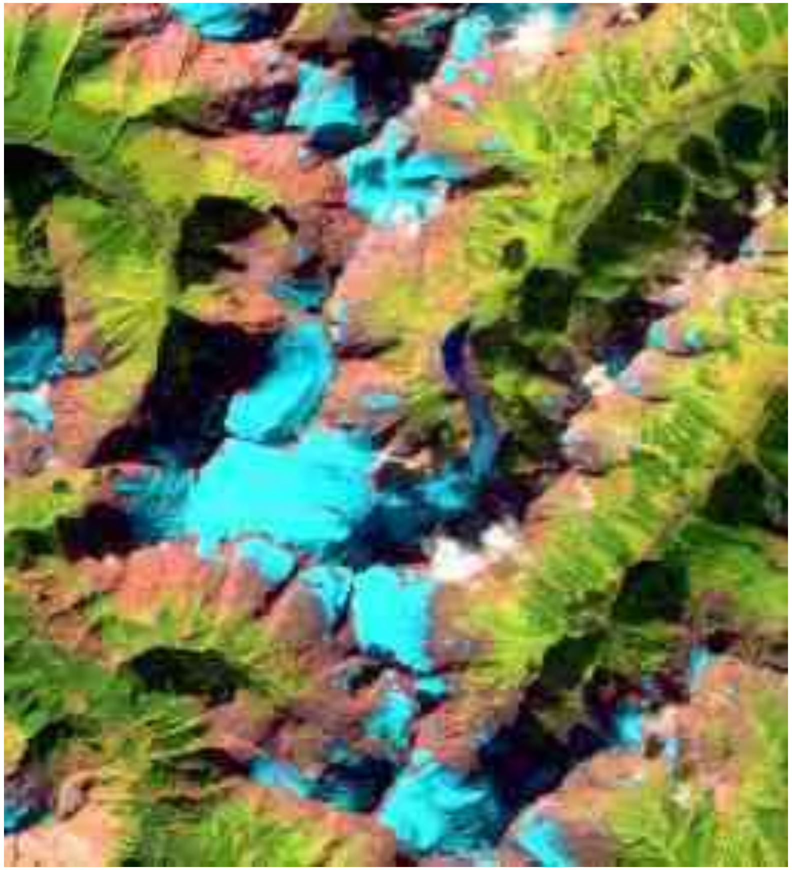


TM543





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



Mid-IR/Near-IR-Red Red-Green-Blue

Glacier extraction relies on this SWIR- Red (visible) contrast

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

1. Classification

a. Unsupervised classification: McBride OLI image including Kristi Glacier (SW corne

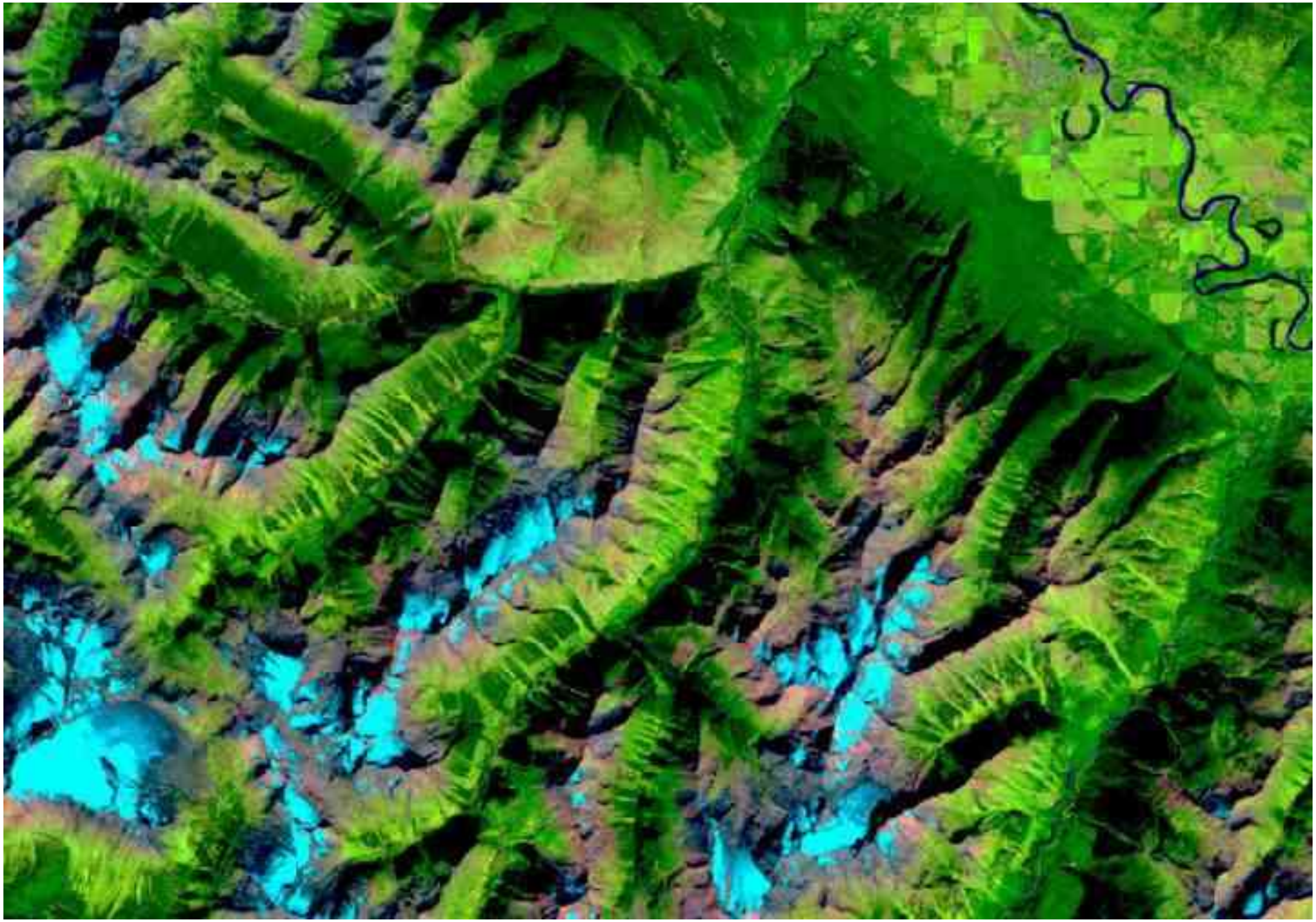
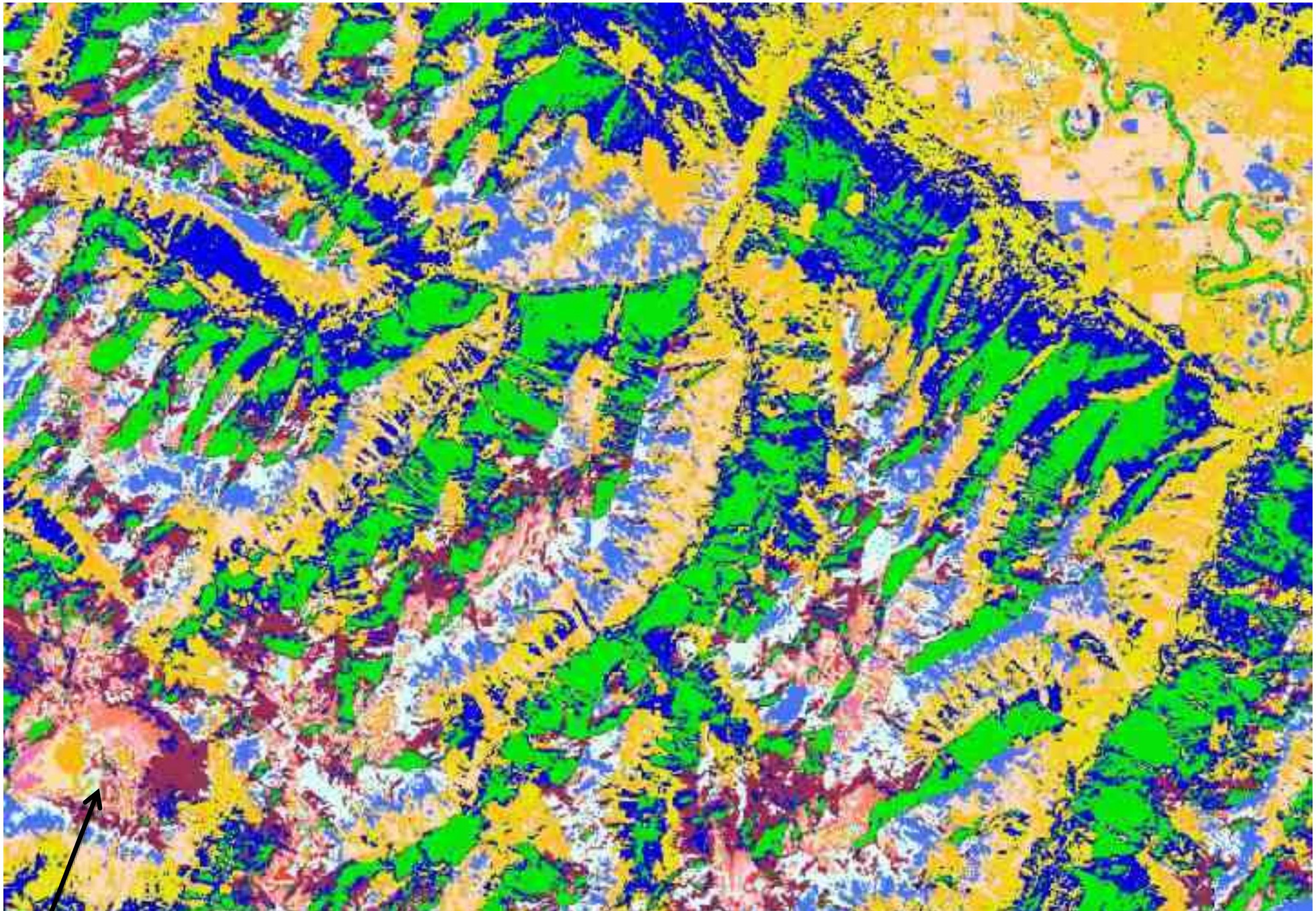


Image classification – Unsupervised … does not really work due to topography



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

b. supervised classification

international journal of remote sensing, 1999, vol. 20, no. 2, 273± 284

Glacier mapping of the Illecillewaet icefield, British Columbia, Canada, using Landsat TM and DEM data

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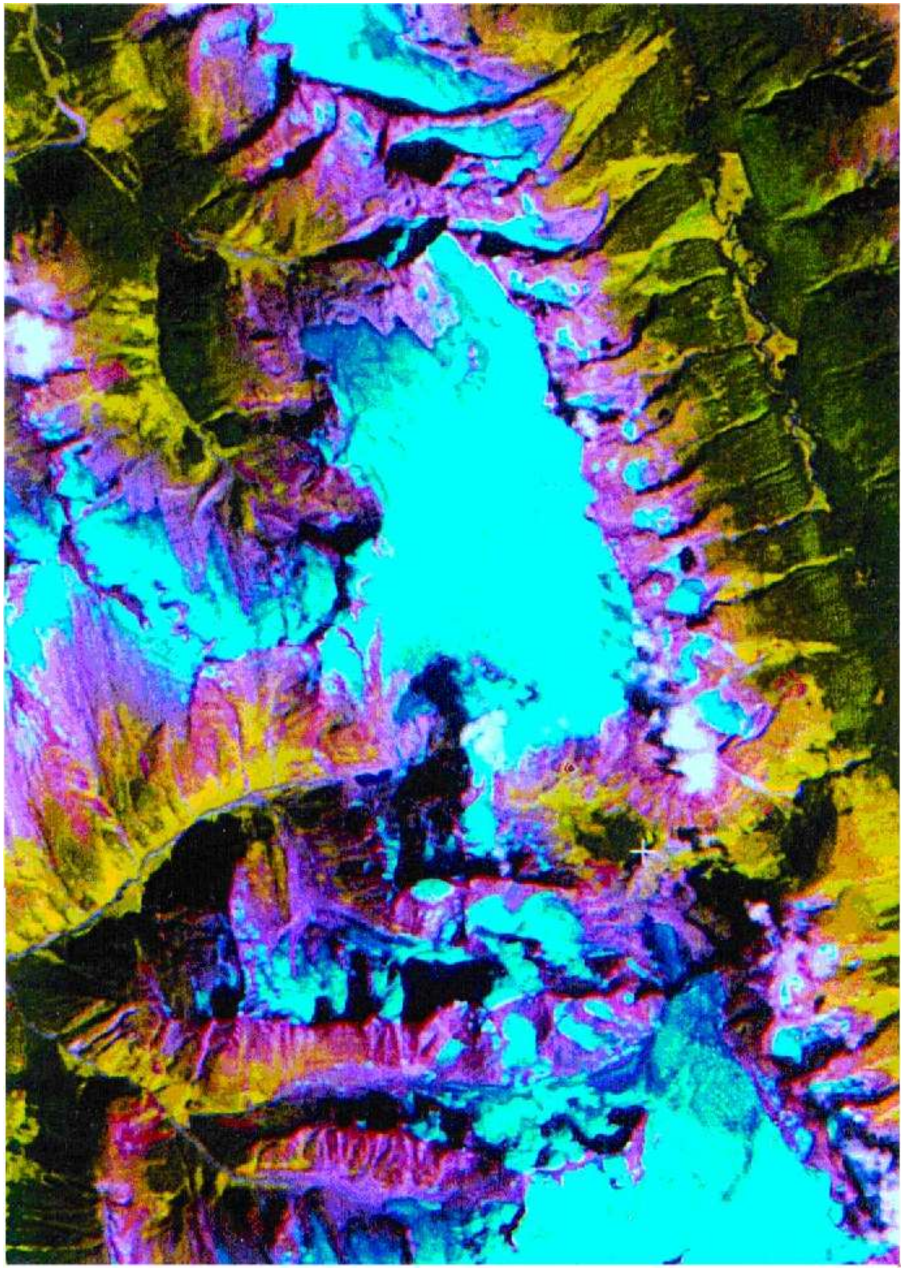
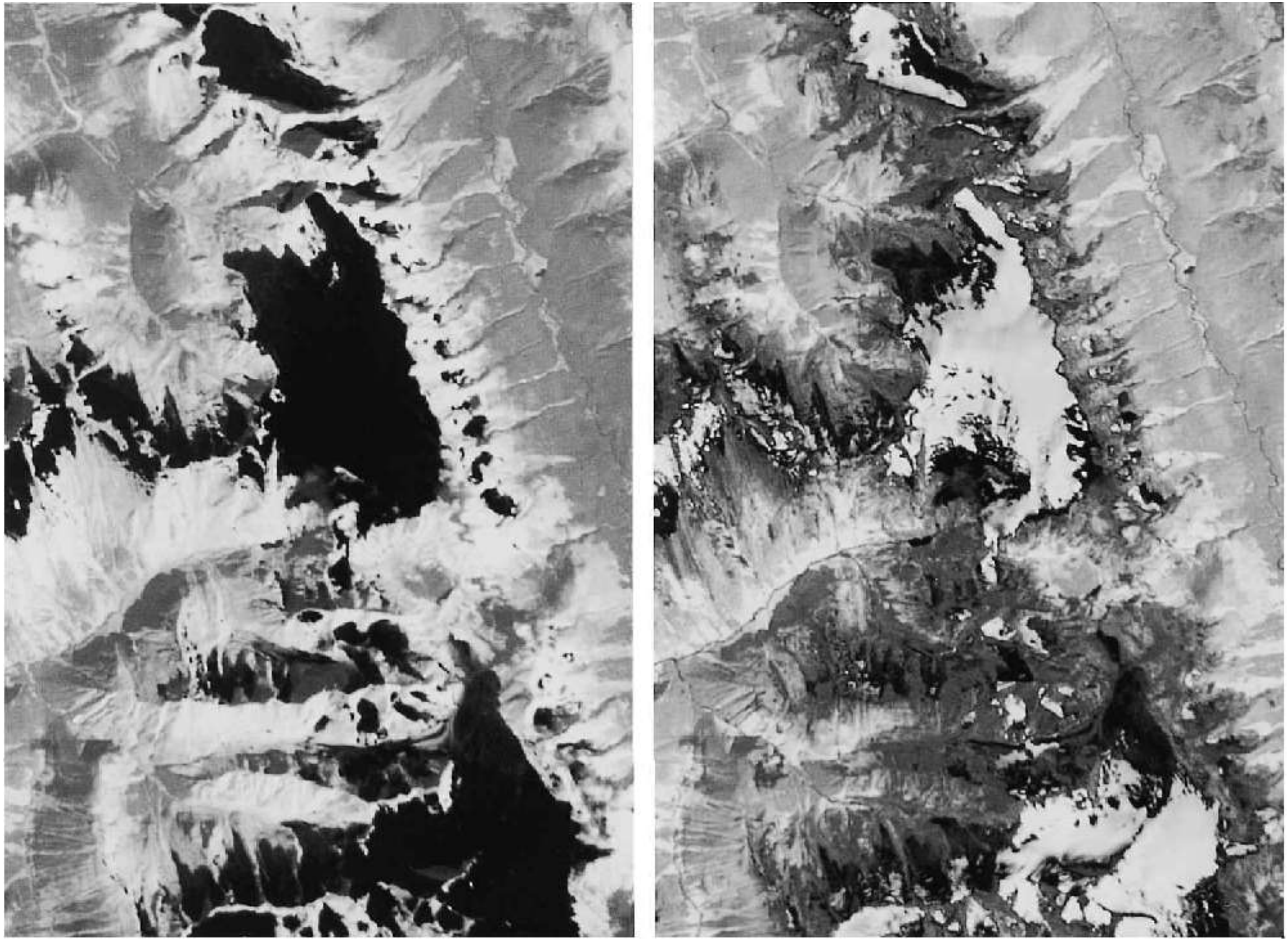
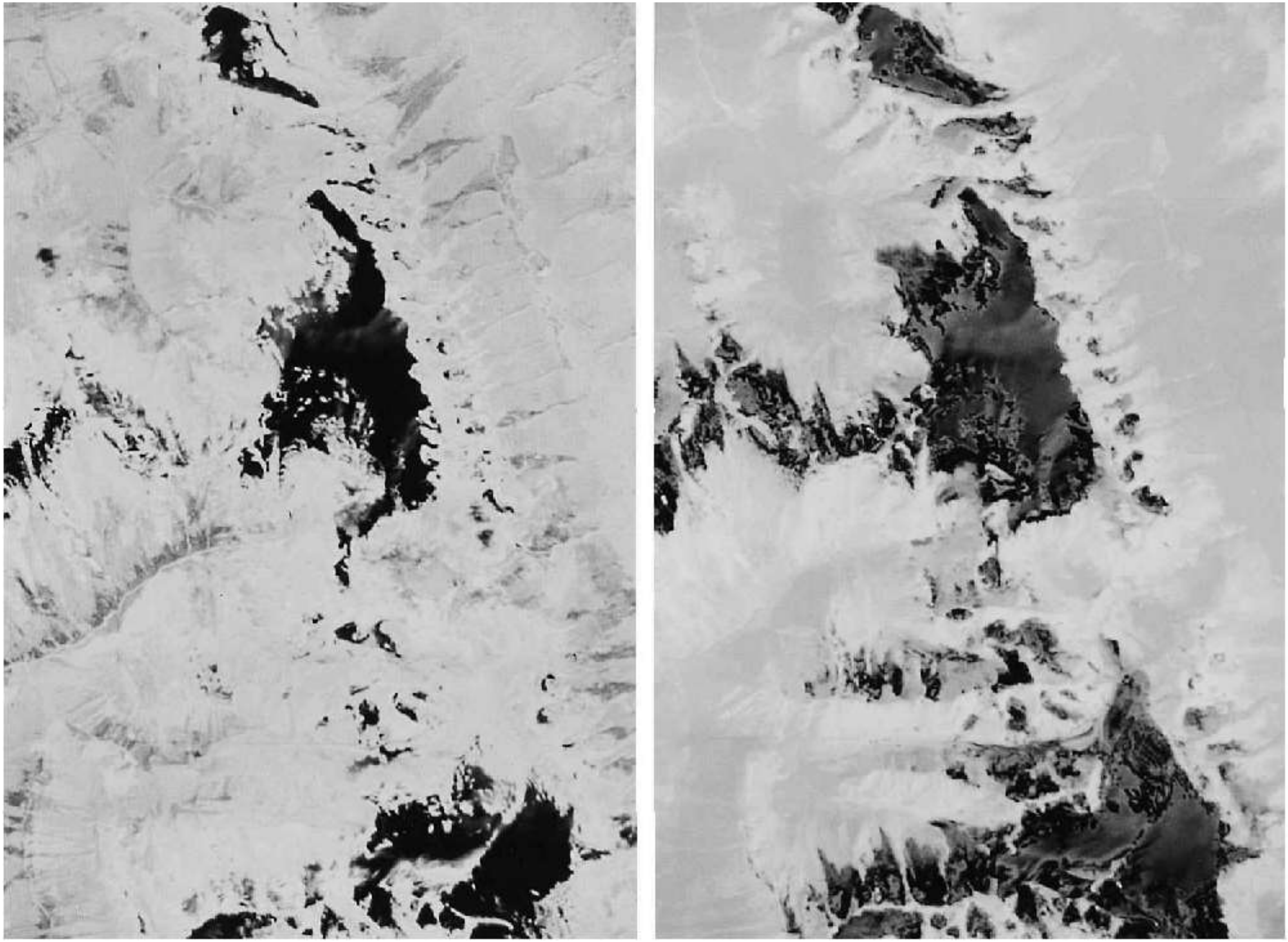




(a) (b)

Principal components PC2 and PC4
based on analysis of sub-scene (7 bands)



(a) (b) Principal components PC3 and PC4 based on analysis under a mask isolating glacier surfaces

(Supervised) Classification trials were performed with the following band combinations:

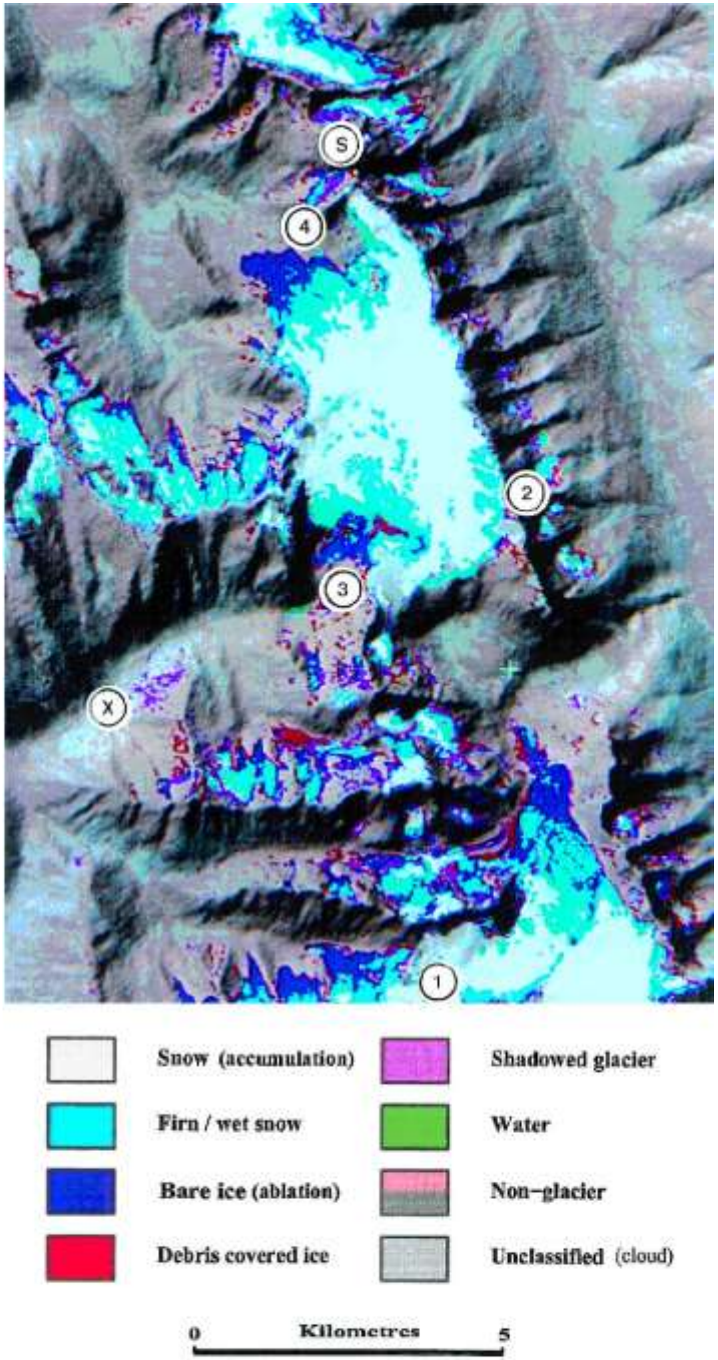
1. TM bands 3, 4, and 5

2. Band ratio TM4/TM5 and NDSI

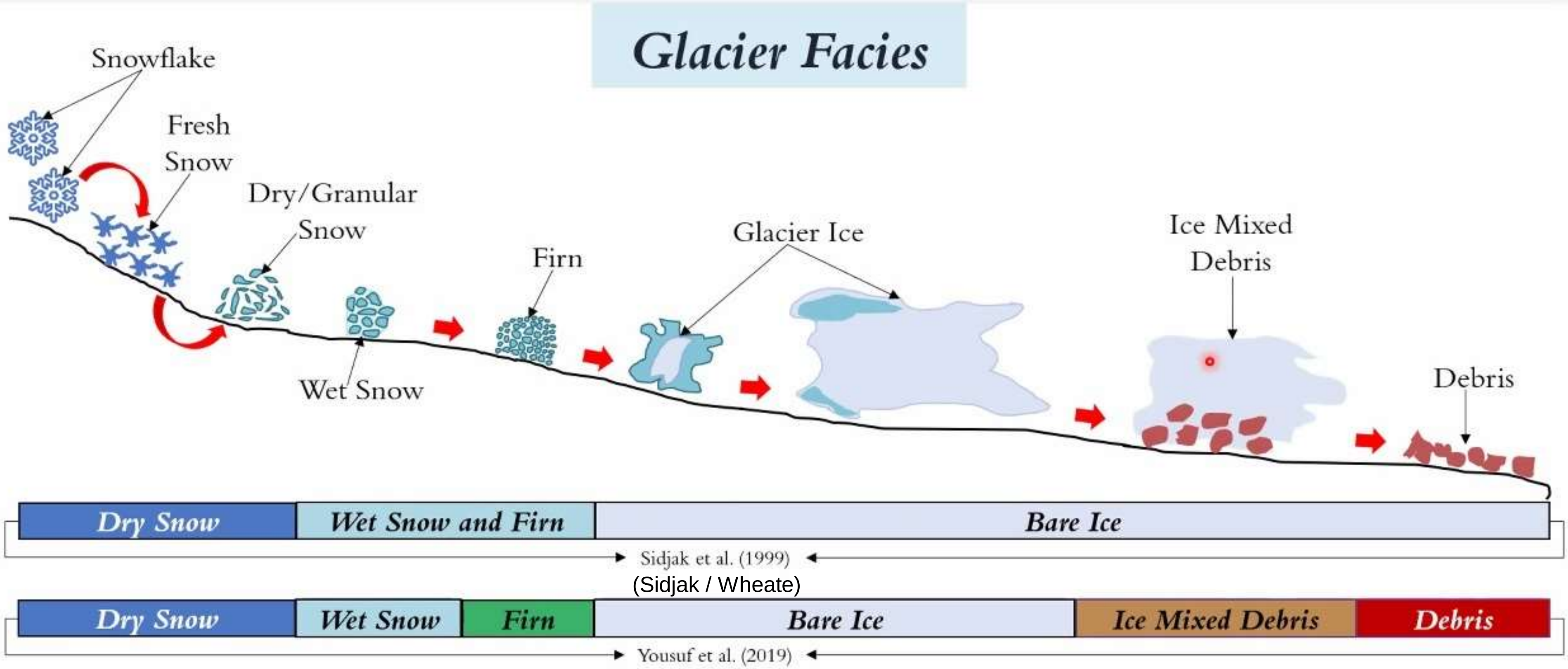
3. Masked principal components 1 + 4

4. Masked principal components 2 + 4

5. Masked principal components 2 + 4 + TM-4/TM-5 ratio + NDSI BEST !



Accumulation Firn Ablation



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.

2. Normalised Difference Snow Index
(NDSI) = (G-SWIR)/(G+SWIR)

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

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

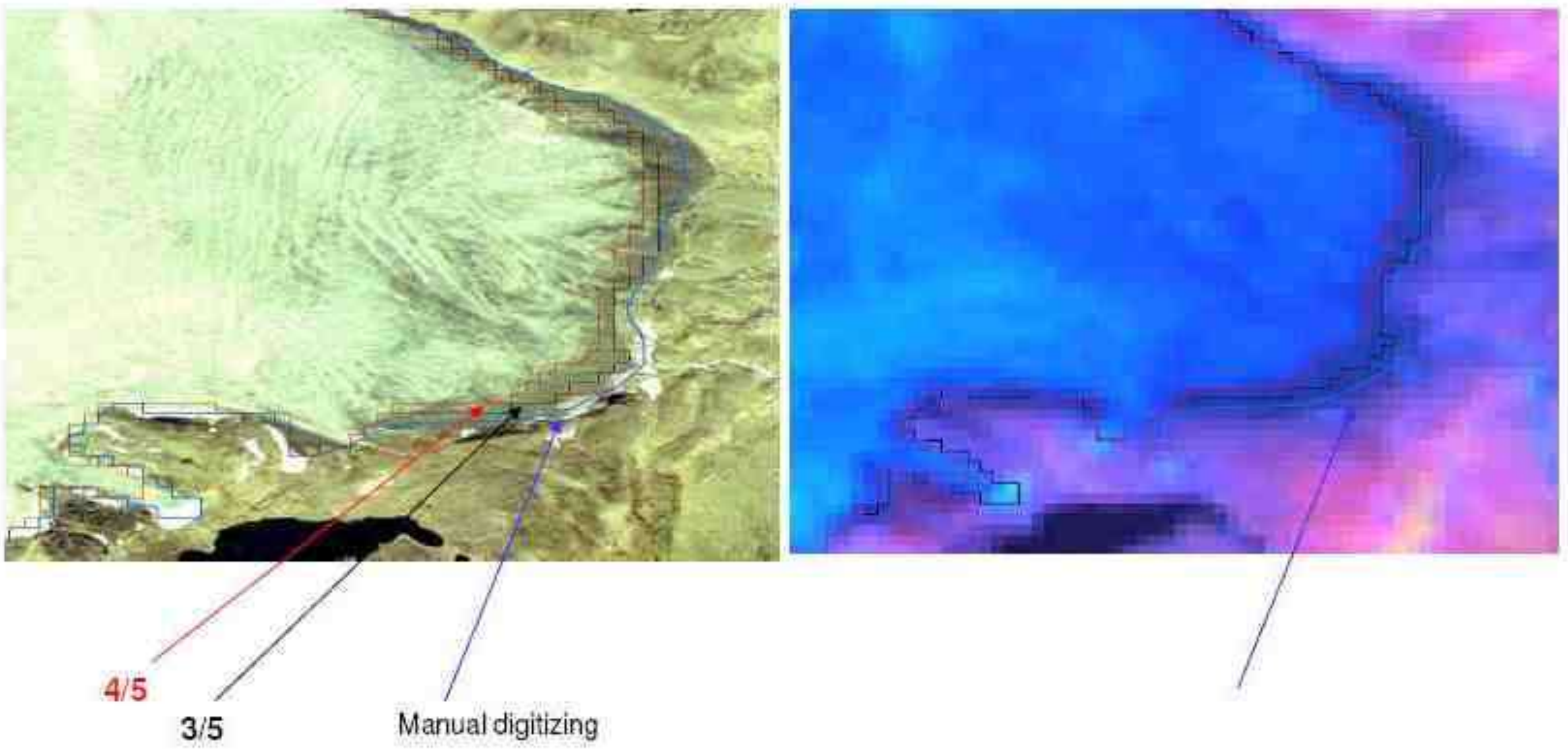
Method: use as threshold value or input in classification

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

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

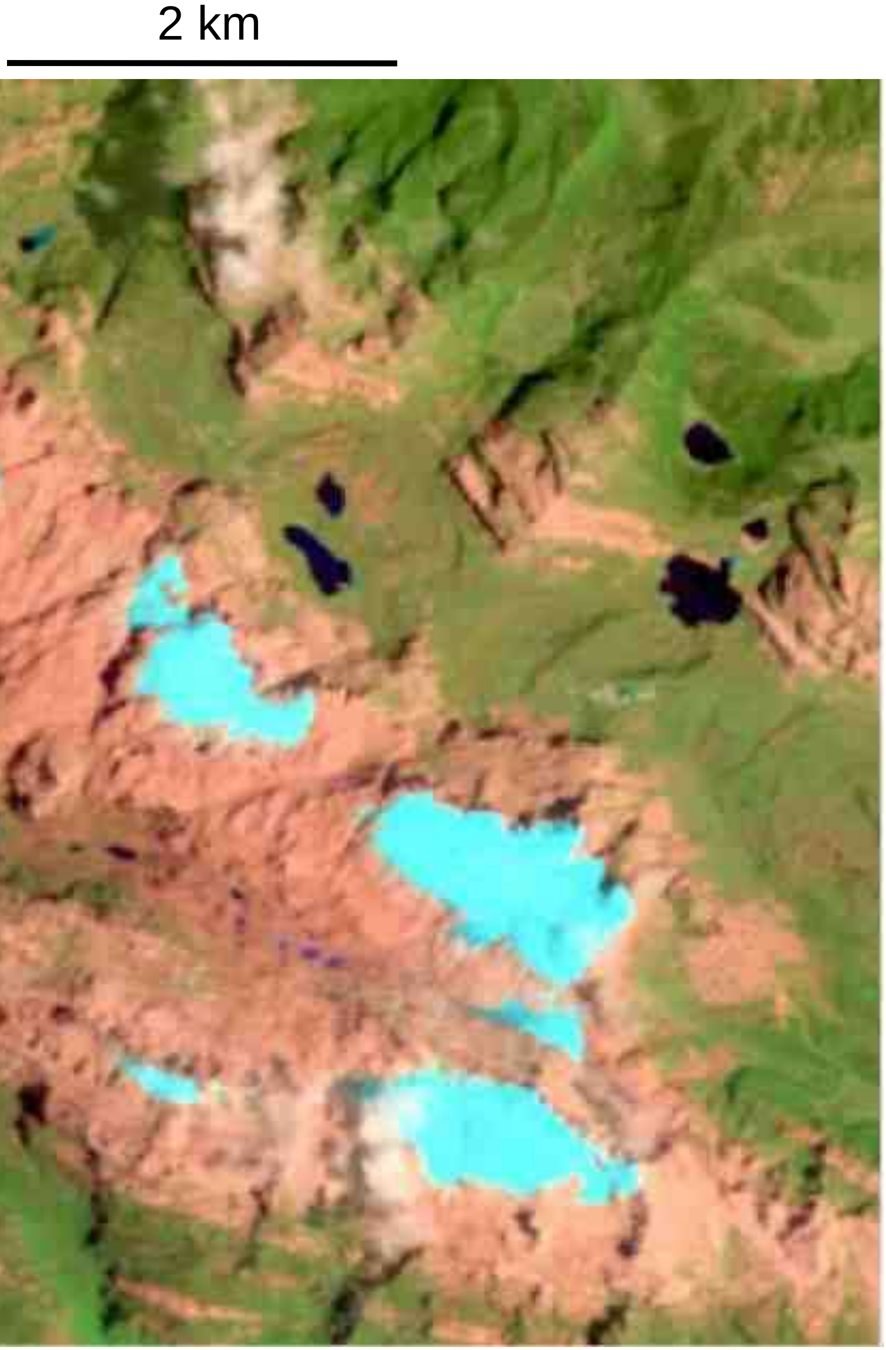
Ratio = Visible (Red) to SWIR captures snow/ice almost exclusively

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

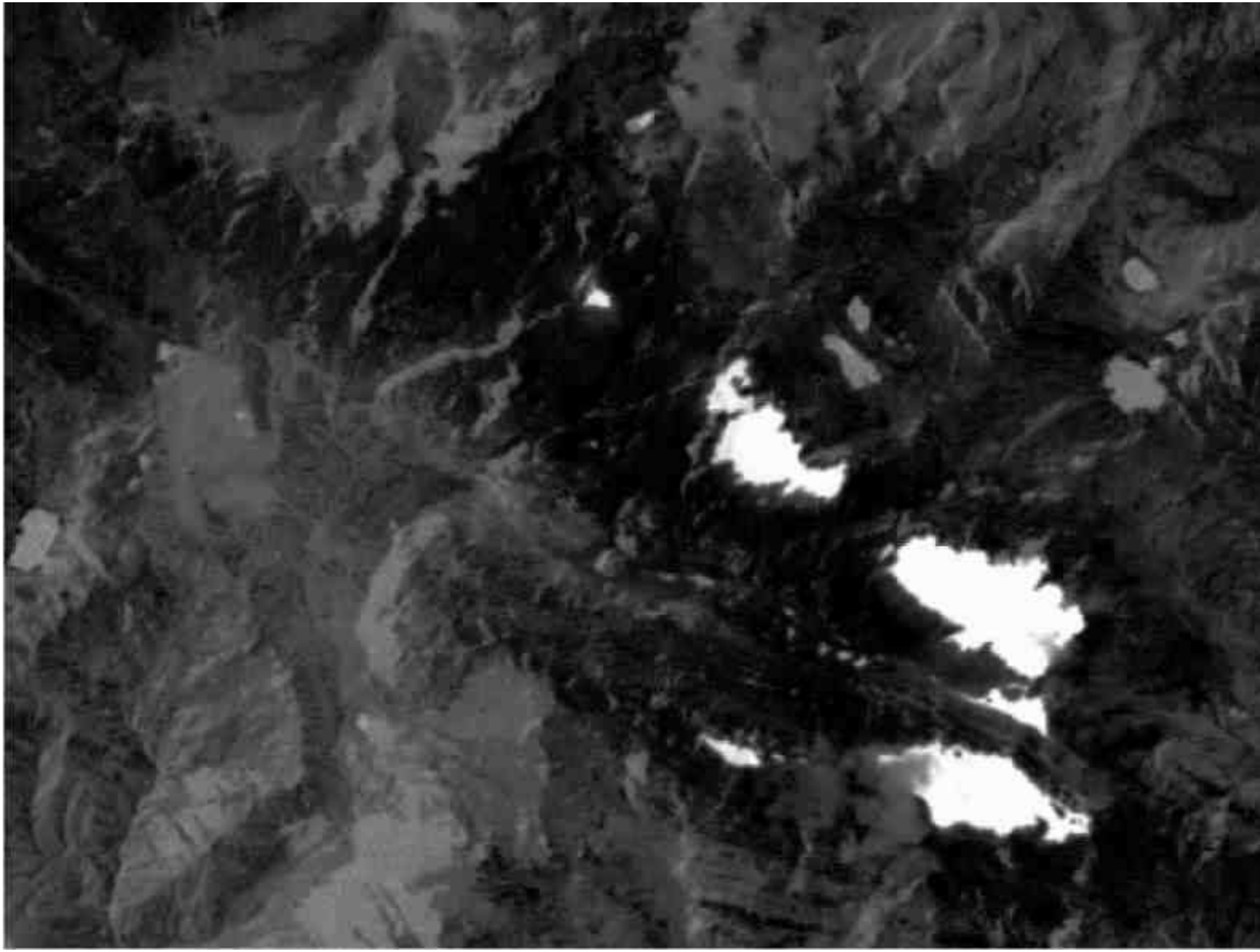
Puncak Jaya, Indonesia 4°S, 137°E elevation m. asl: 4884m

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

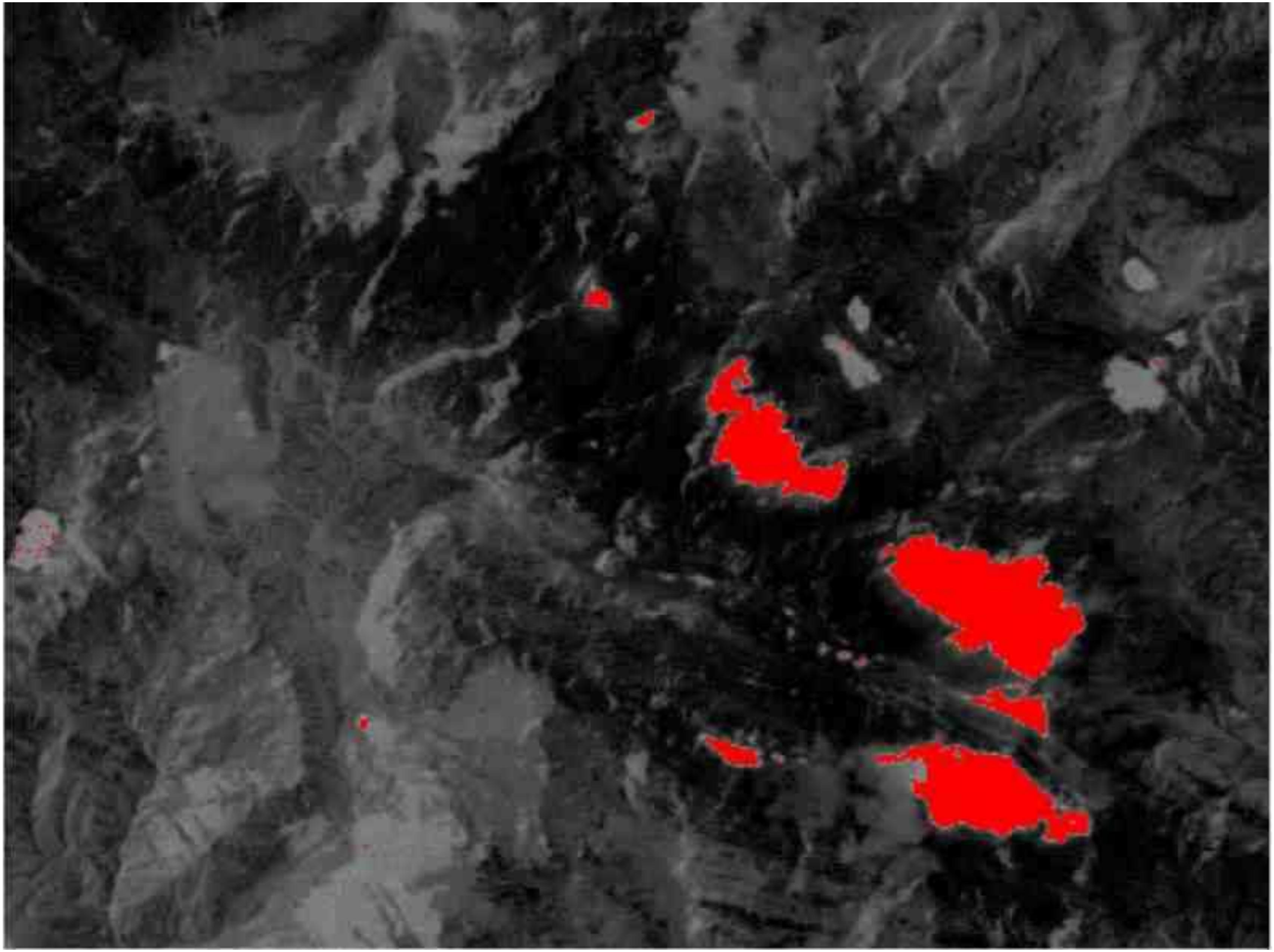
Landsat 1992



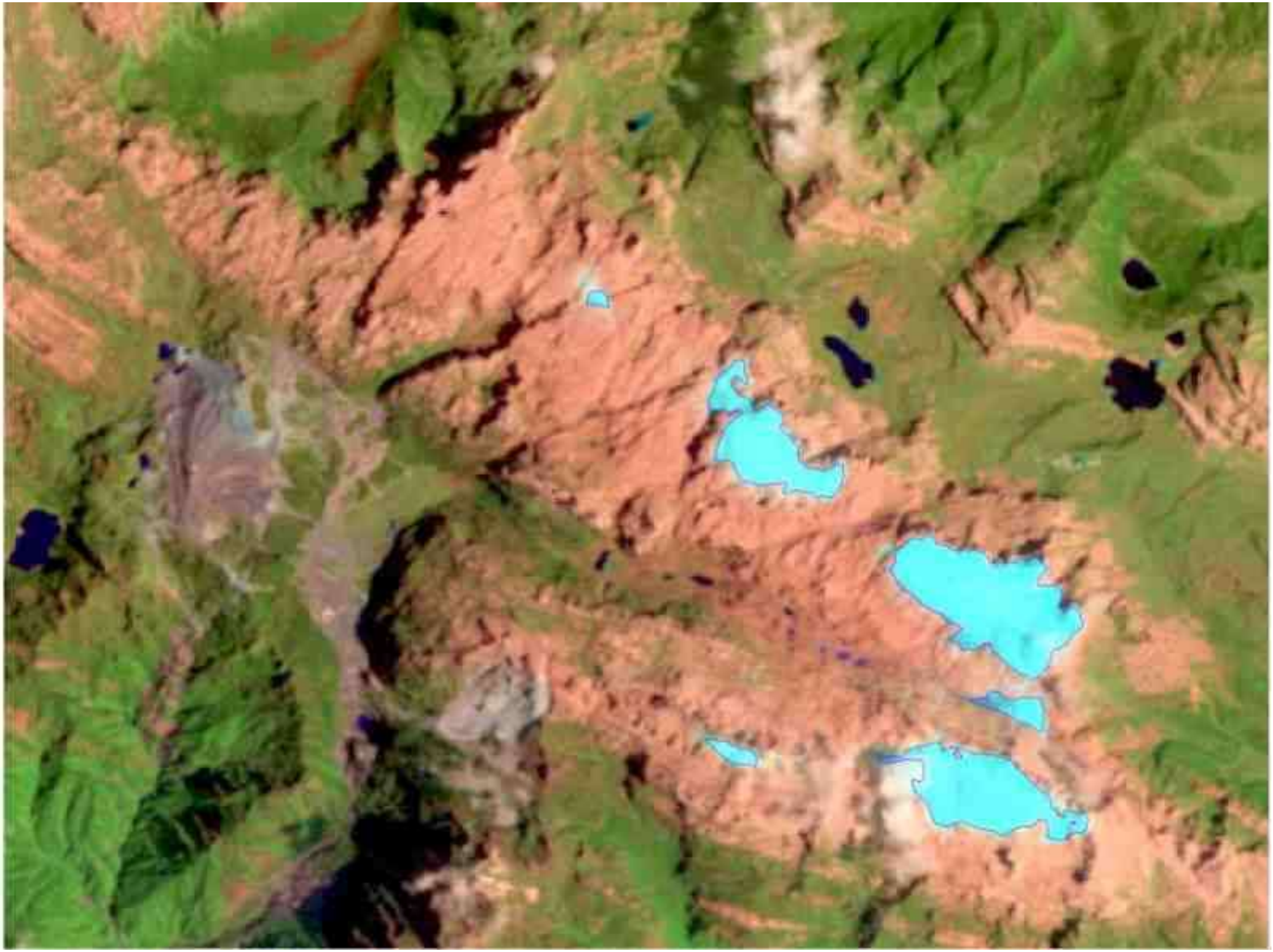
Red/SWIR ratio



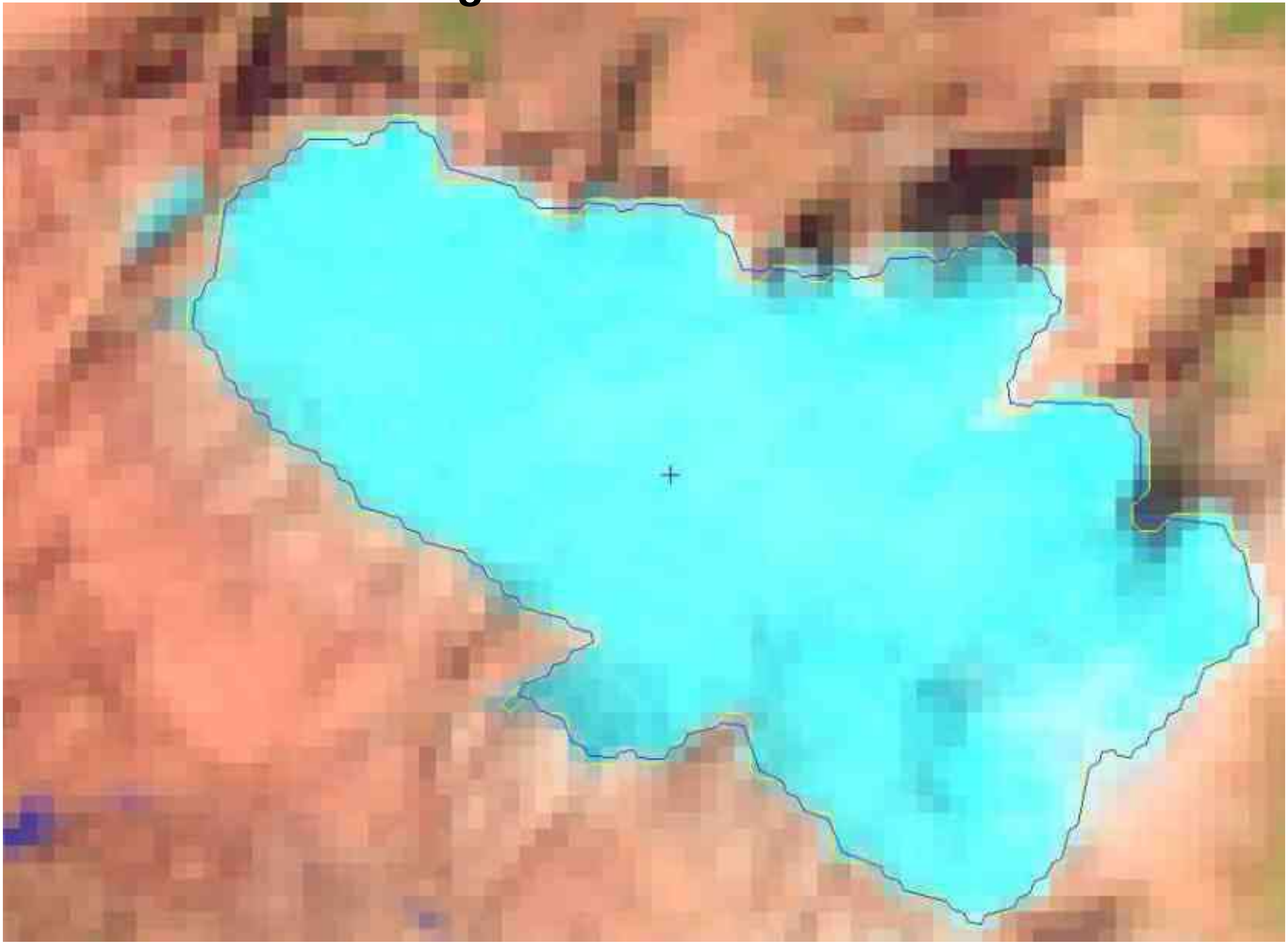
Threshold value 2.0



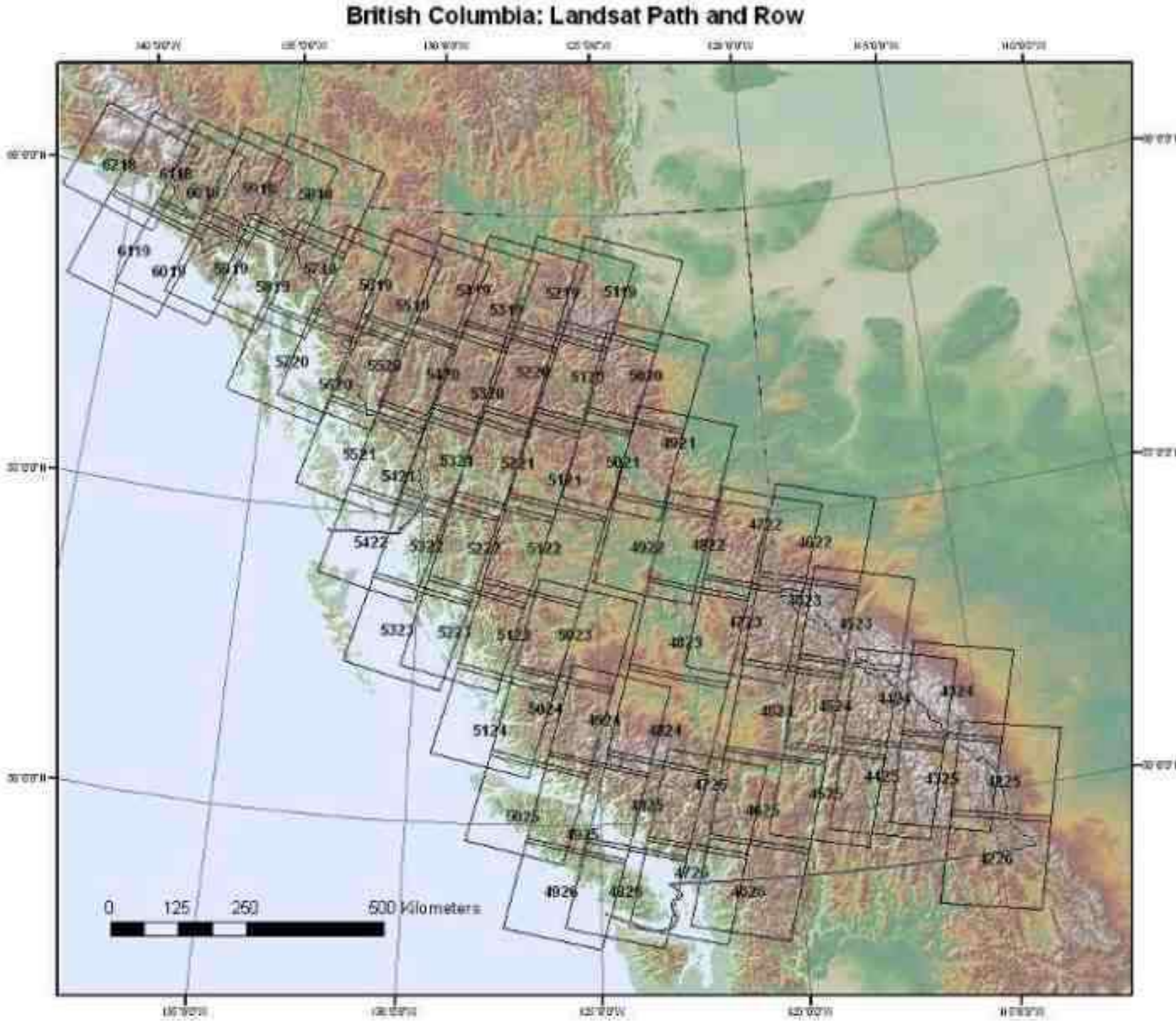
Convert bitmap to polygon



Vector smoothing



The cordilleran glaciers of western Canada- mapped at UNBC, 2008



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

1 – Mapping of Glaciers

Challenges:

1: Clouds

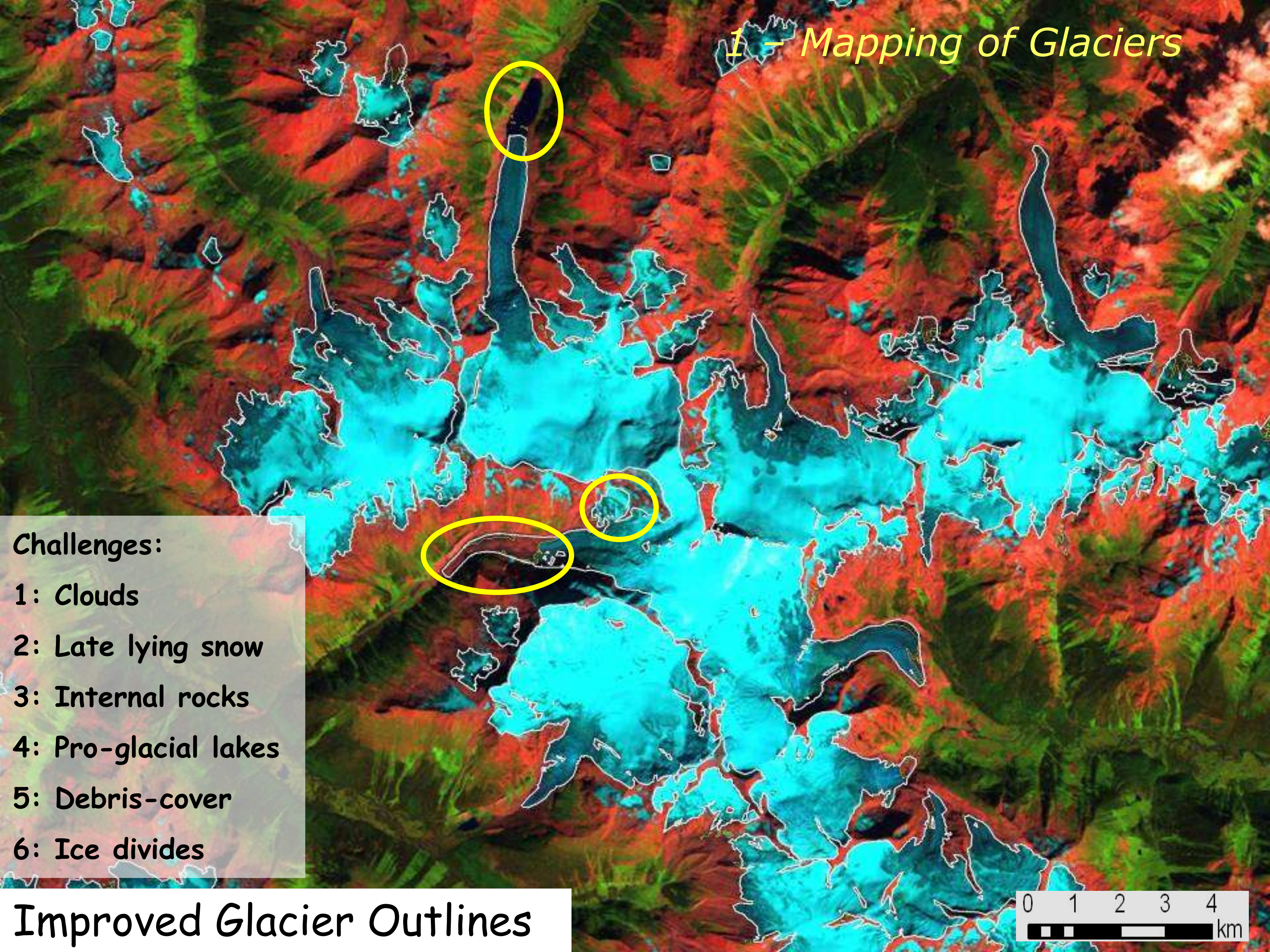
2: Late lying snow

3: Internal rocks

4: Pro-glacial lakes

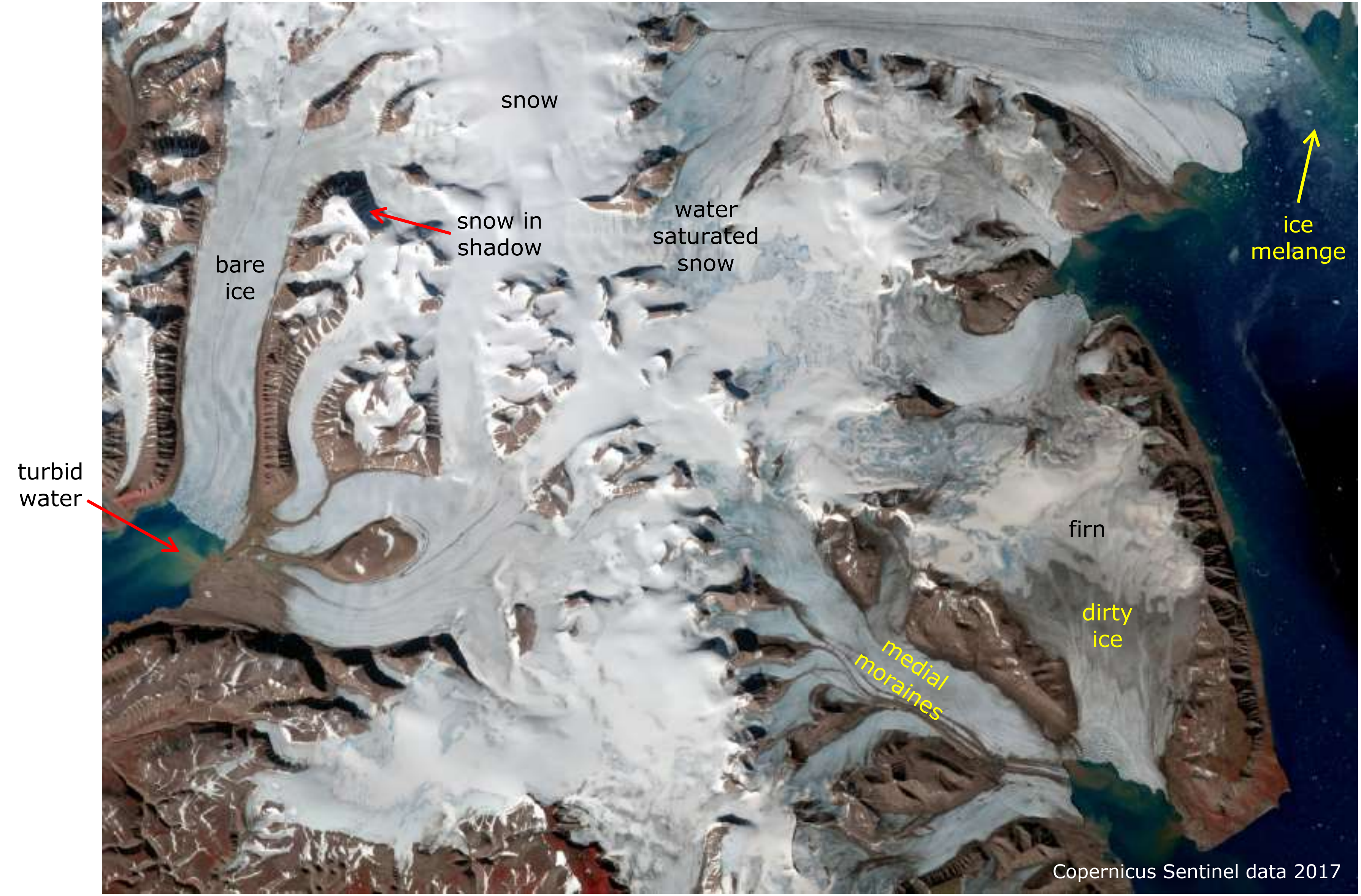
5: Debris-cover

6: Ice divides

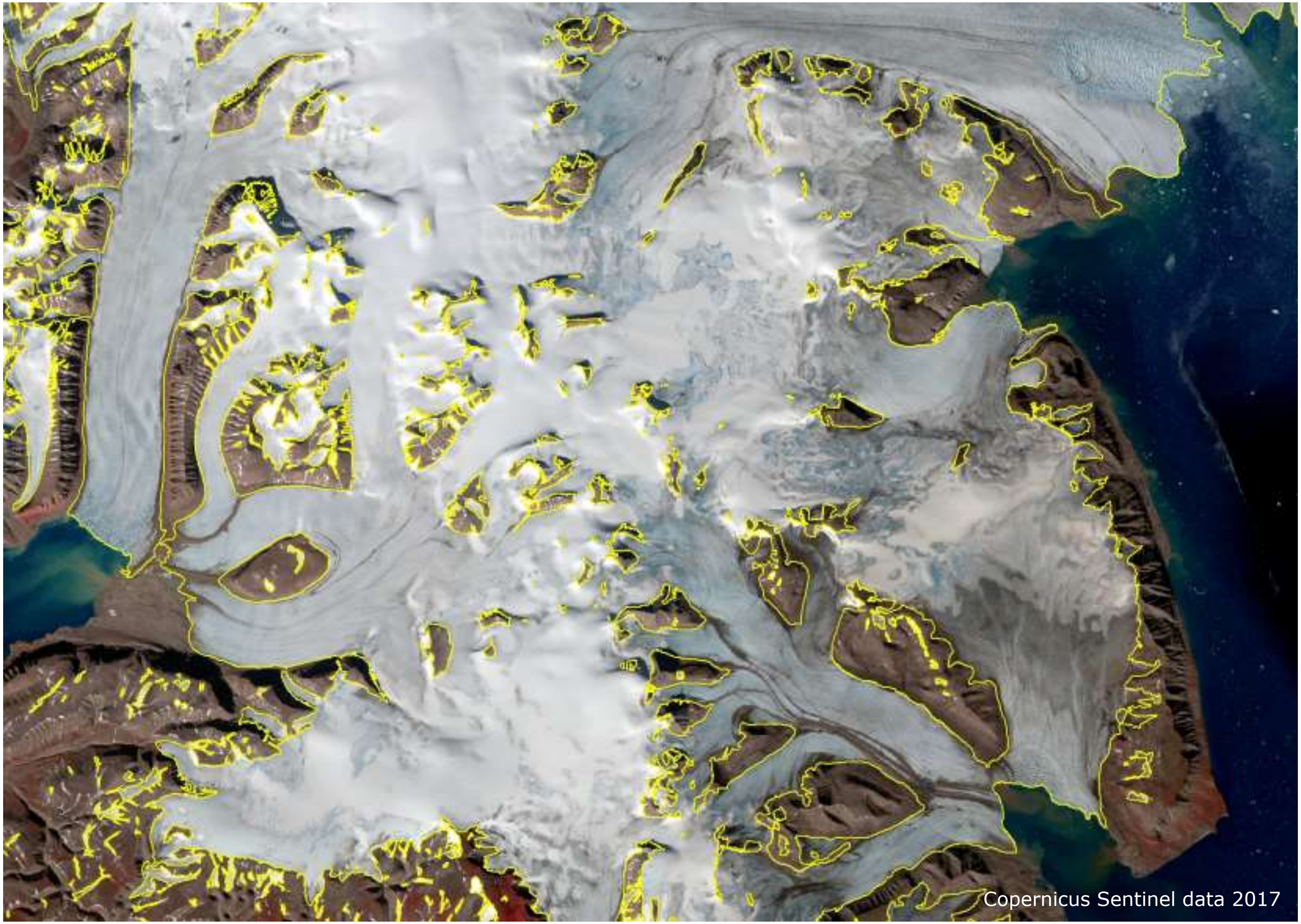


Improved Glacier Outlines

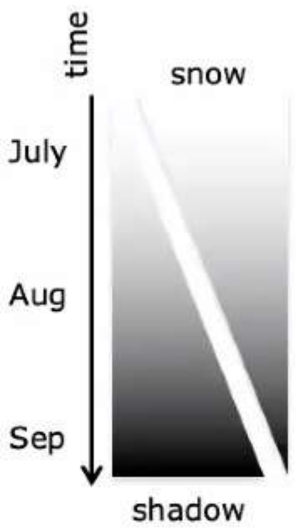
Svalbard subset overview (bands 8 4 3)

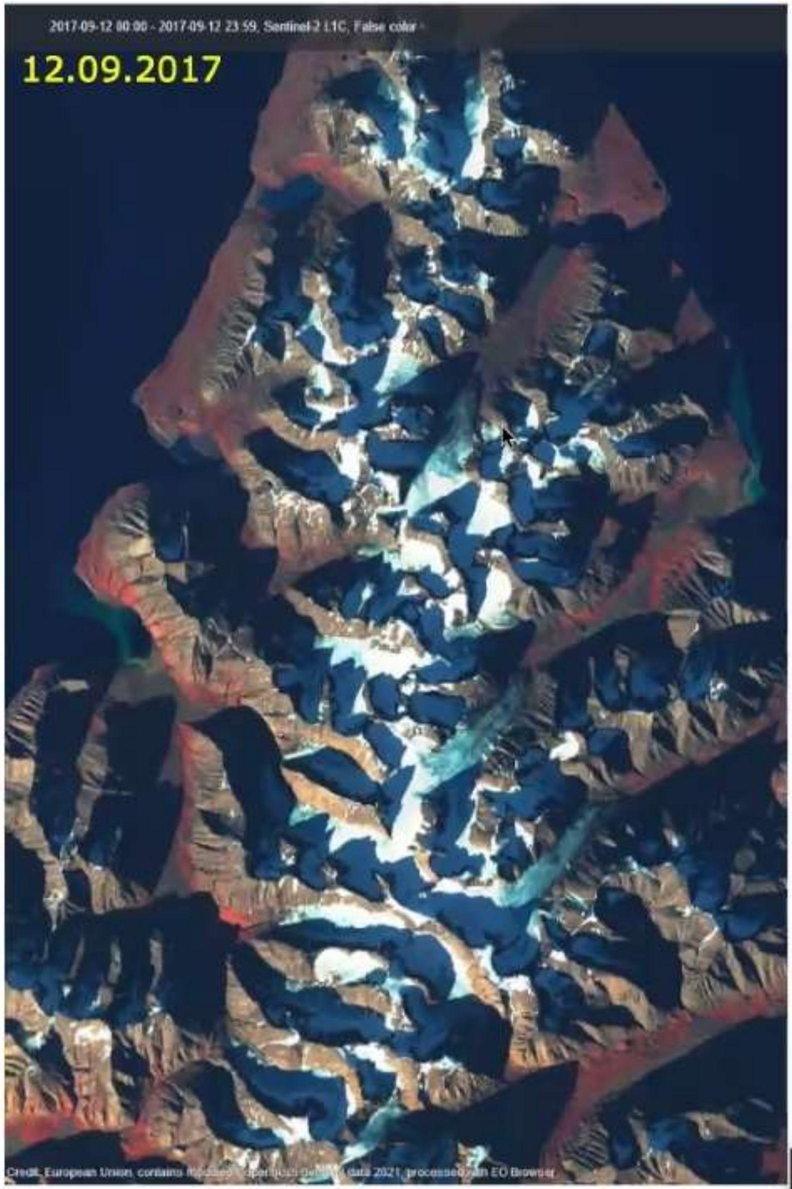


Resulting corrected outlines



Later in the year: less snow, more shadow





Approach:
map with July scene, correct with September

Svalbard: 80 N

Challenges

1. mixed pixels → lower threshold

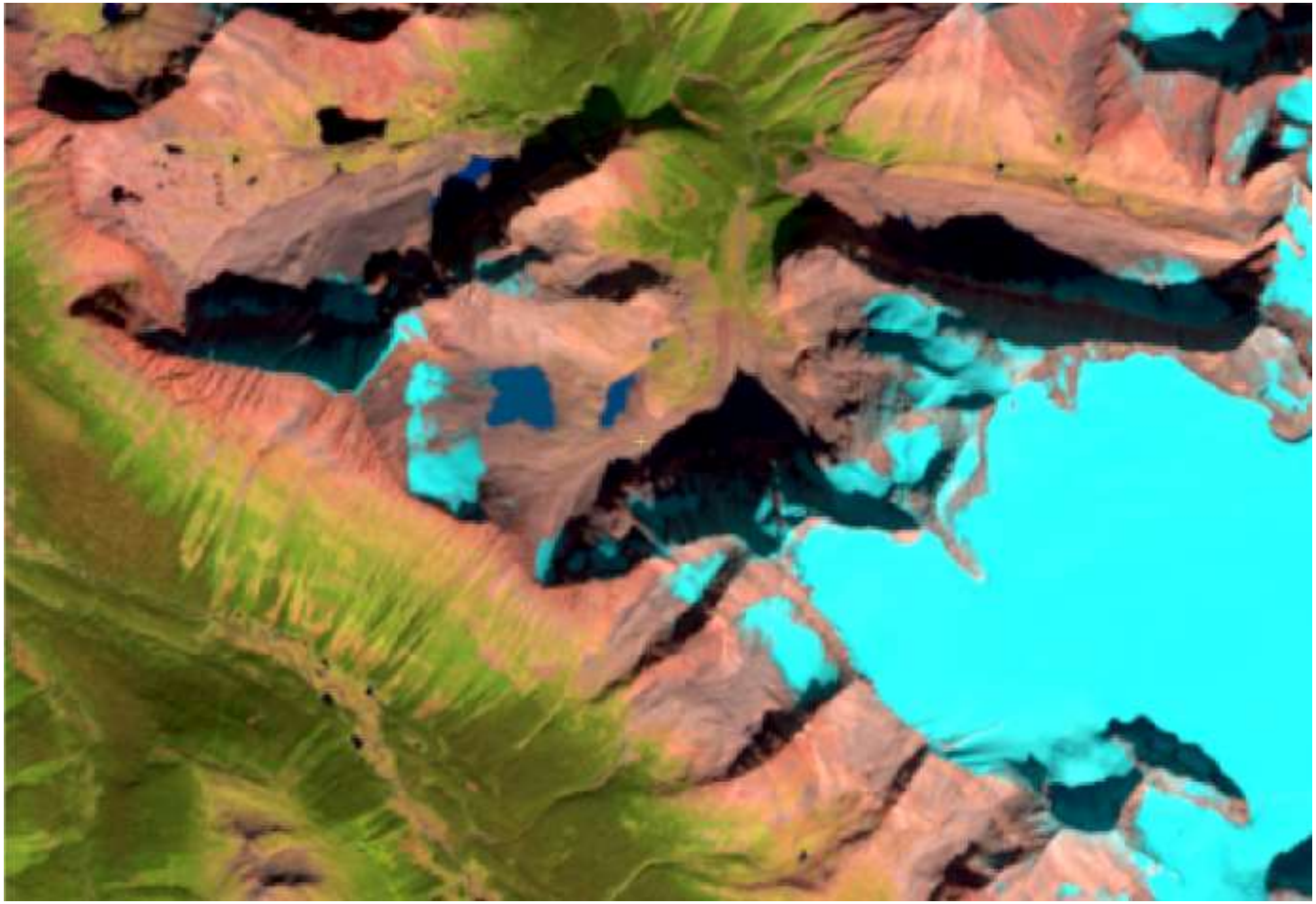
2. shadows → lower threshold

3. Misclassified lakes → higher threshold

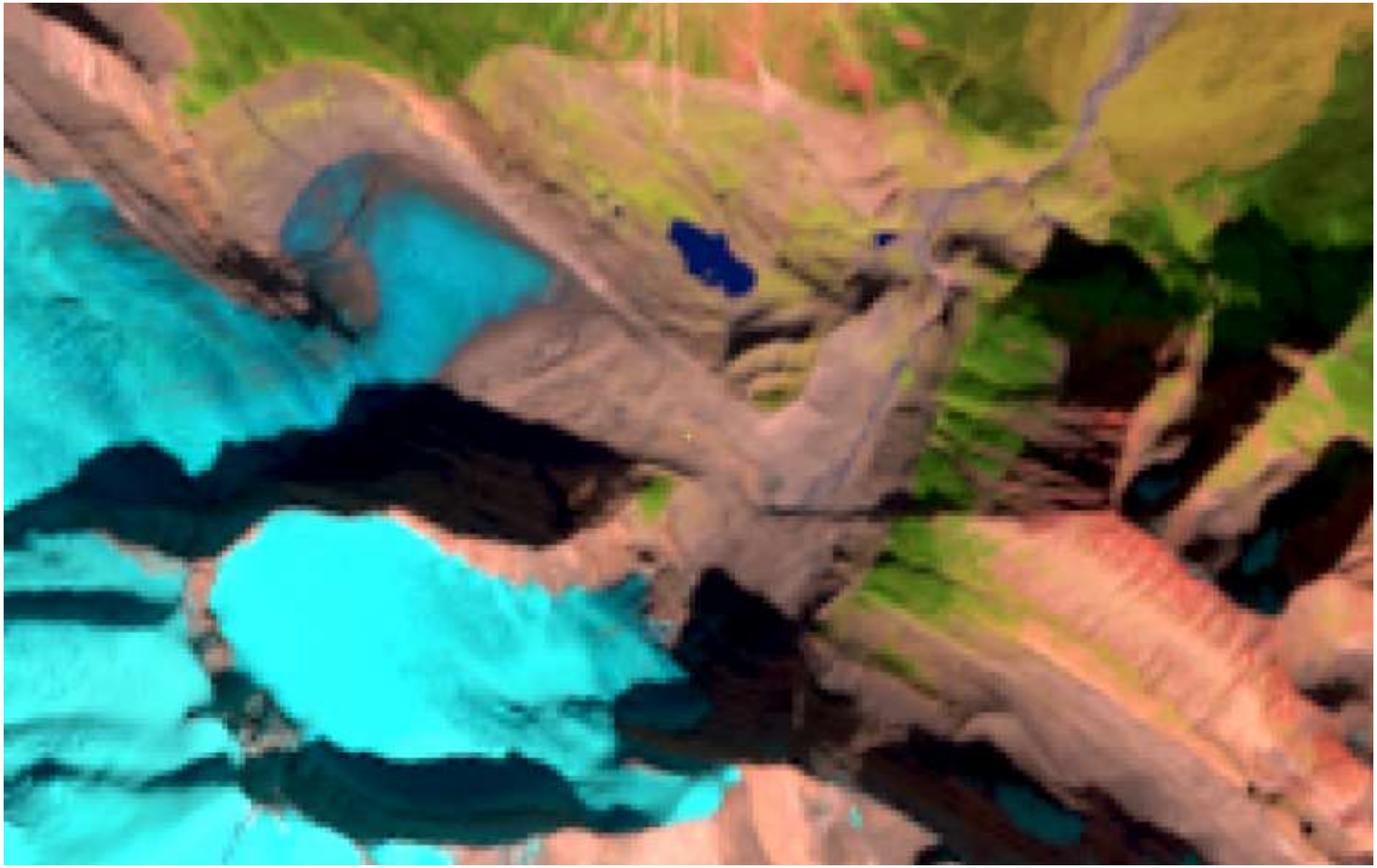
4. Debris Cover ?

5. Late snow ?

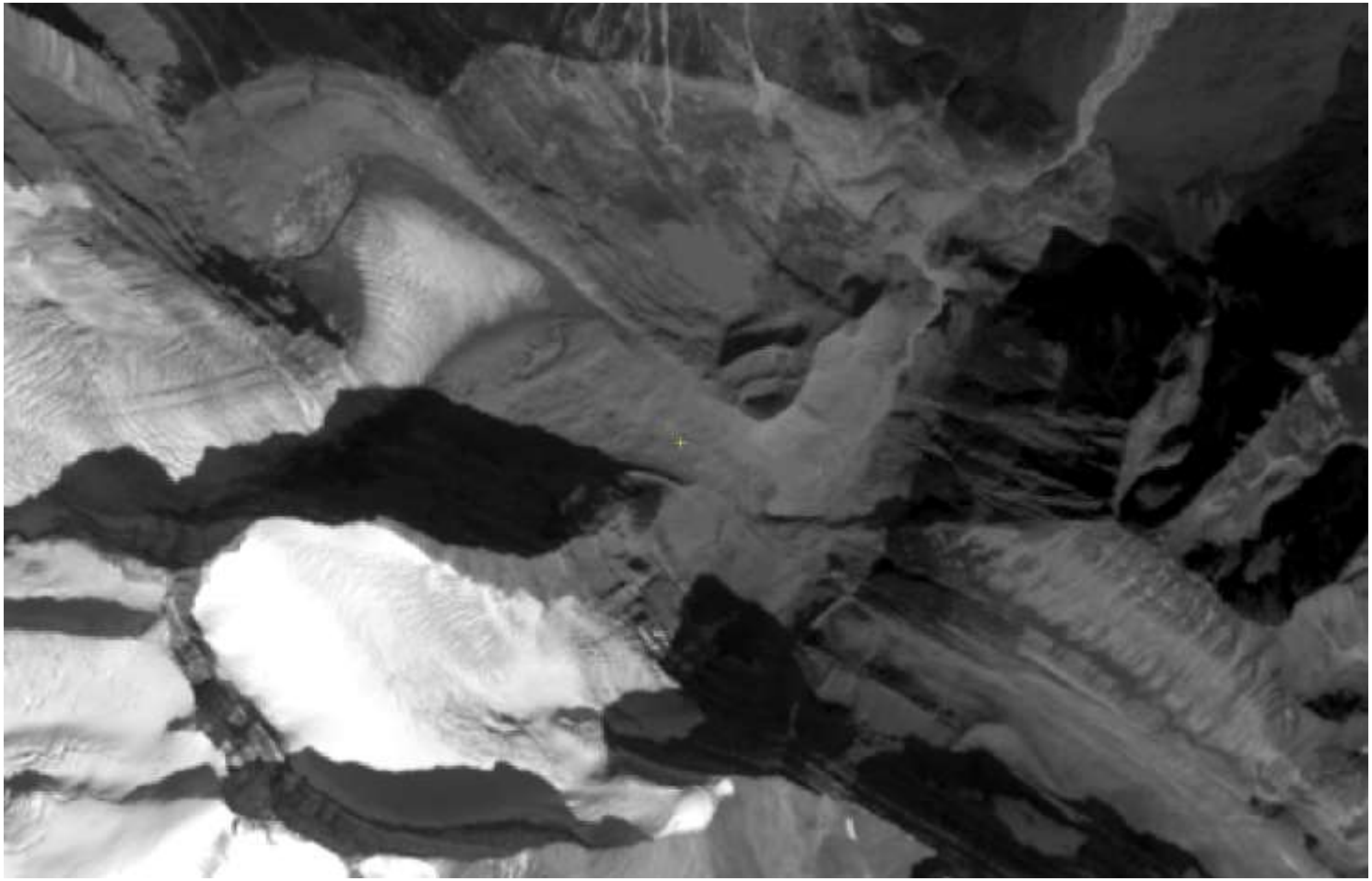
Lab 7: Resthaven Icefield, Willmore Wilderness, AB
Tricky parts – shadows, debris covered ice



Resthaven Icefield, Willmore Wilderness, AB
Tricky parts – shadows, debris covered ice



Resthaven Icefield, Willmore Wilderness, AB (Lab 7)
Pan layer (15m resolution) – greater detail visible in shadows



Ratio Improvements with Landsat 8/9 (2013) and Sentinel (2015)
- taking advantage of higher resolution Pan layer - switch Pan for Red

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

- Landsat 8/9 OLI: VNIR/SWIR 30m PAN 15m (glaciers 2013-2024)

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

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

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

16 bit data: we may need to have a lower threshold value e.g. 1.75

Remote Sensing of Glaciers

Image processing can be used to map:

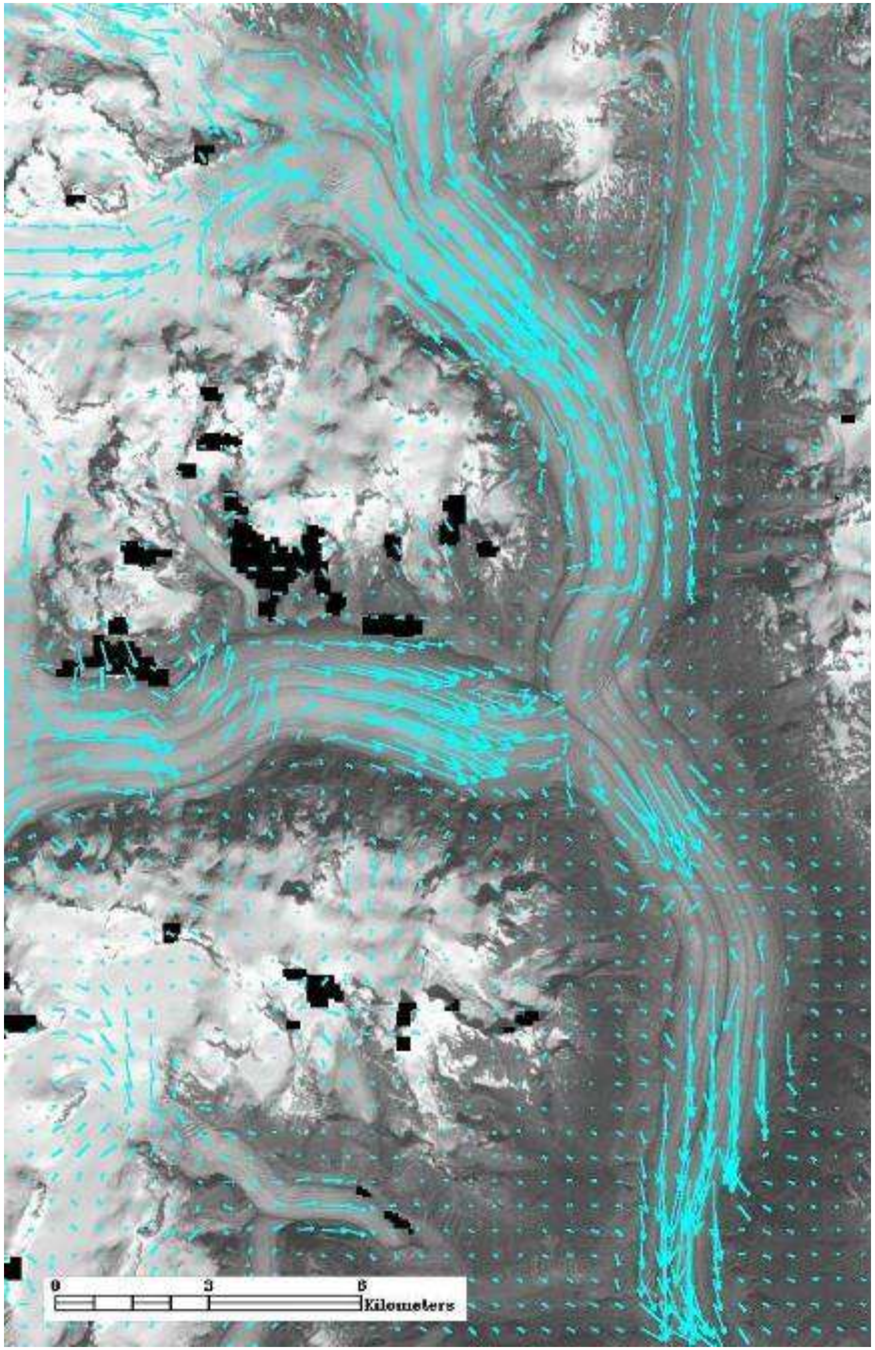
a. Glacier extents (e.g. Lab 7)

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

c. Glacier movement /velocity

d. Animation – image series (change detection lab/lecture)

e. Elevation change / Volume loss (DEM/change lab/lecture)



4. Glacier velocity

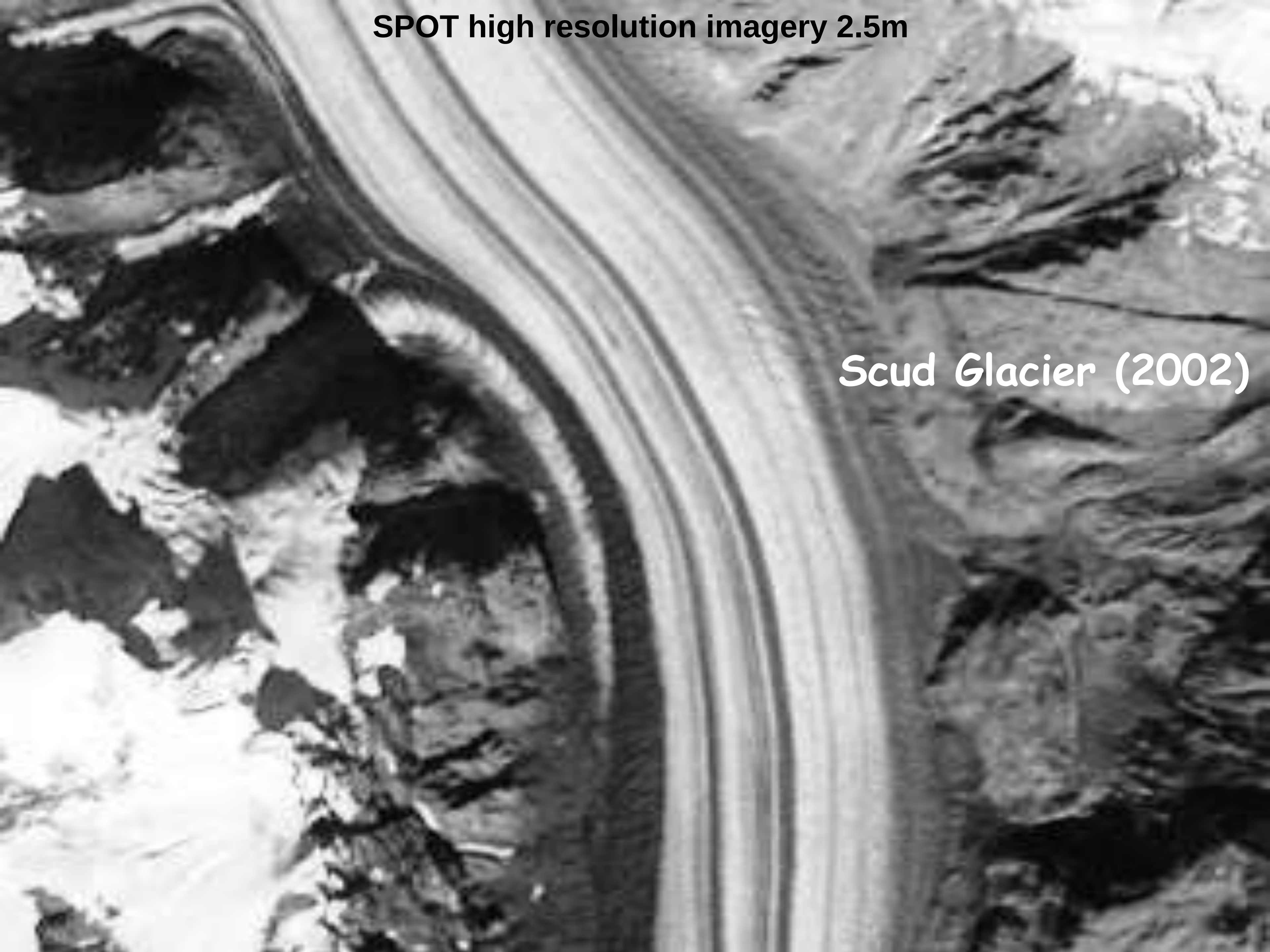
Klinaklini Glacier

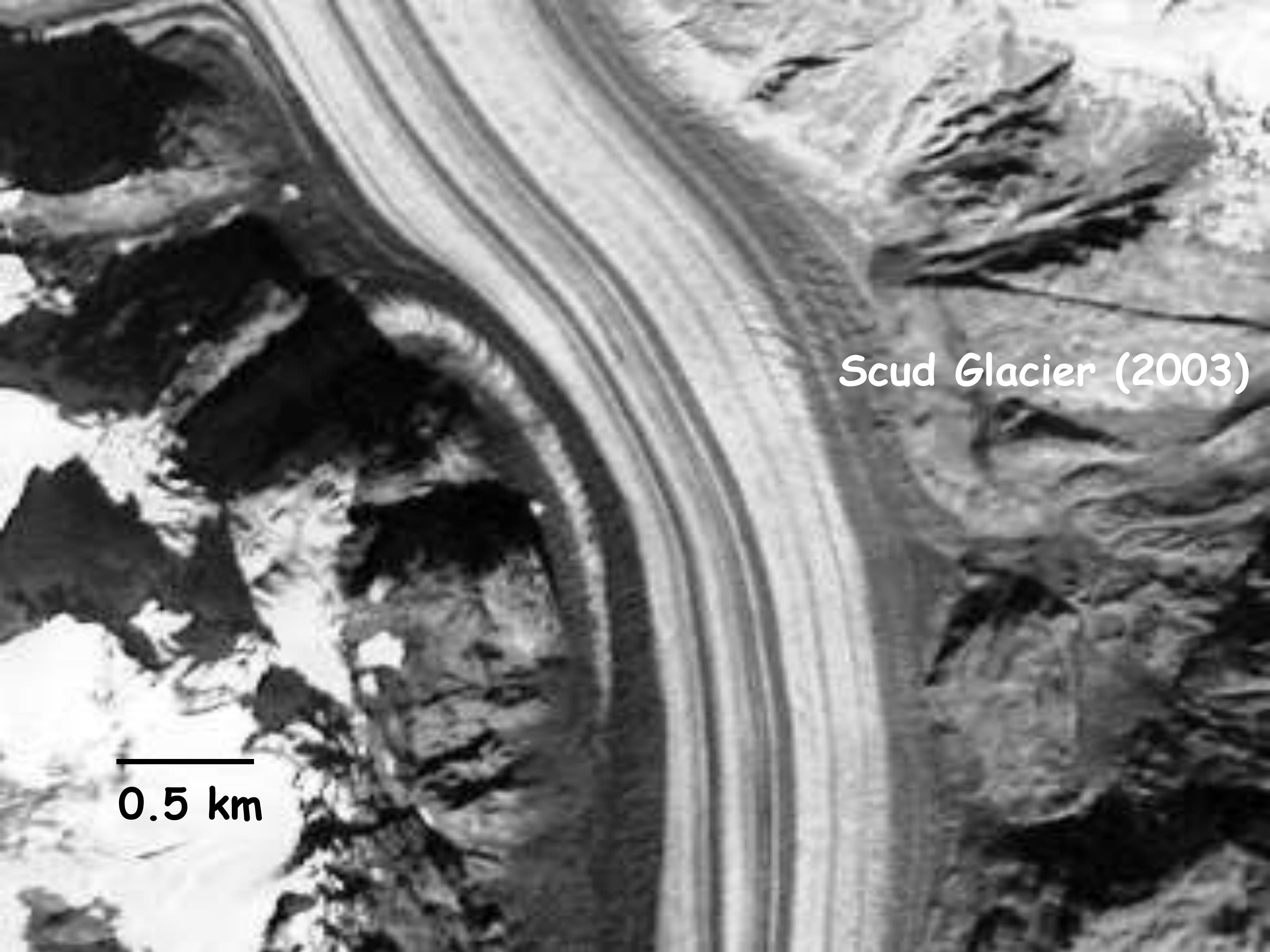
Annual movement ranges from 30 – 500 m / year mostly in summer)
= ~1m / day in summer

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

Uses ENVI COSI-CORR

Example next 2 slides


SPOT high resolution imagery 2.5m
Scud Glacier (2002)


Scud Glacier (2003)
0.5 km