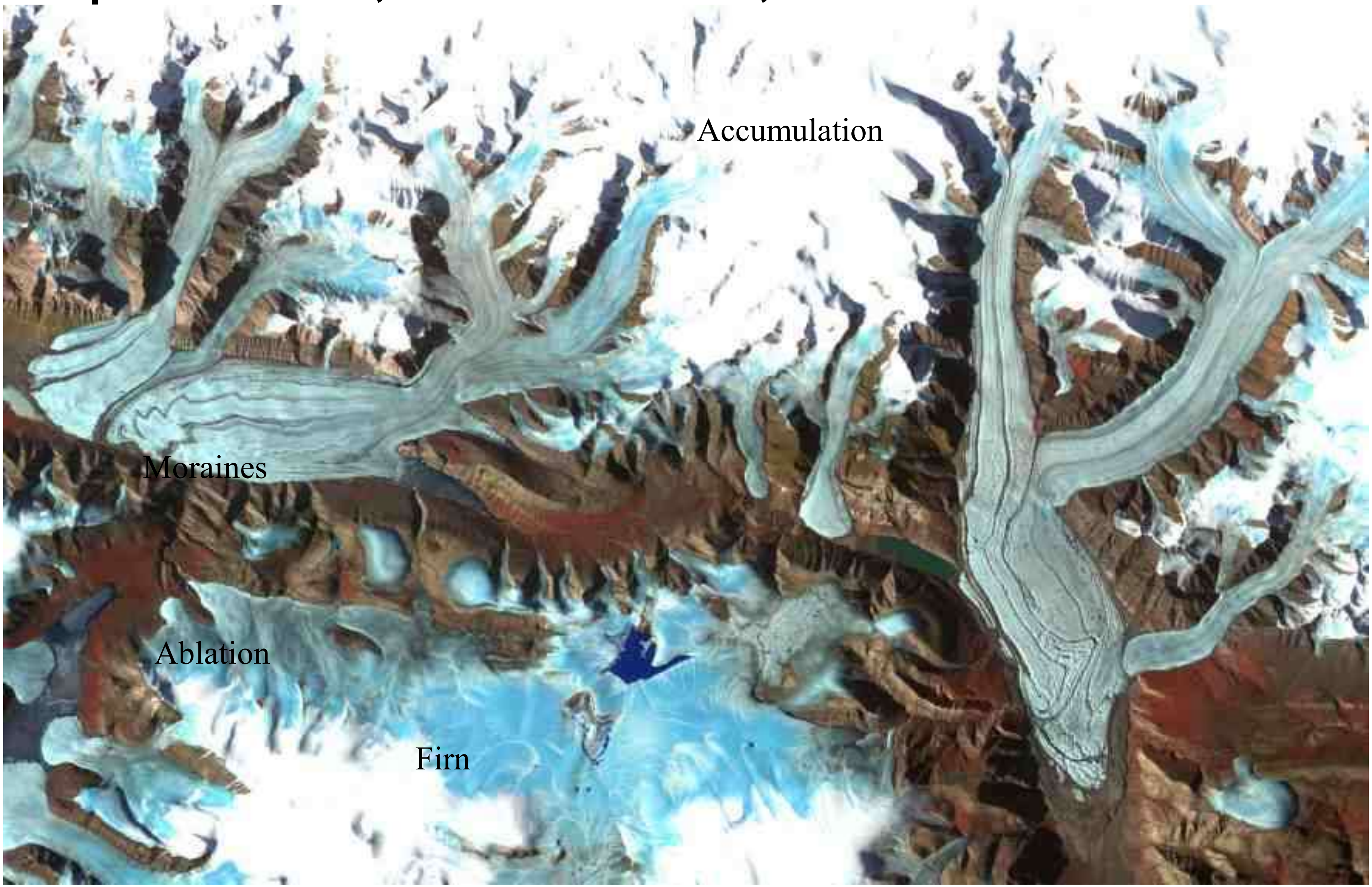
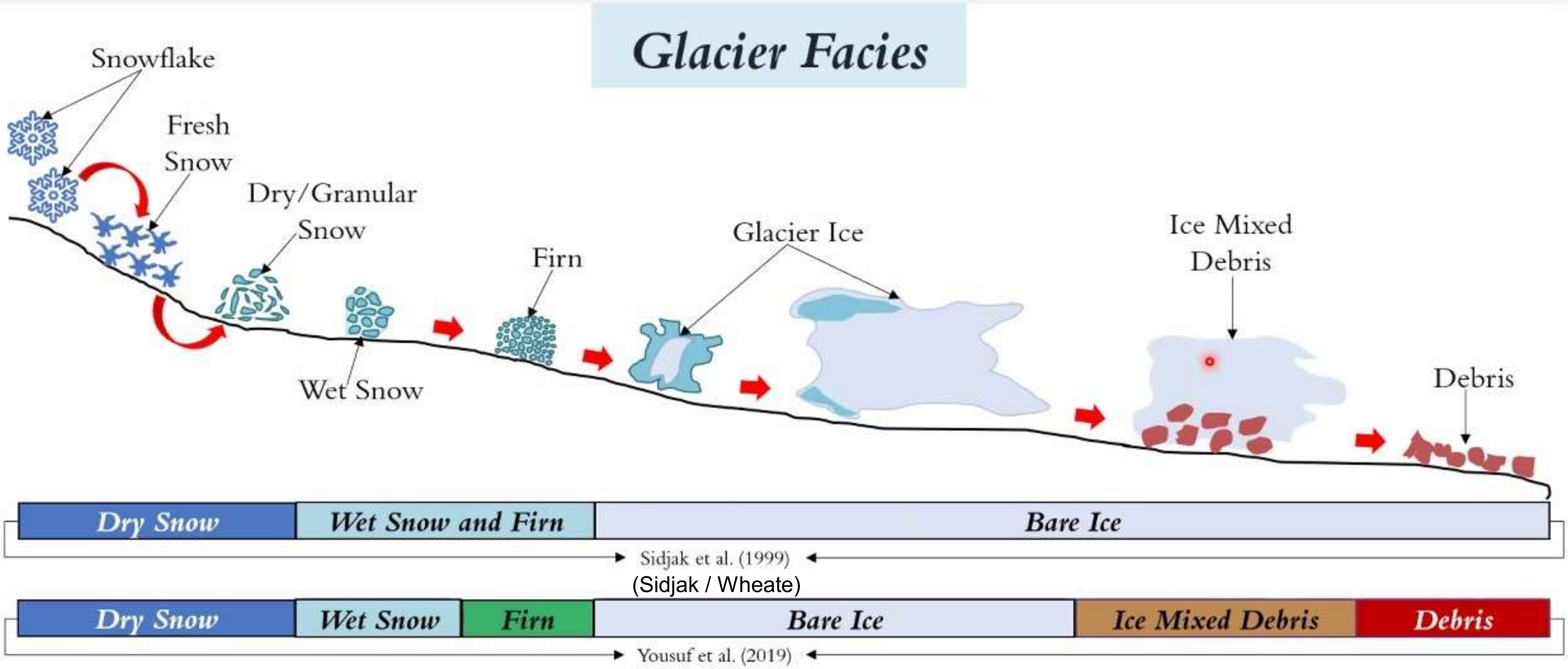
Remote Sensing of Glaciers

Chapman Glacier, Ellesmere Island, Nunavut – ASTER 2000



Surging Glaciers – winding moraines

Accumulation Firn Ablation



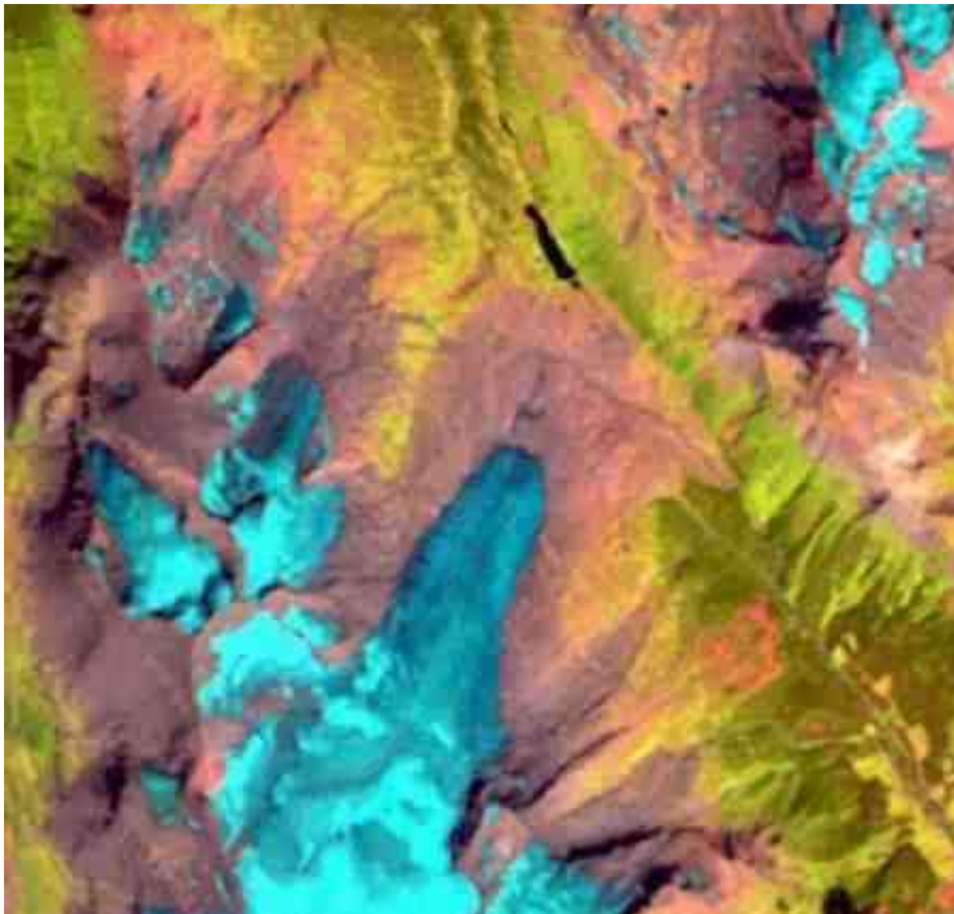
Glacier facies are natural zones of distinct variations of snow and ice which are formed as a result of the evolution of precipitated snow to ice, the cyclic process of ablation, refreezing, and eventually its melt.

Landsat Images (since MSS1972 / TM 1984)

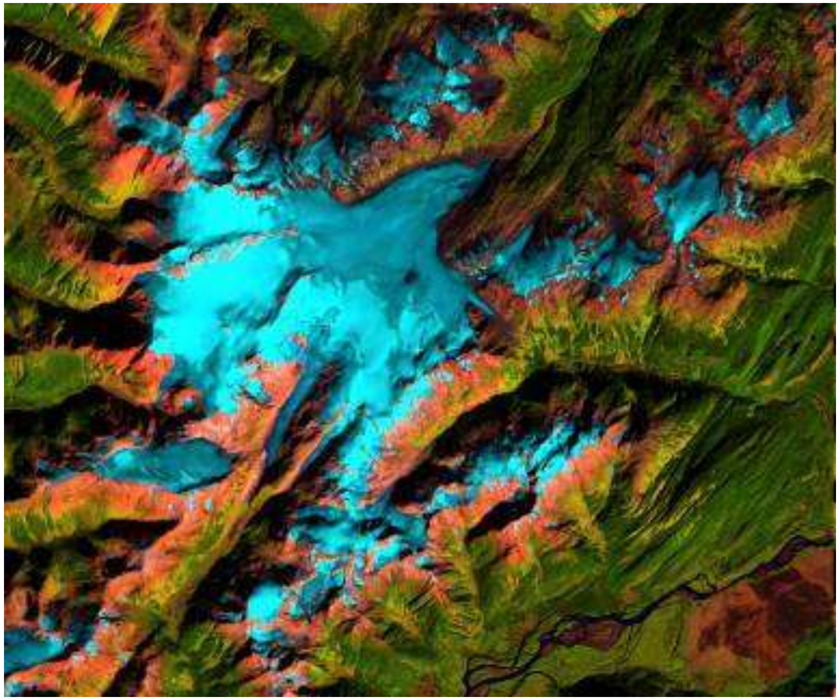
Note mark of Little Ice Age (LIA) ~ 1850

Note late lying snow cover
Muskwa-Kechika-northern BC

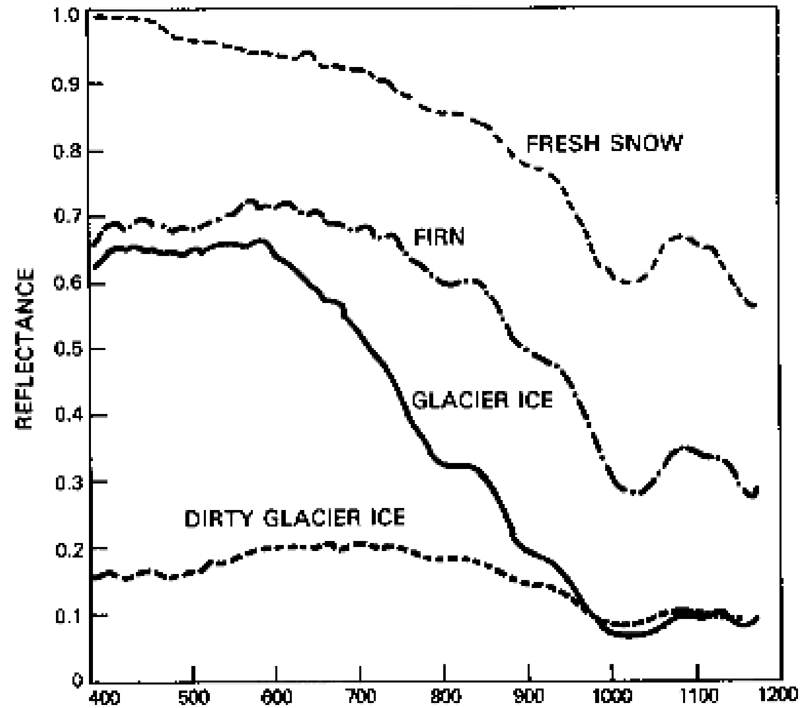
Castle Glacier- SW of McBride

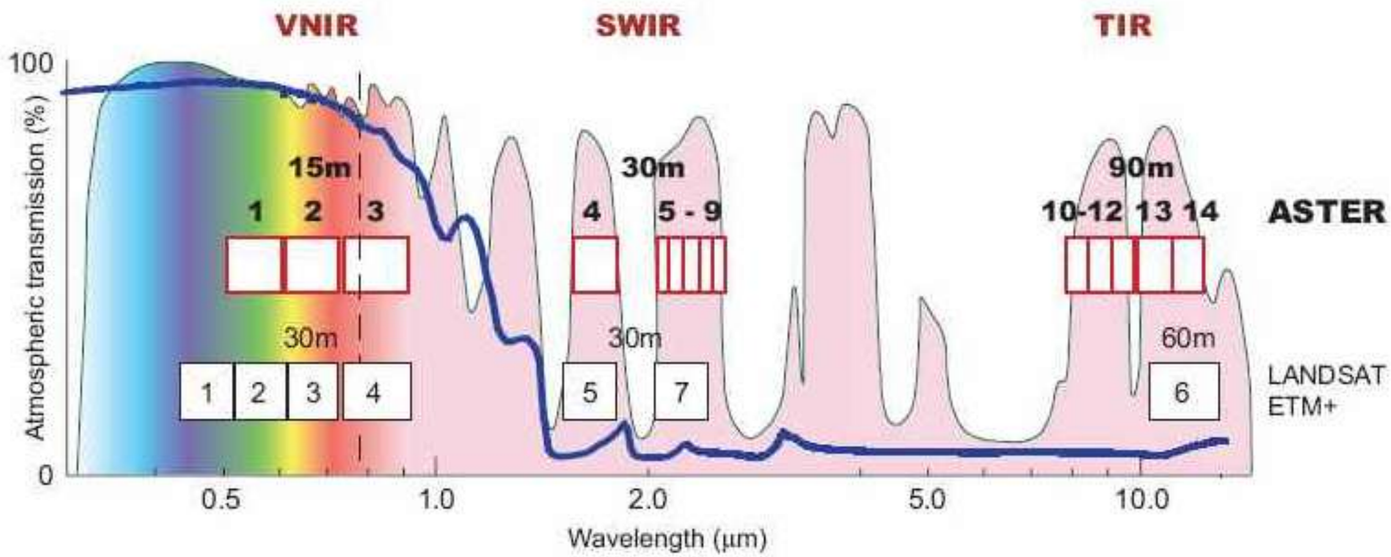


Spectral characteristics of snow and ice

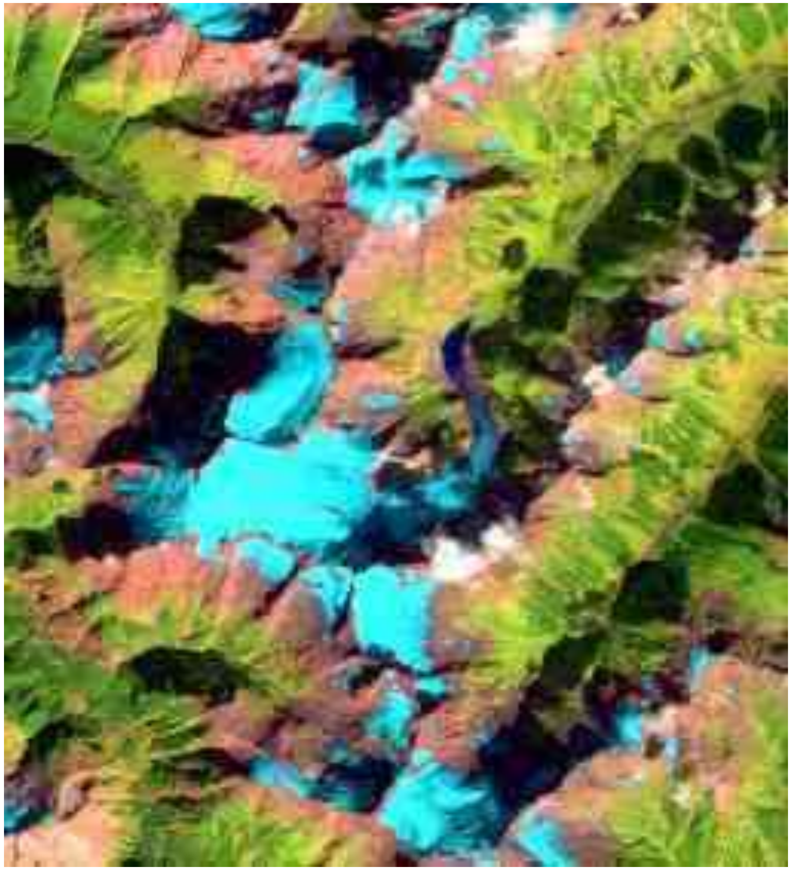


TM543





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?)



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

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

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

1. Classification

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

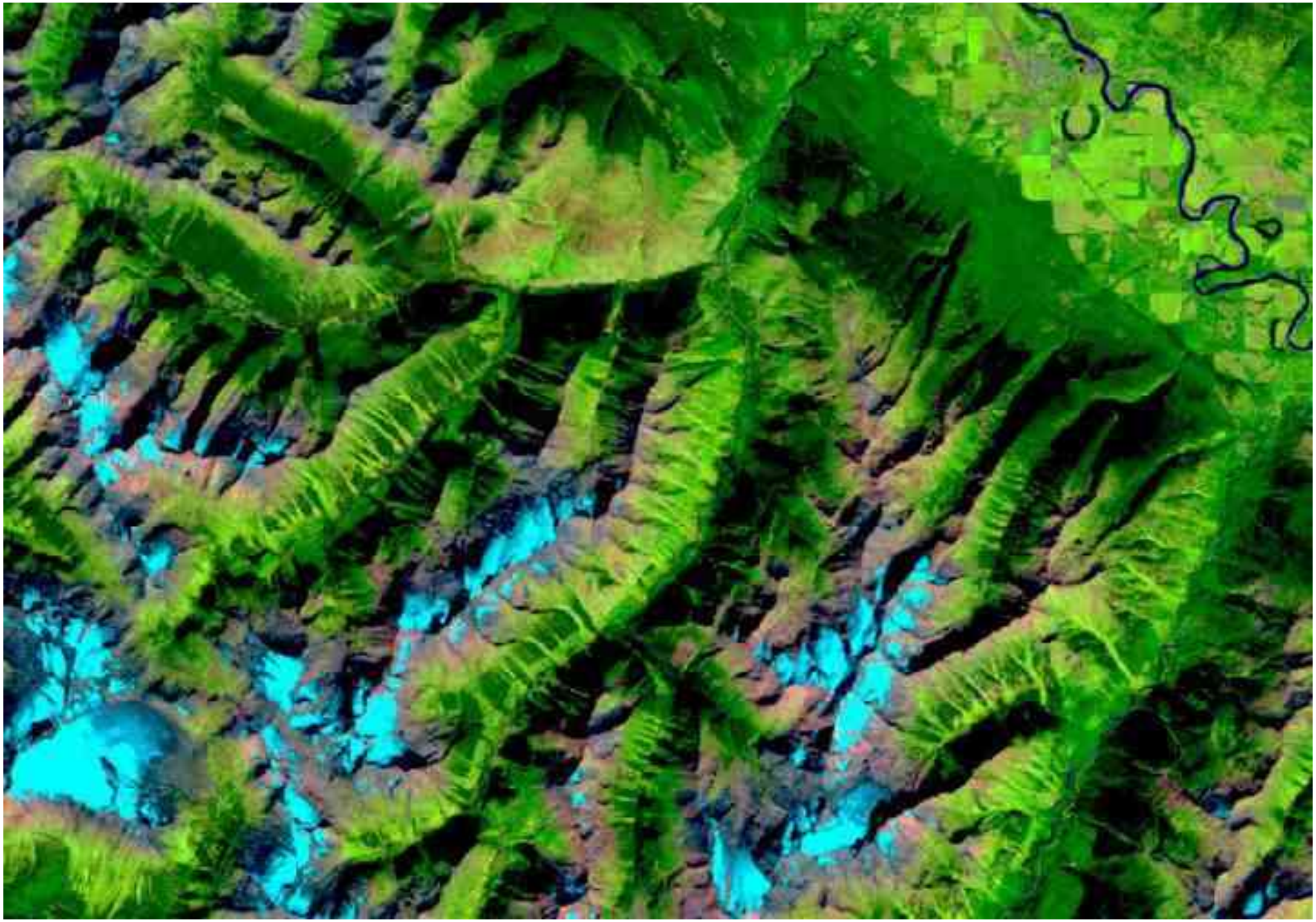
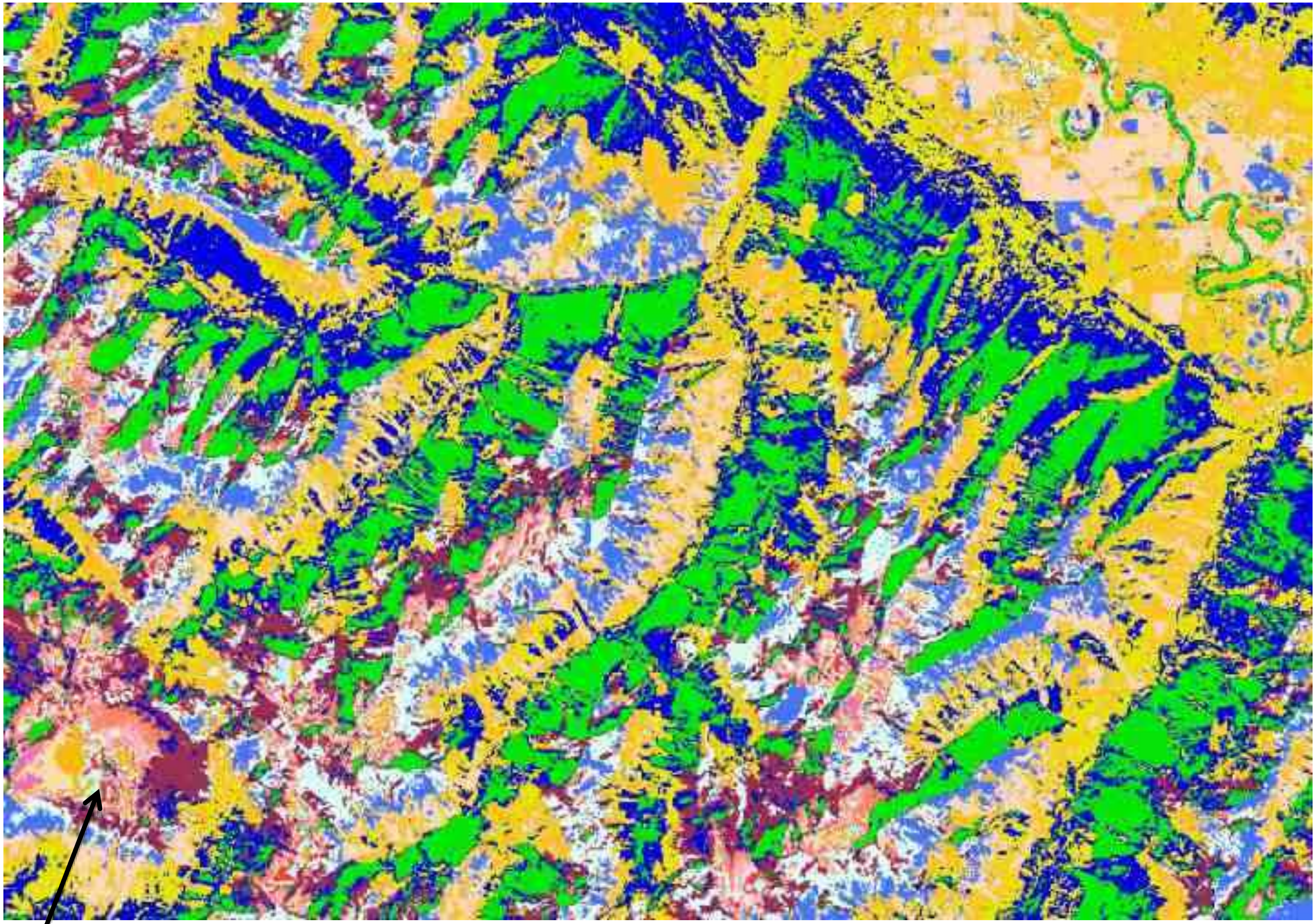


Image classification – Unsupervised … does not really work due to topography



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

Normalised Difference Snow Index (NDSI)

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

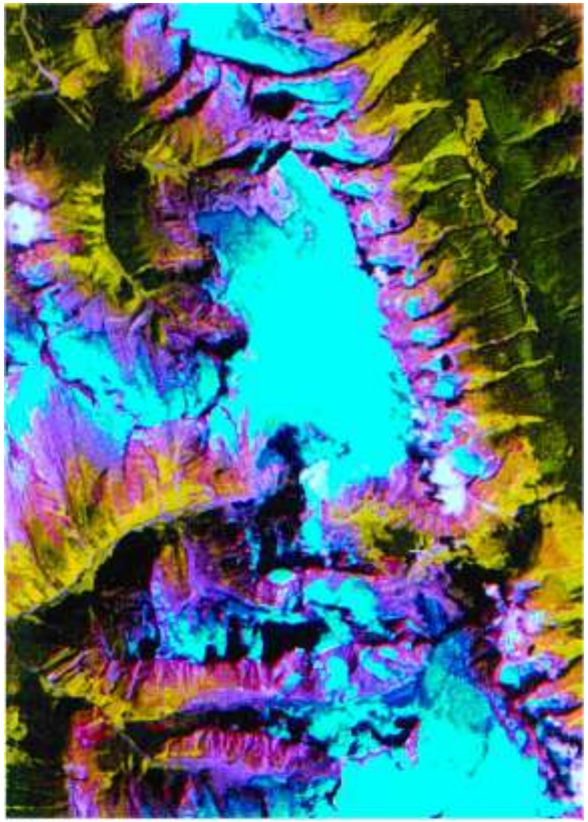
NDSI (TM) = (2-5)/(2+5)

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

Method: use this as a threshold value or input in classification

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

b. supervised classification

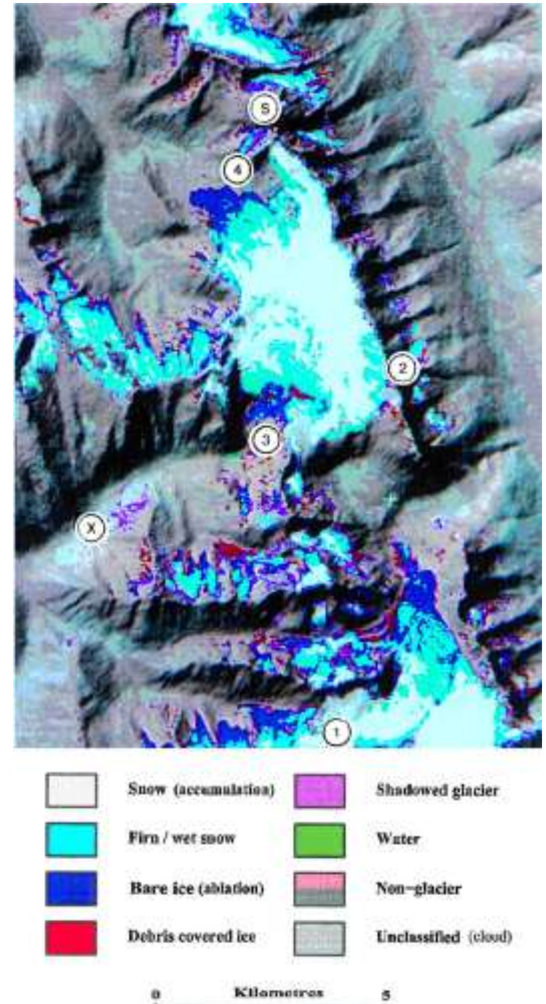


Classification Trials

1. TM bands 3, 4, 5

2. Band ratio TM4/TM5 and NDSI

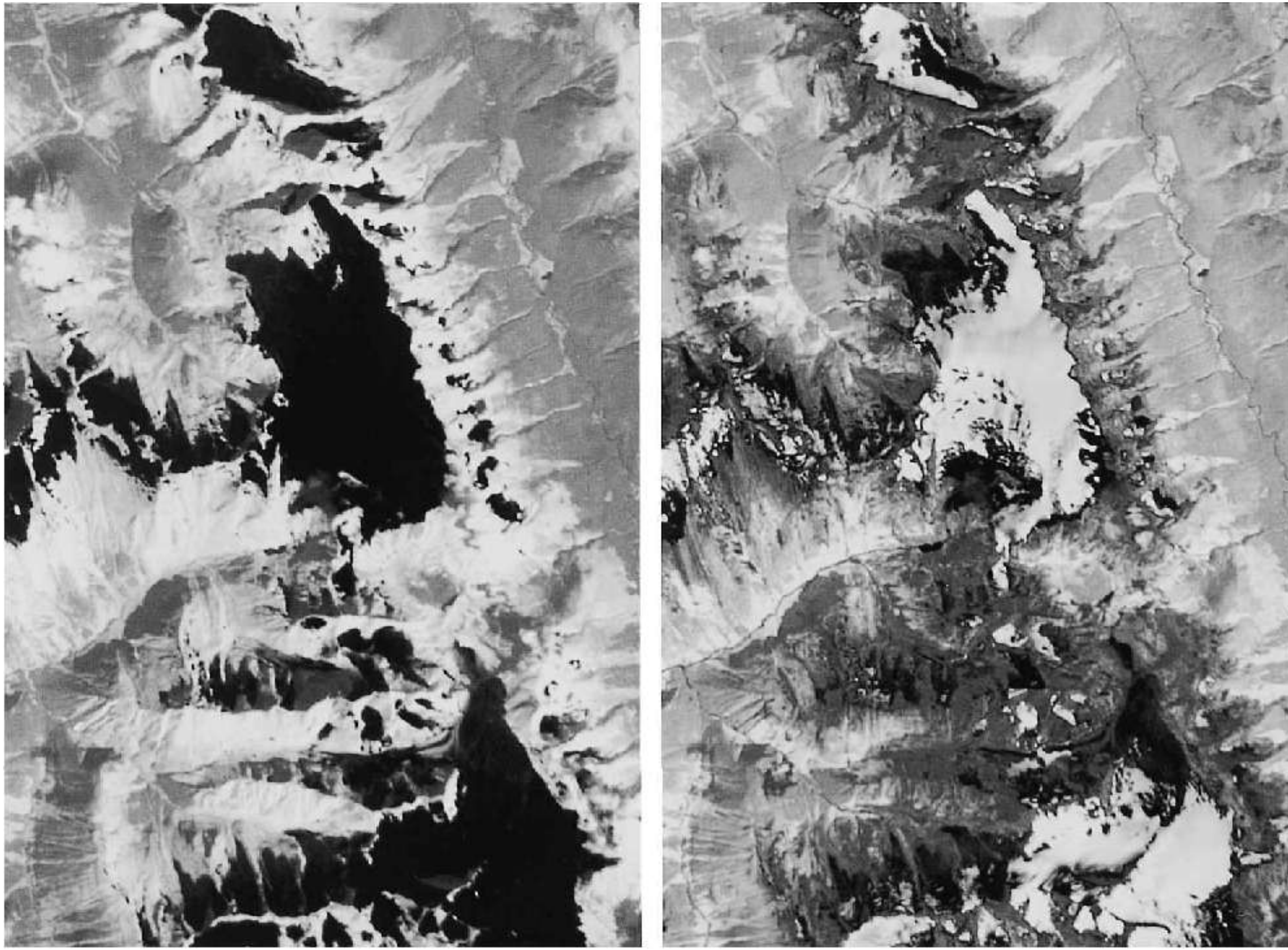
3. Principal components 2 + 4 + TM-4/TM-5 ratio + NDSI



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

R. W. SIDJAK and R. D. WHEATE
Geography Program, University of Northern British Columbia, 3333 University Way, Prince George, BC



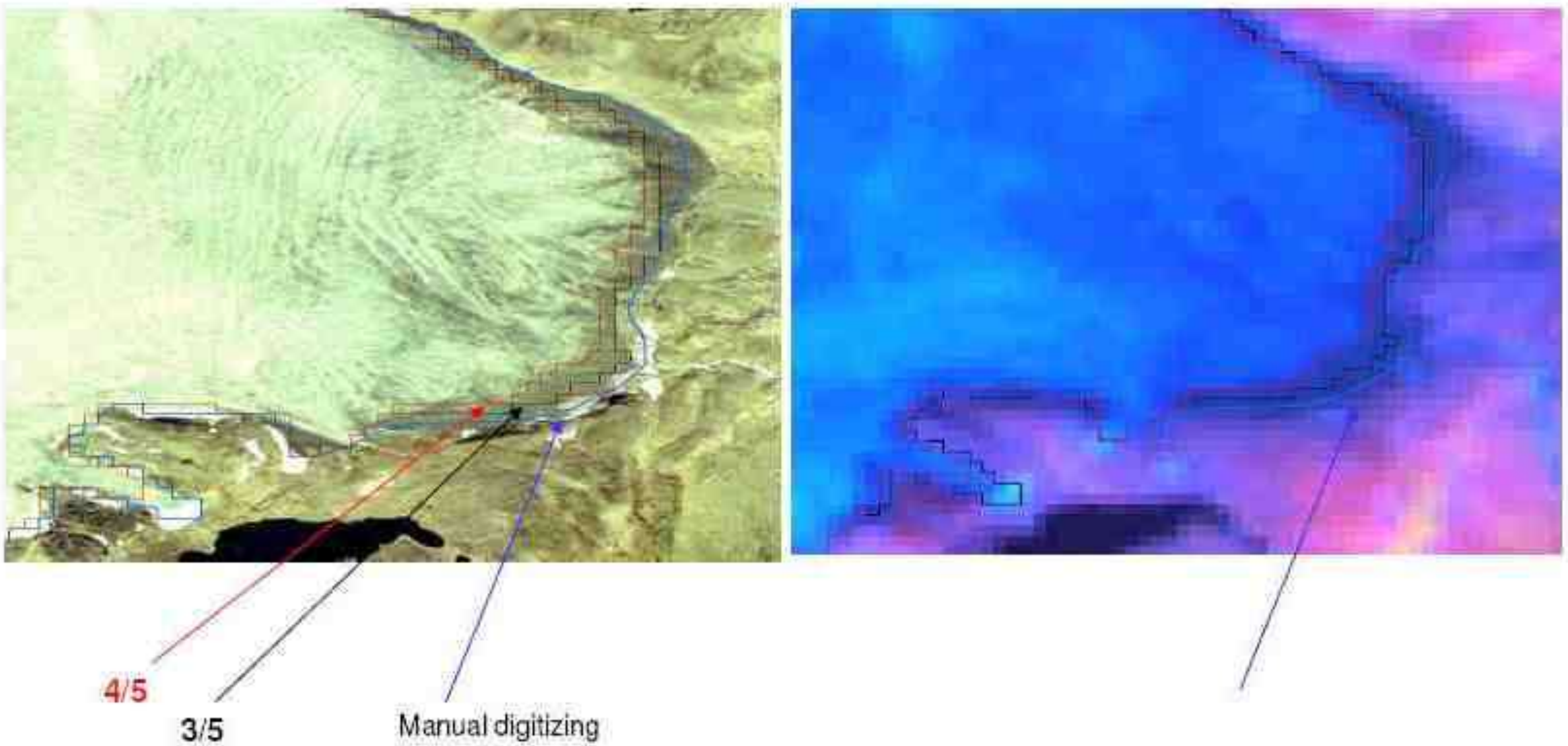
Principal components PC2 and PC4

(a) (b)

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

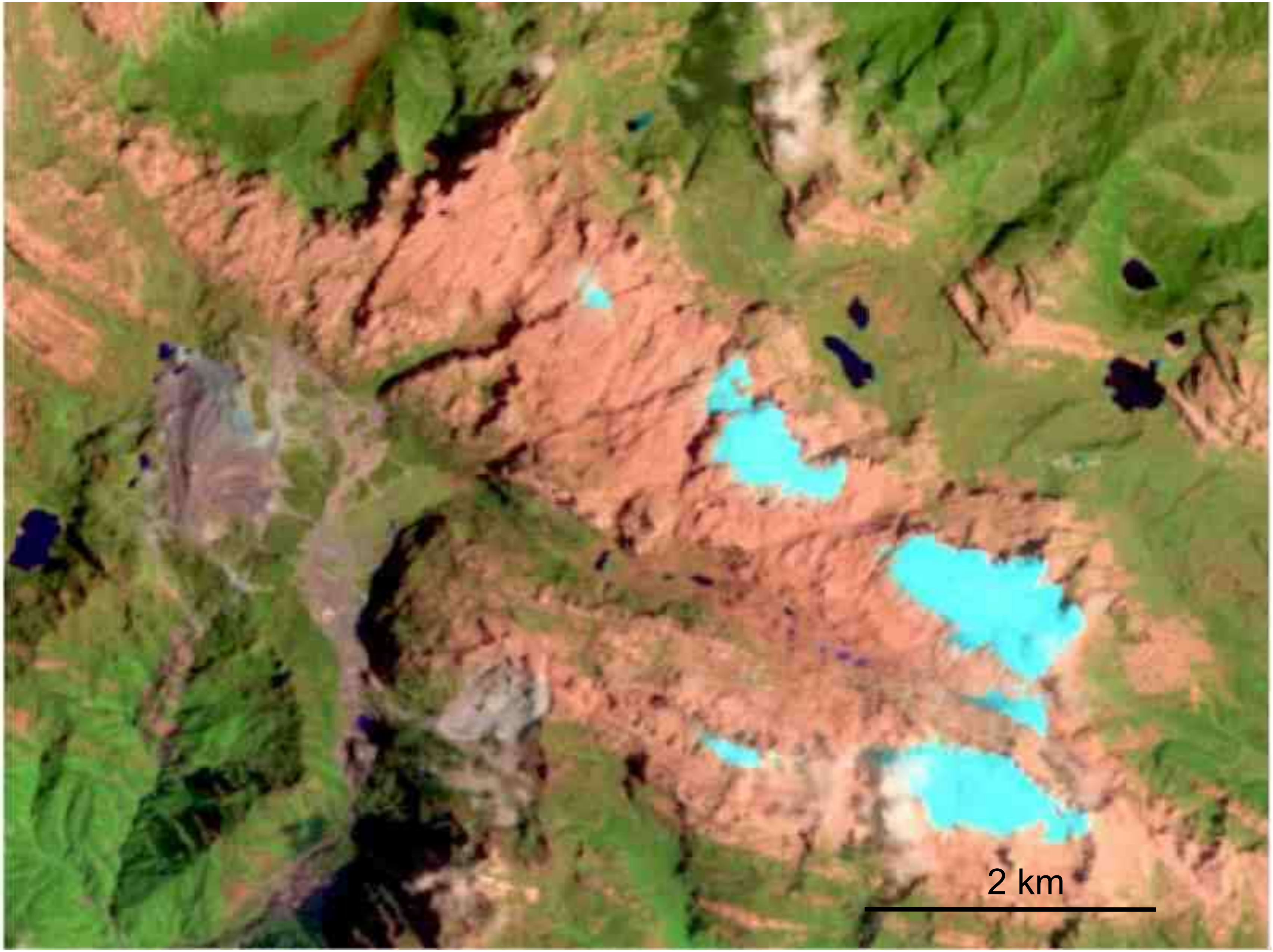


Snow and ice: very high in visible, very low in SWIR
Ratio = Visible (Red) to SWIR captures snow/ice almost exclusively
- But some issues with silt-laden water, shadowed glaciers and debris cover

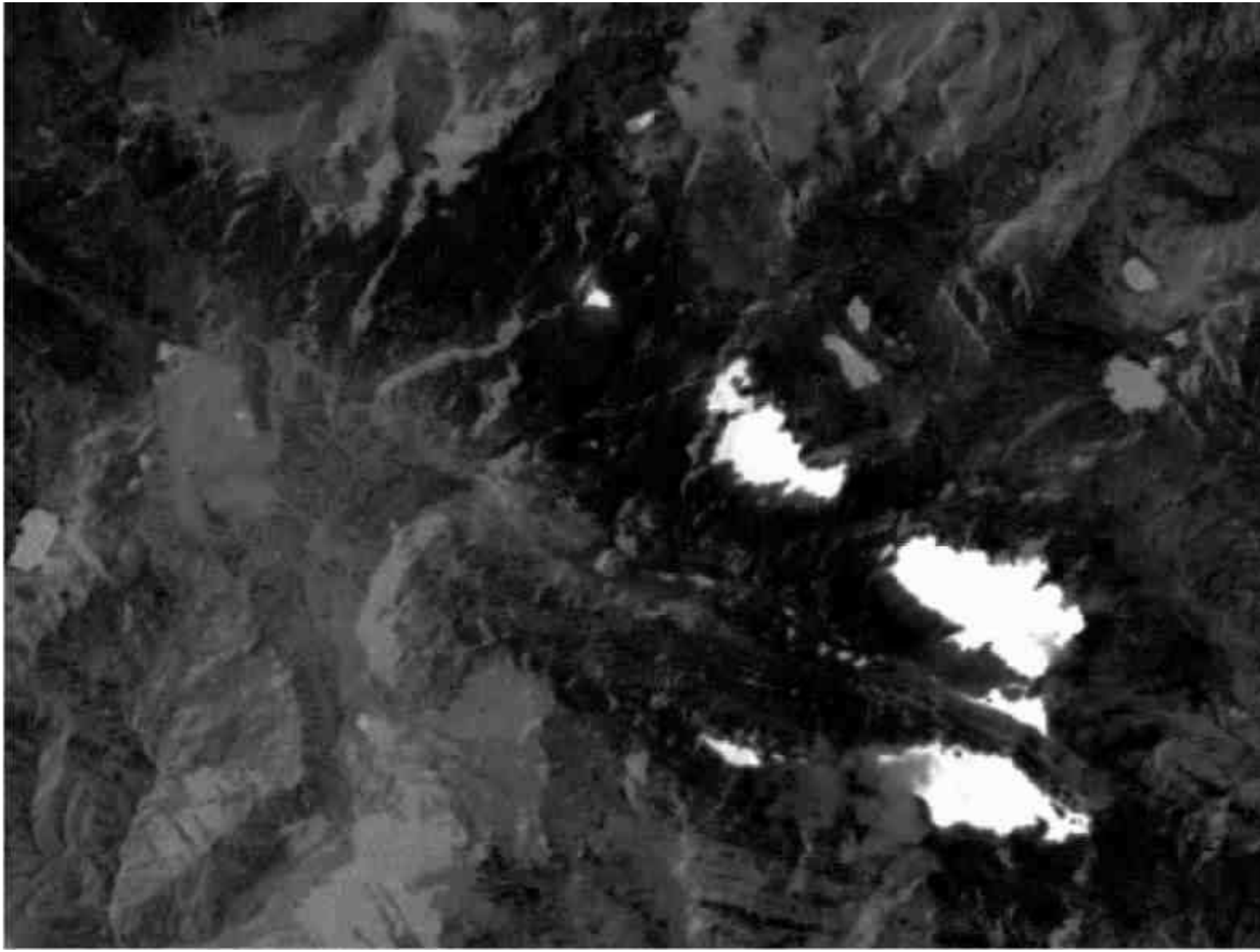
Puncak Jaya, Indonesia 4°S, 137°E   elevation m. asl: 4884m

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

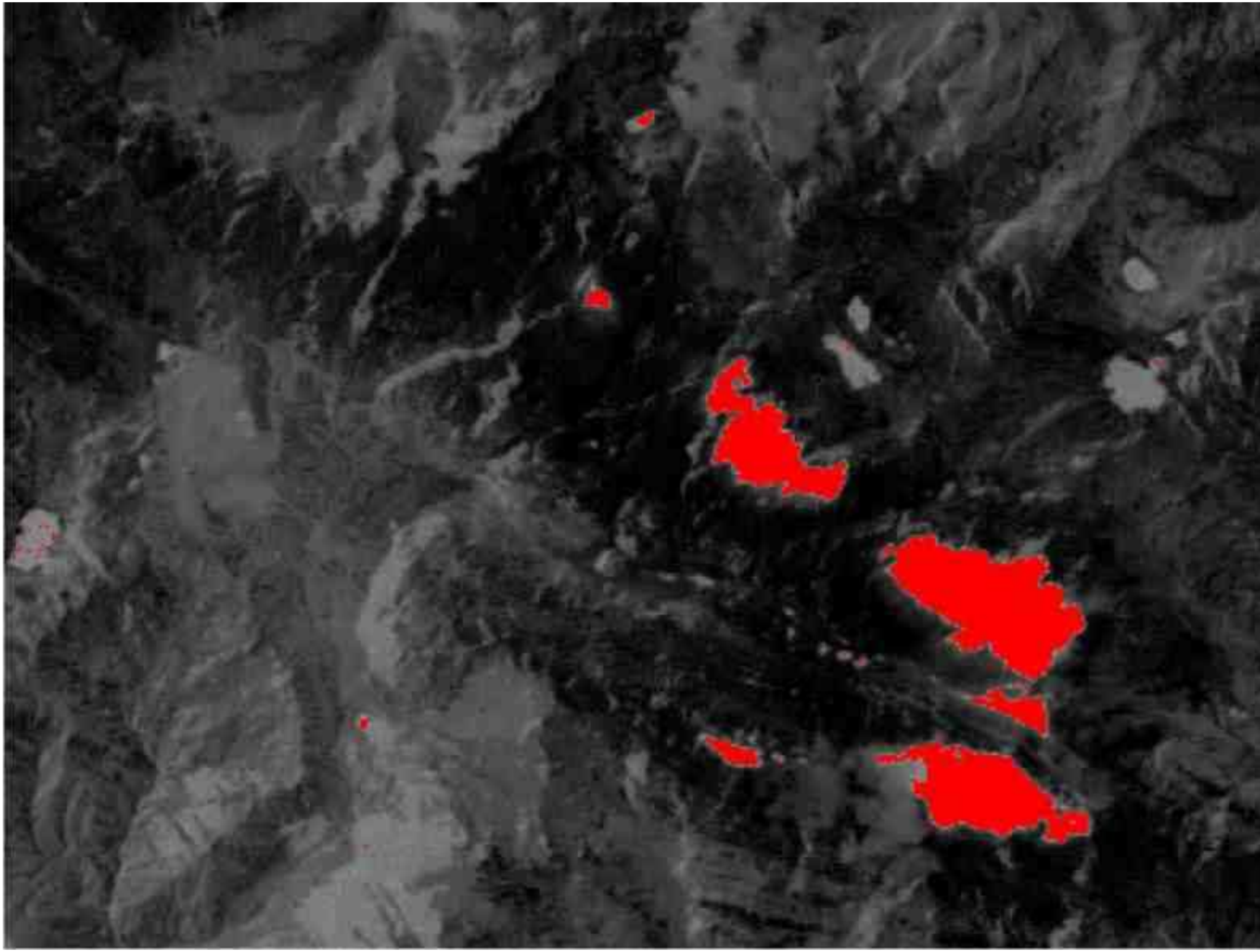
Landsat 5, 1992: near equator = little shadow



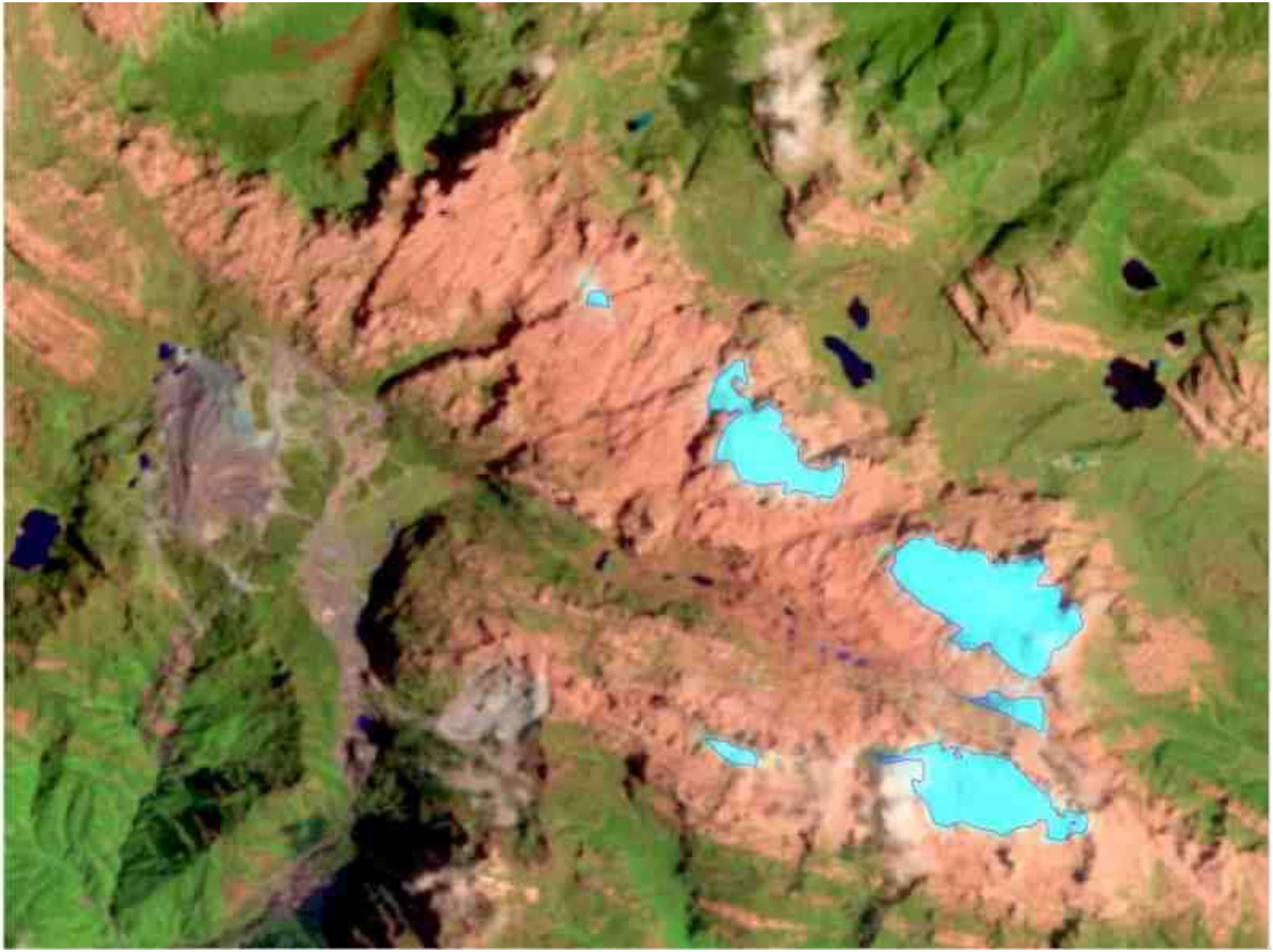
TM Red / SWIR ratio



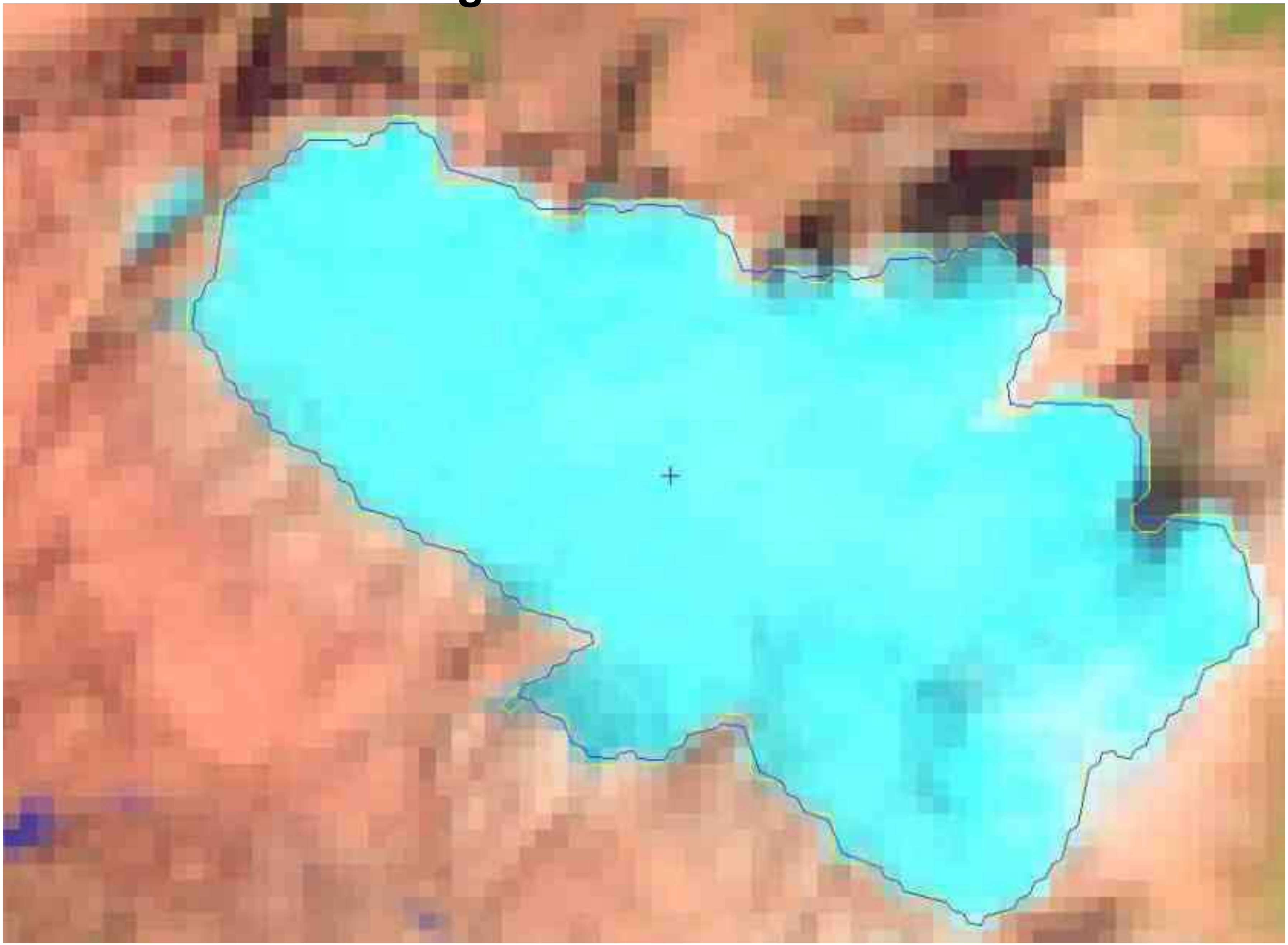
Threshold value 2.0



Convert bitmap to polygon

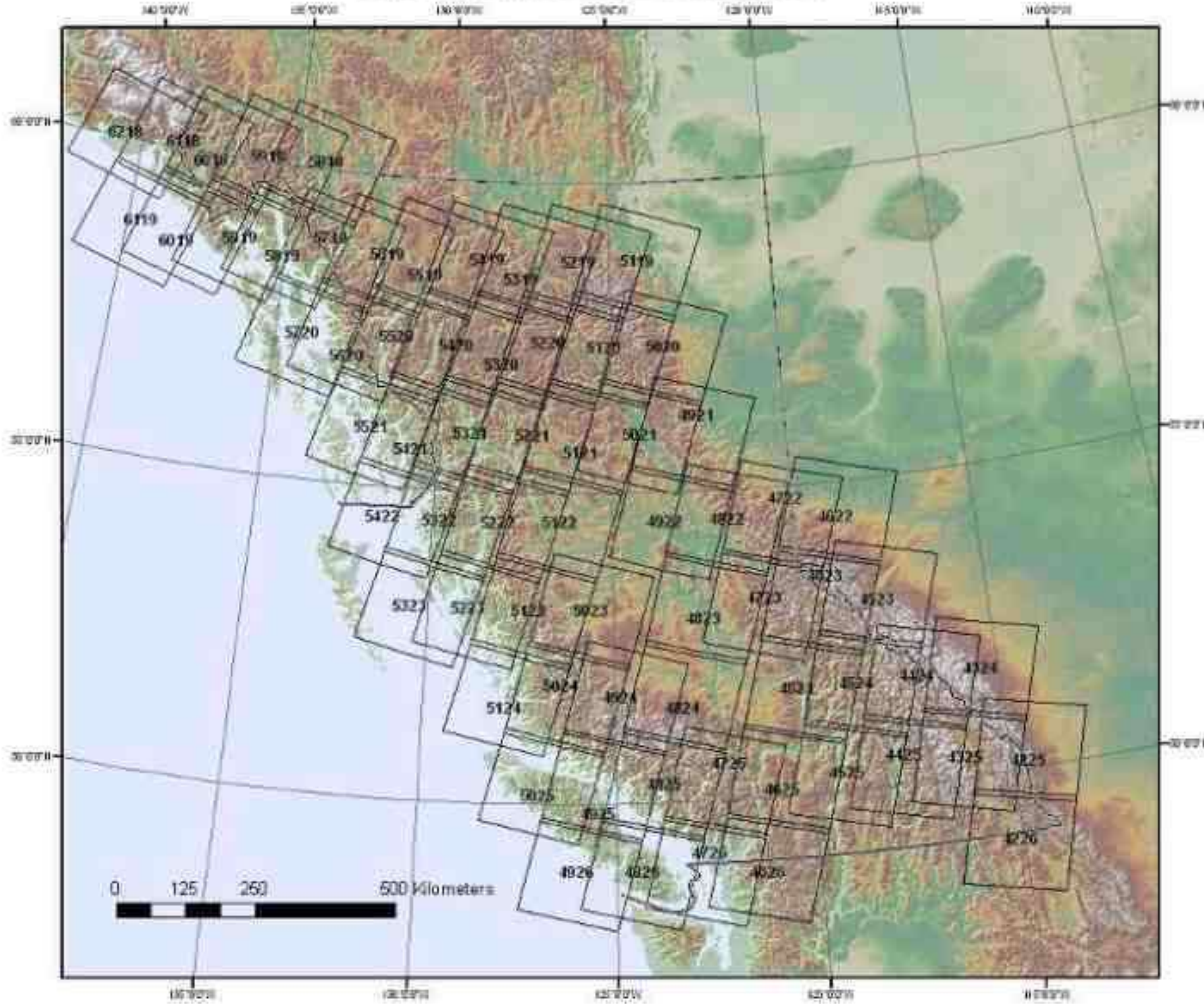


Vector smoothing



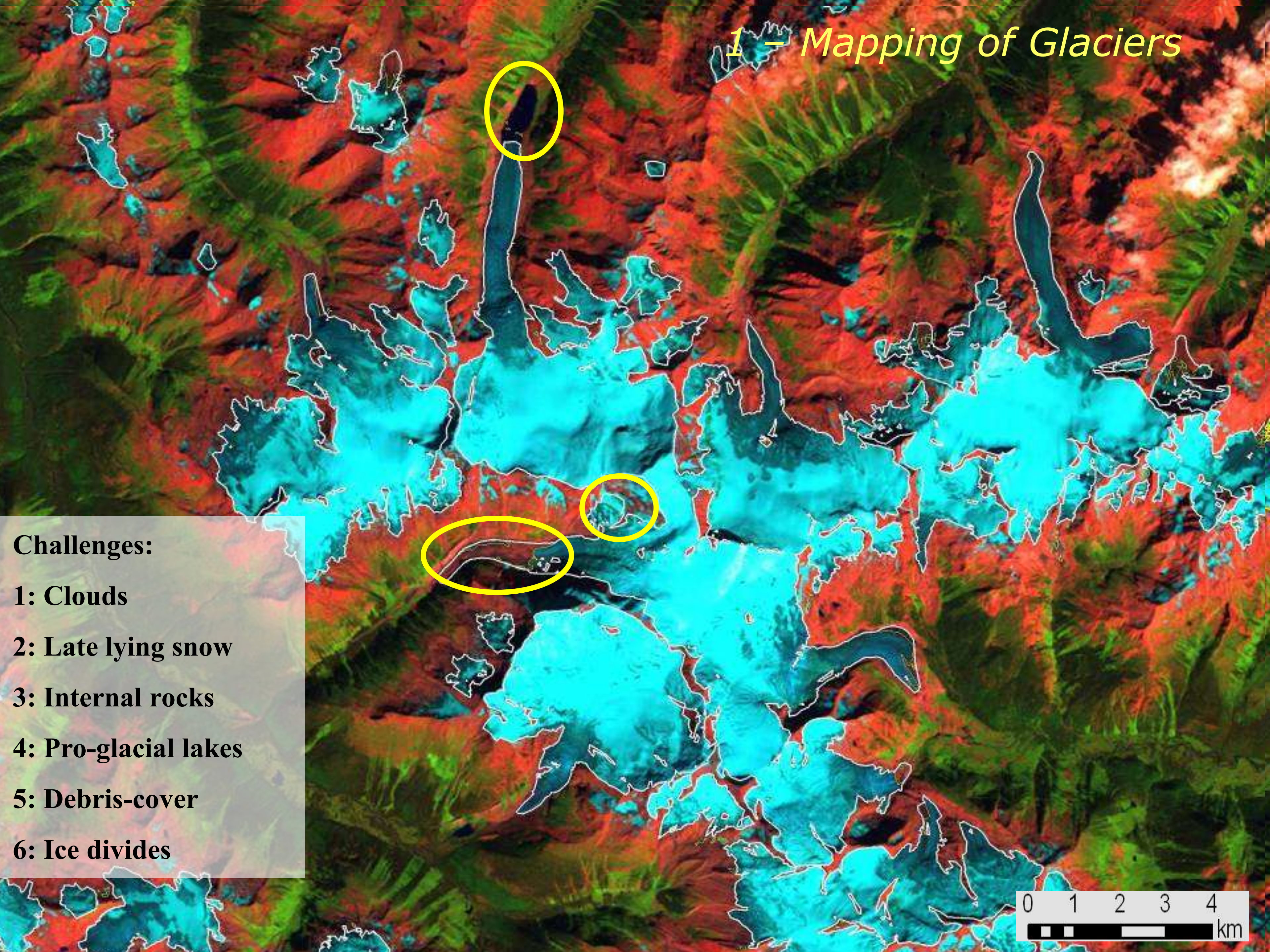
The cordilleran glaciers of western Canada - mapped at UNBC, 2008

British Columbia: Landsat Path and Row



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

1 – Mapping of Glaciers



Challenges:

1: Clouds

2: Late lying snow

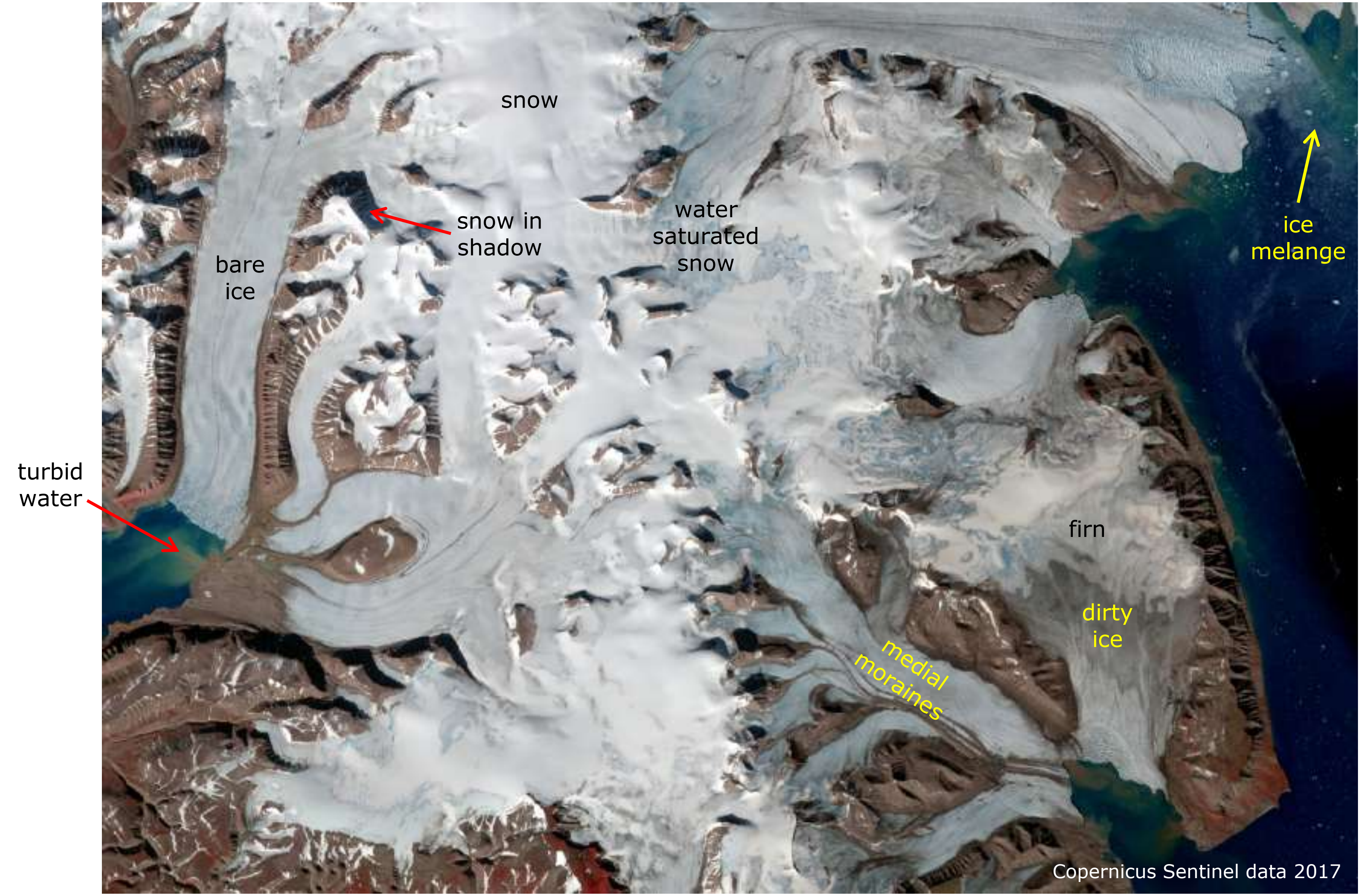
3: Internal rocks

4: Pro-glacial lakes

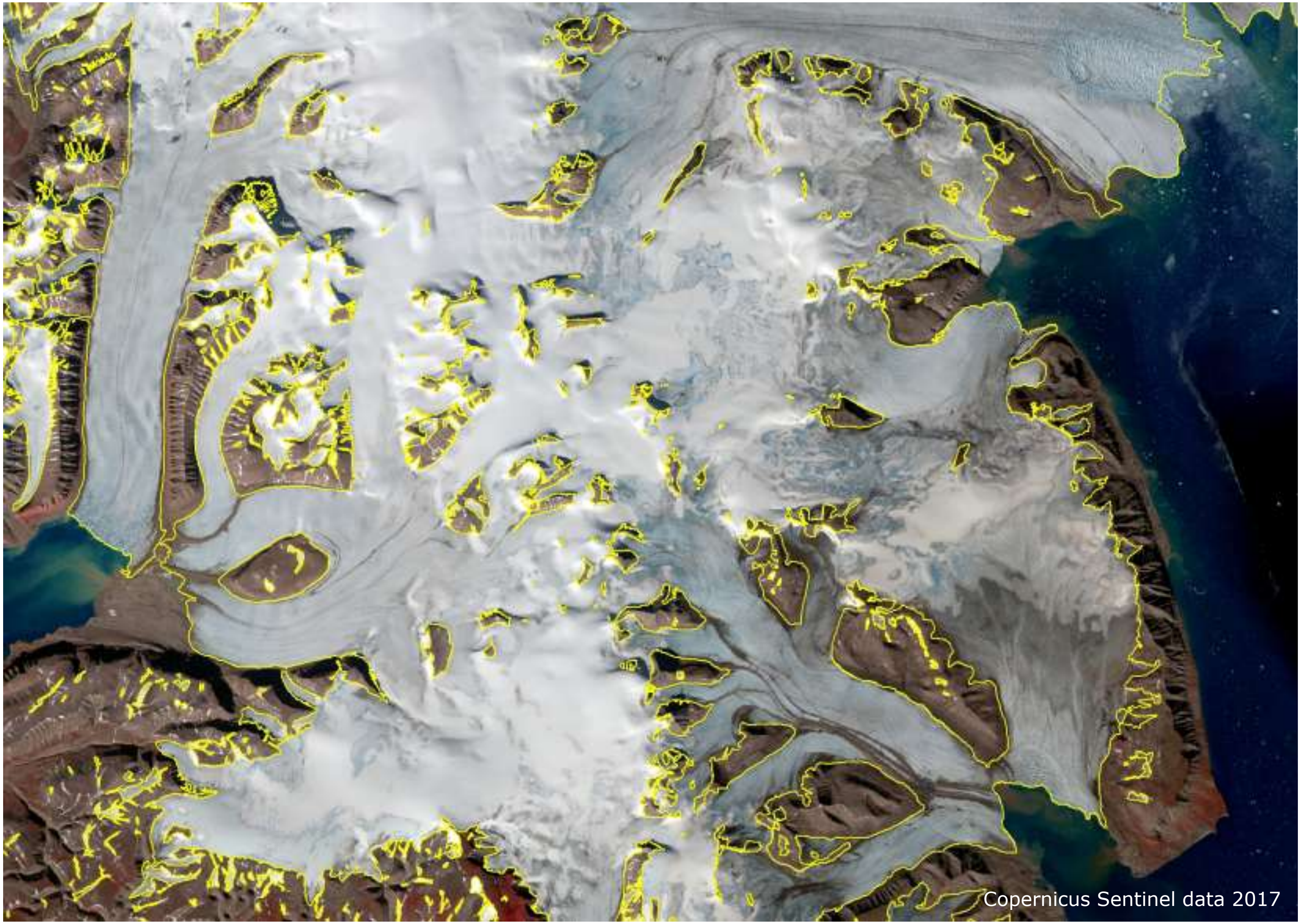
5: Debris-cover

6: Ice divides

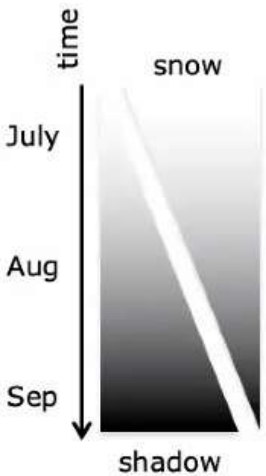
Svalbard subset overview: Sentinel bands 8 4 3 (NIR-Red-Green)

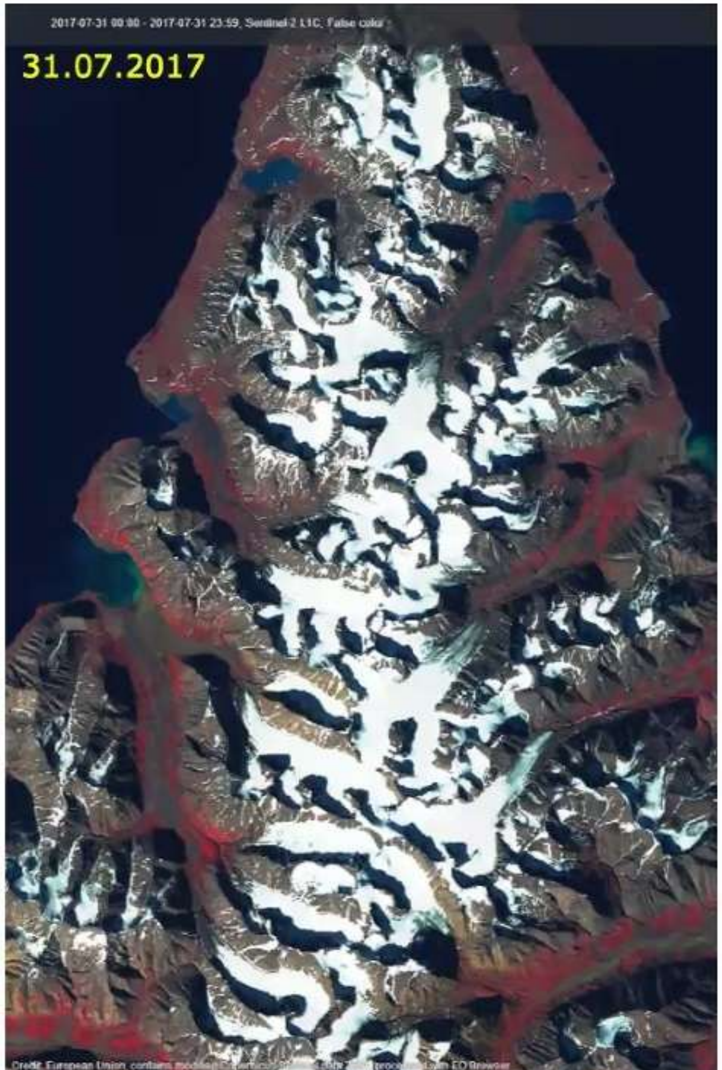


Resulting corrected outlines: Red / SWIR ratio, Threshold = 1.8



Later in the year: less snow, more shadow





Approach:
map with July
scene, correct
with September

Svalbard: 80 N

Challenges

1. mixed pixels → use lower threshold

2. shadows → use lower threshold

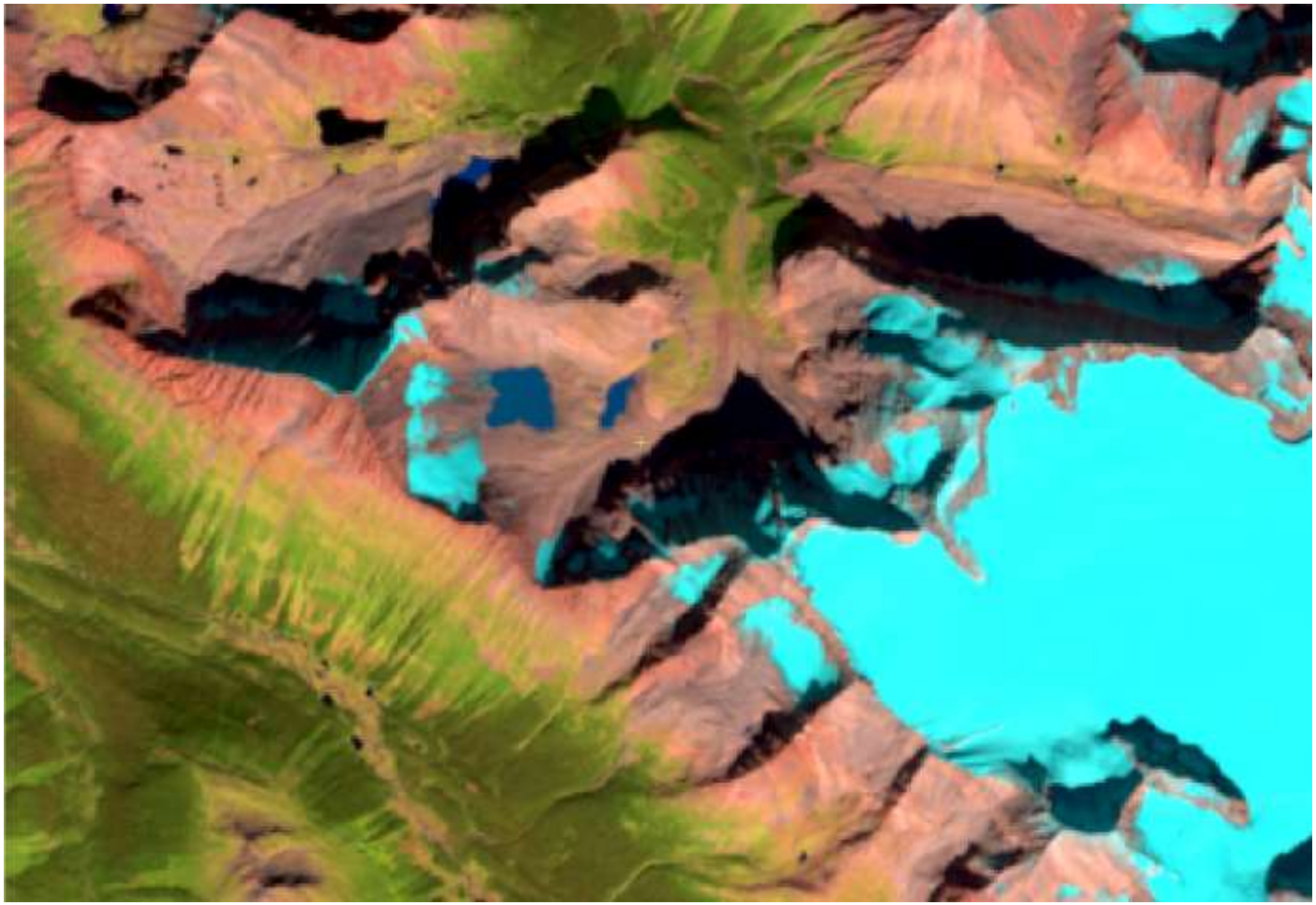
3. Misclassified lakes → use higher threshold / NDWI

4. Late snow - find later images ?

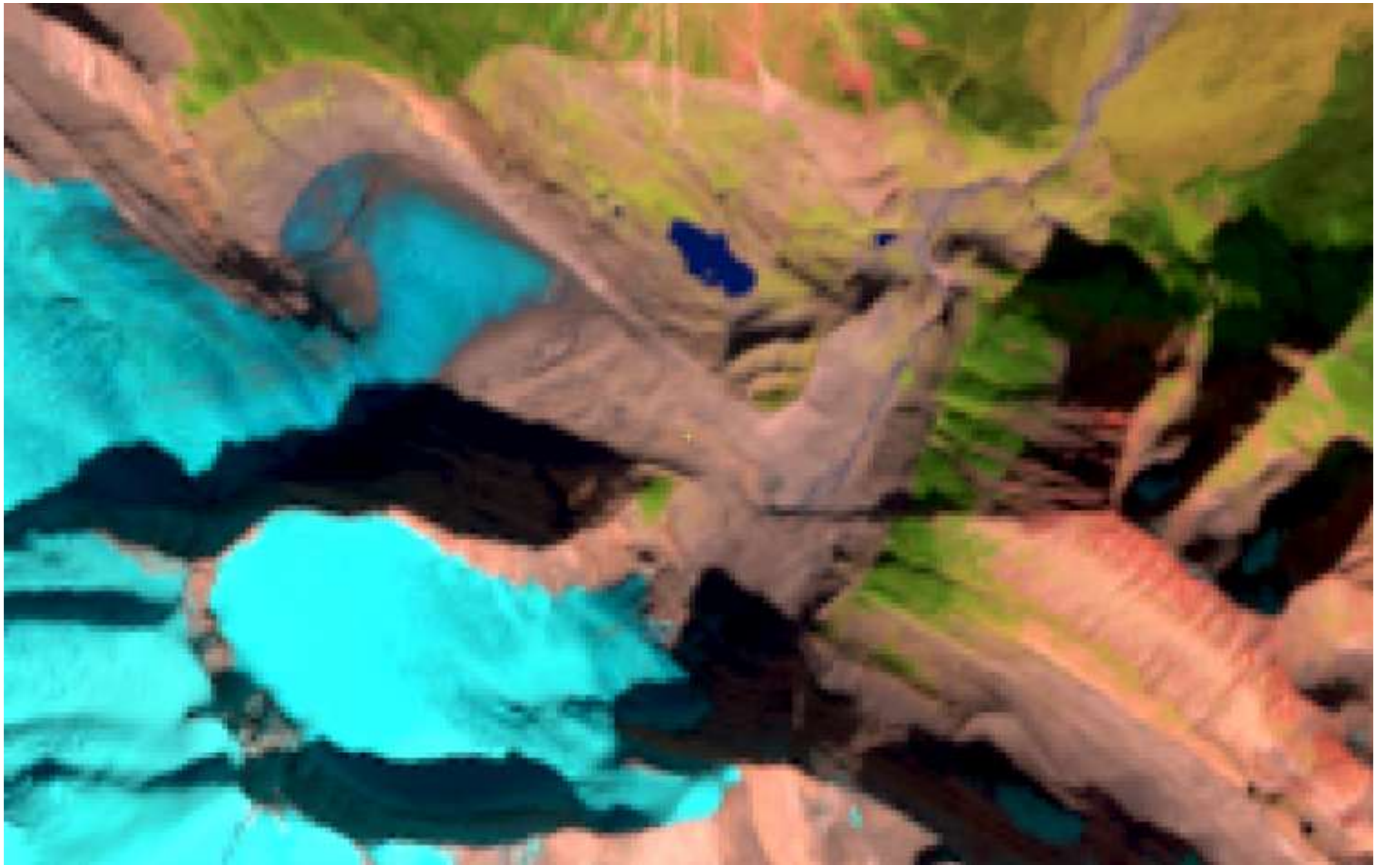
5. Debris Cover ?

Lab 6: Resthaven Icefield, Willmore Wilderness, AB
Tricky parts – shadows, debris covered ice

Use of Panchromatic layer helps with shadows and resolution

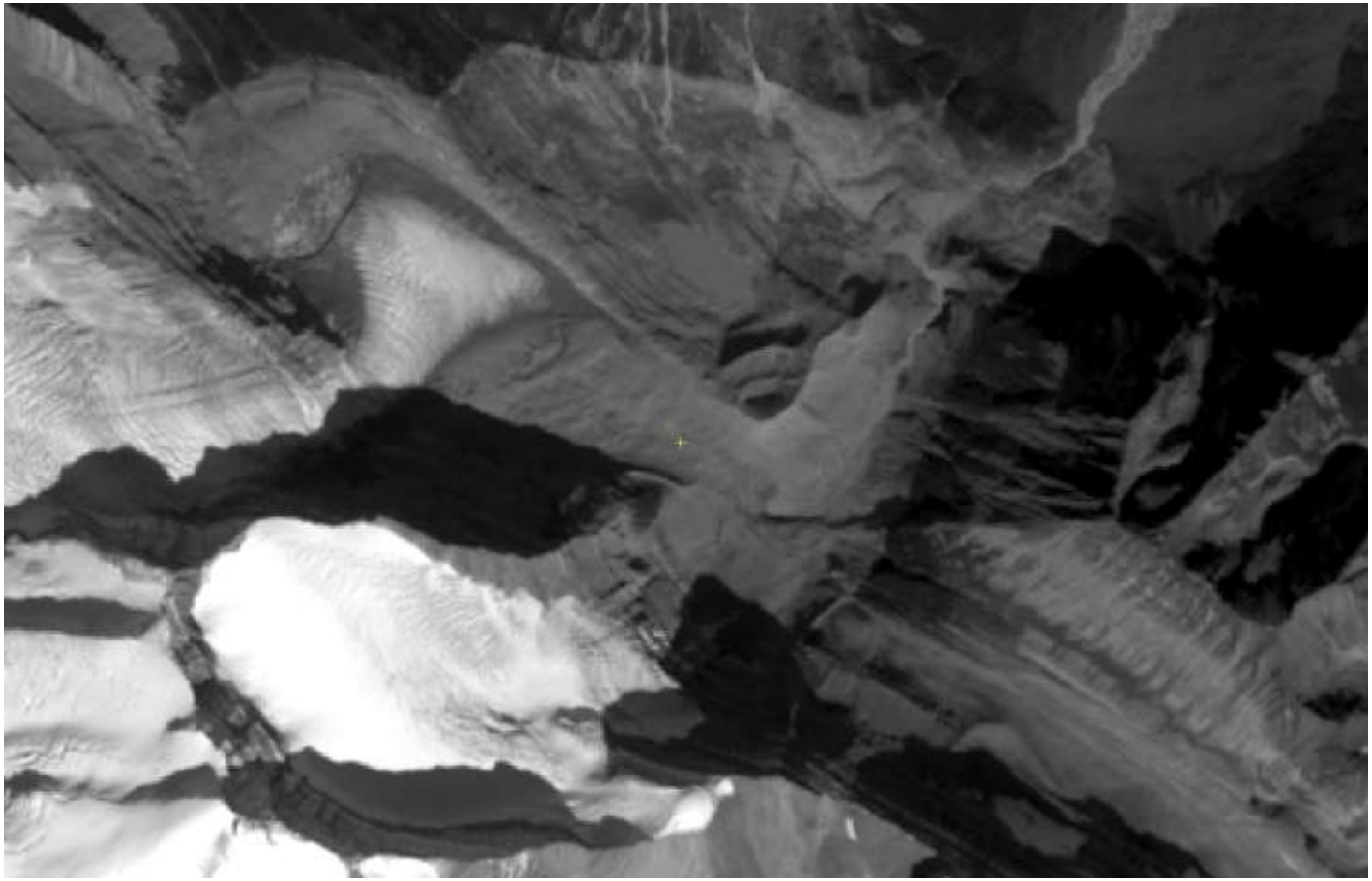


Lab 6: Resthaven Icefield, Willmore Wilderness, AB
Tricky parts – shadows, debris covered ice



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 add 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 usually need a lower threshold value vs Landsat TM e.g. 1.75

Remote Sensing of Glaciers

Image processing can be used to map:

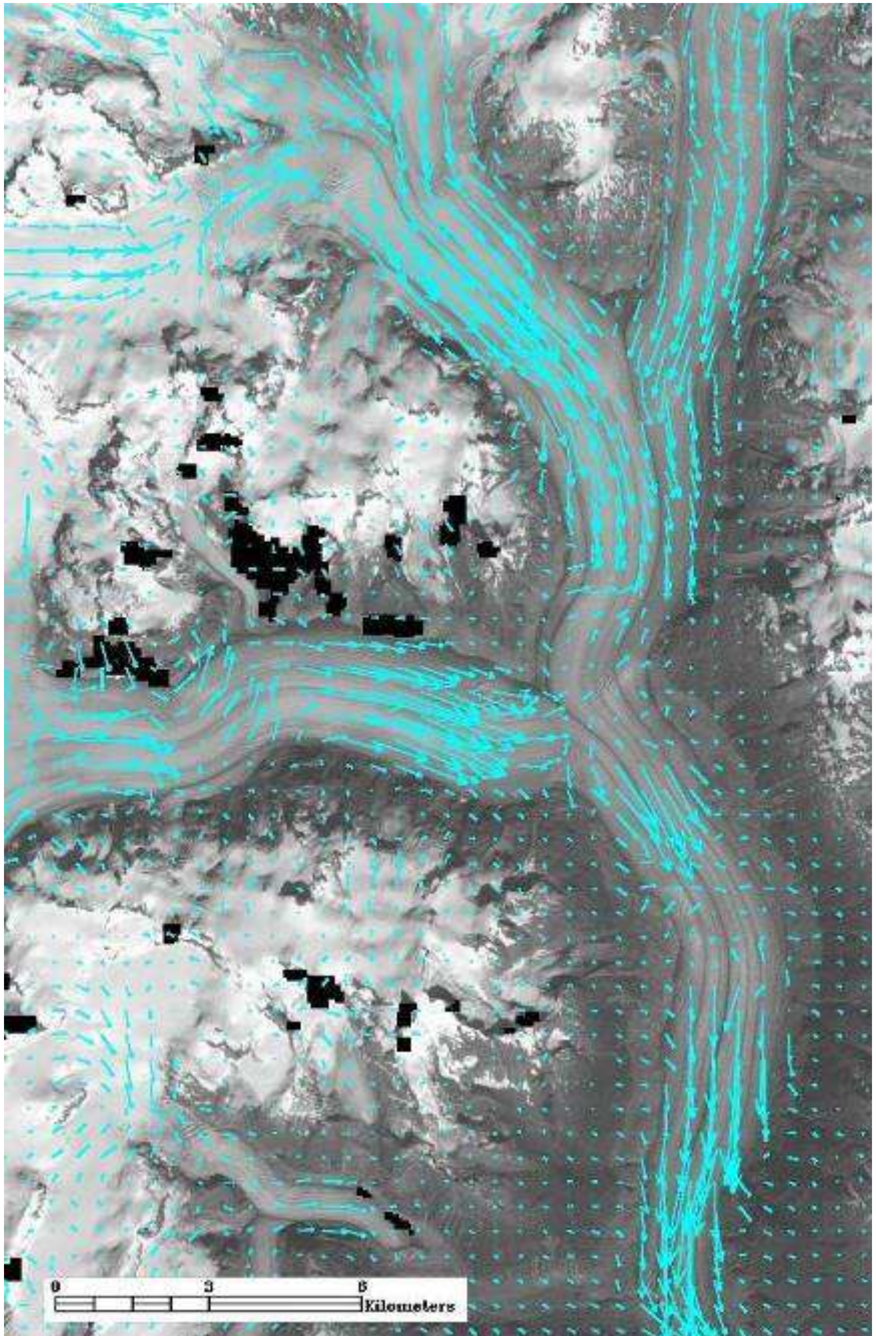
a. Surface characteristics (e.g. accumulation-ablation)

b. Glacier extents (e.g. Lab 6)

c. Glacier movement / velocity

d. Animation – image series (change detection lab7 / lecture Oct 22)

e. Elevation change / Volume loss (DEM/change lab8 / lecture Oct 27)



3. Glacier movement/ velocity

Correction and Measurement depends on identifying definite points e.g. boulders on the glacier surface

Example: Klinaklini Glacier (left)

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

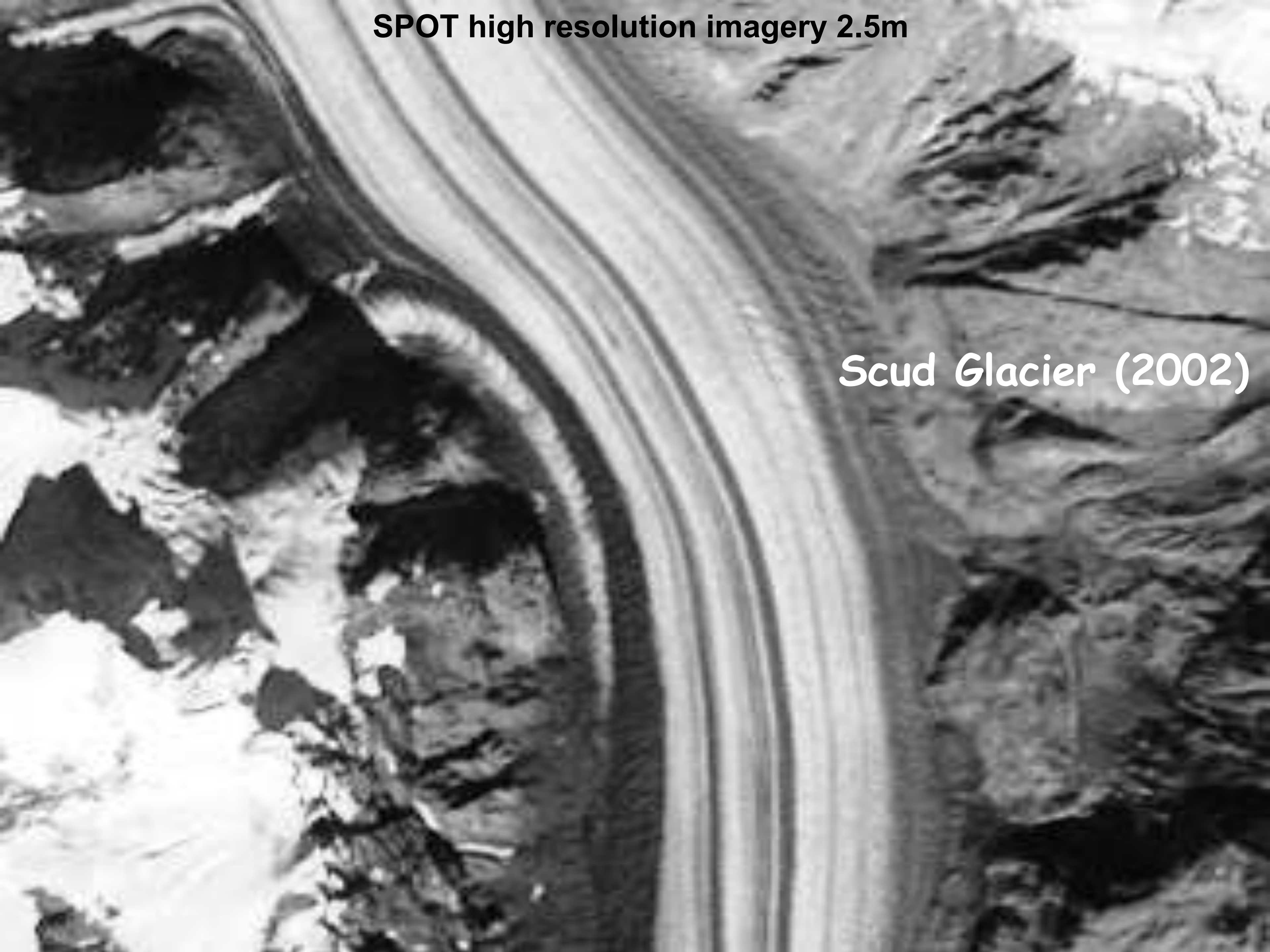
= **~1m / day in summer**

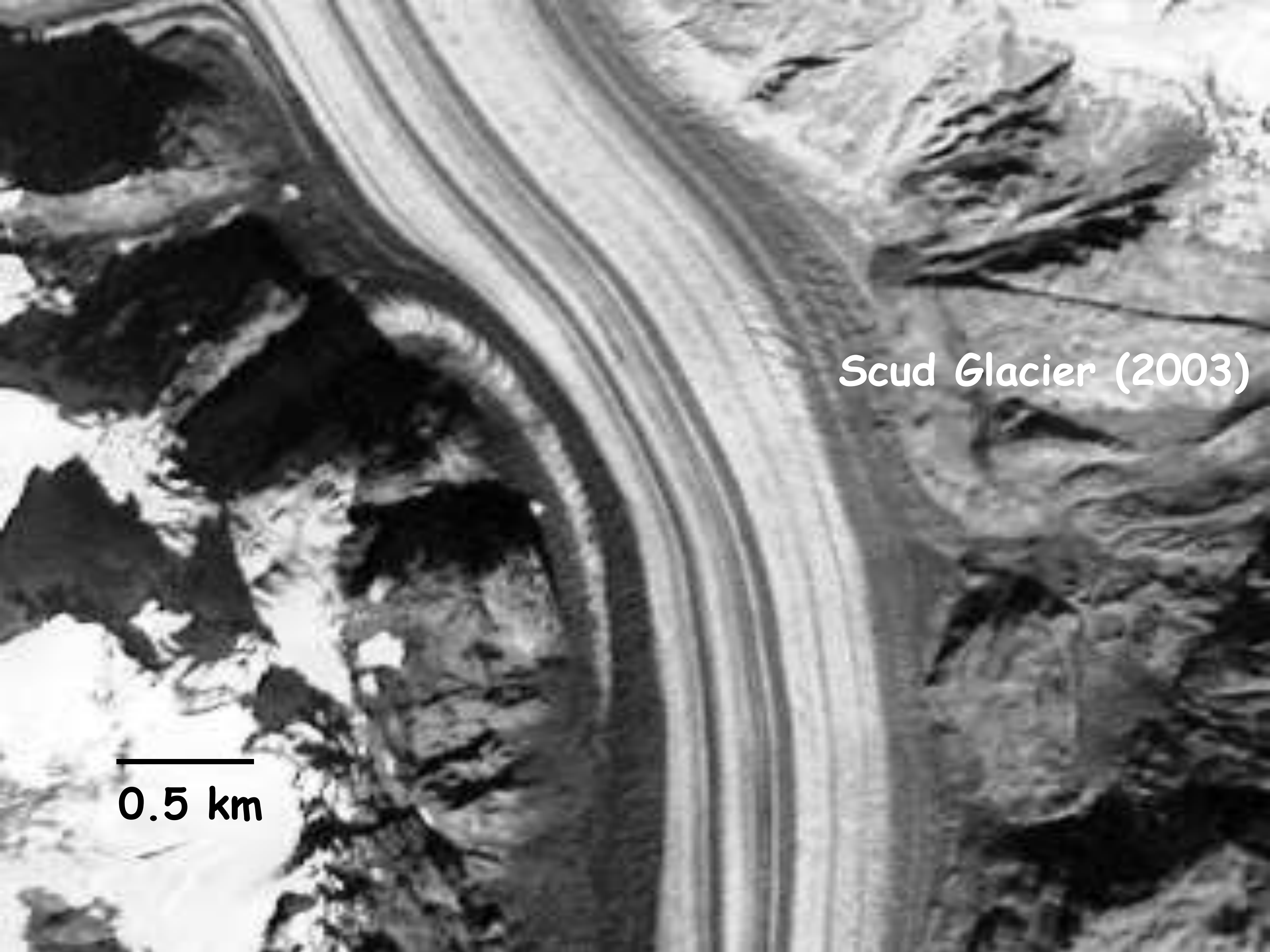
Surging glaciers can be much faster

Length of vector proportional to change between sequential images Oct 2001/Sep 02

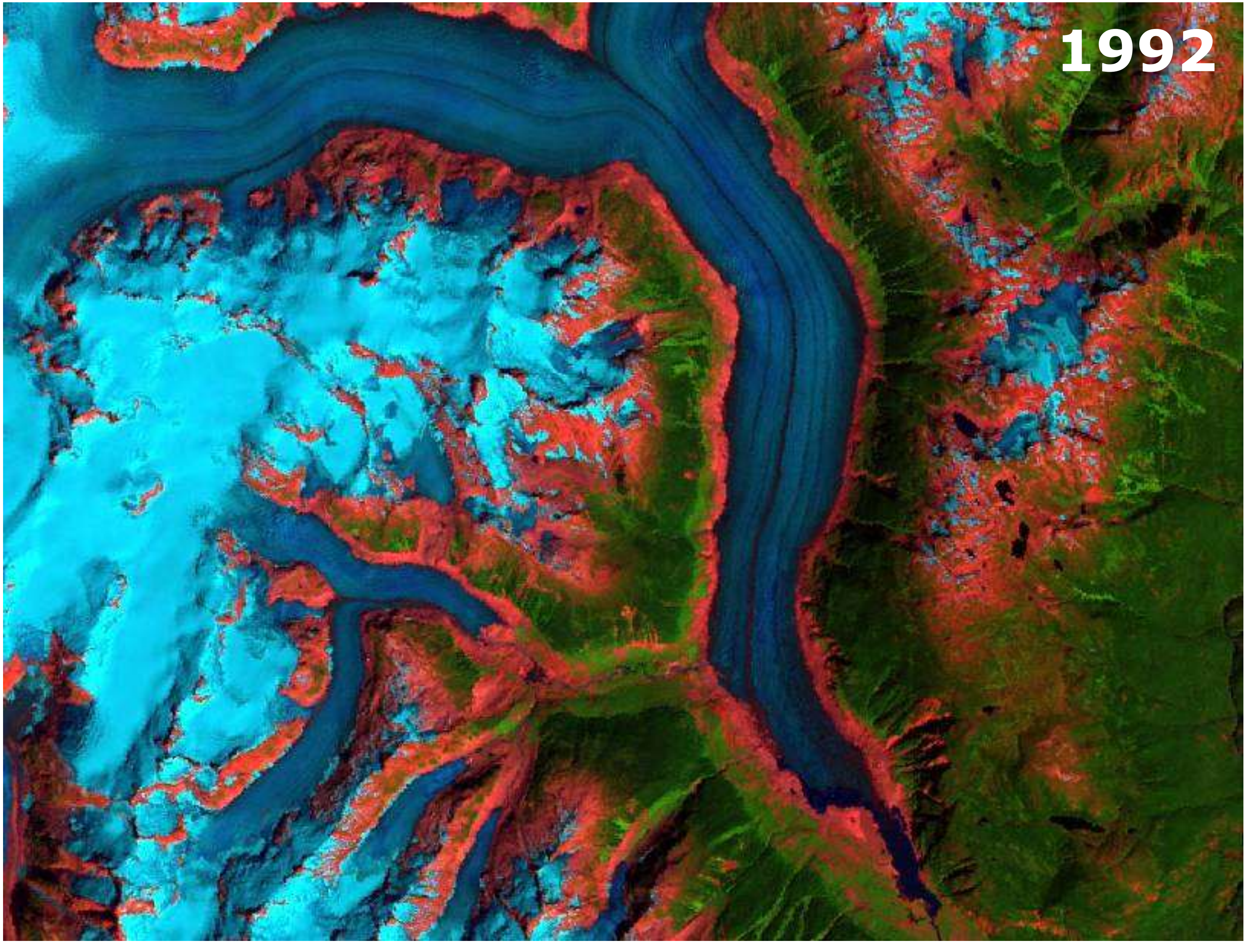
Software: ENVI COSI-CORR

Another example next 2 slides


SPOT high resolution imagery 2.5m
Scud Glacier (2002)


Scud Glacier (2003)
0.5 km

4. Animation series: Klinaklini Glacier




2006