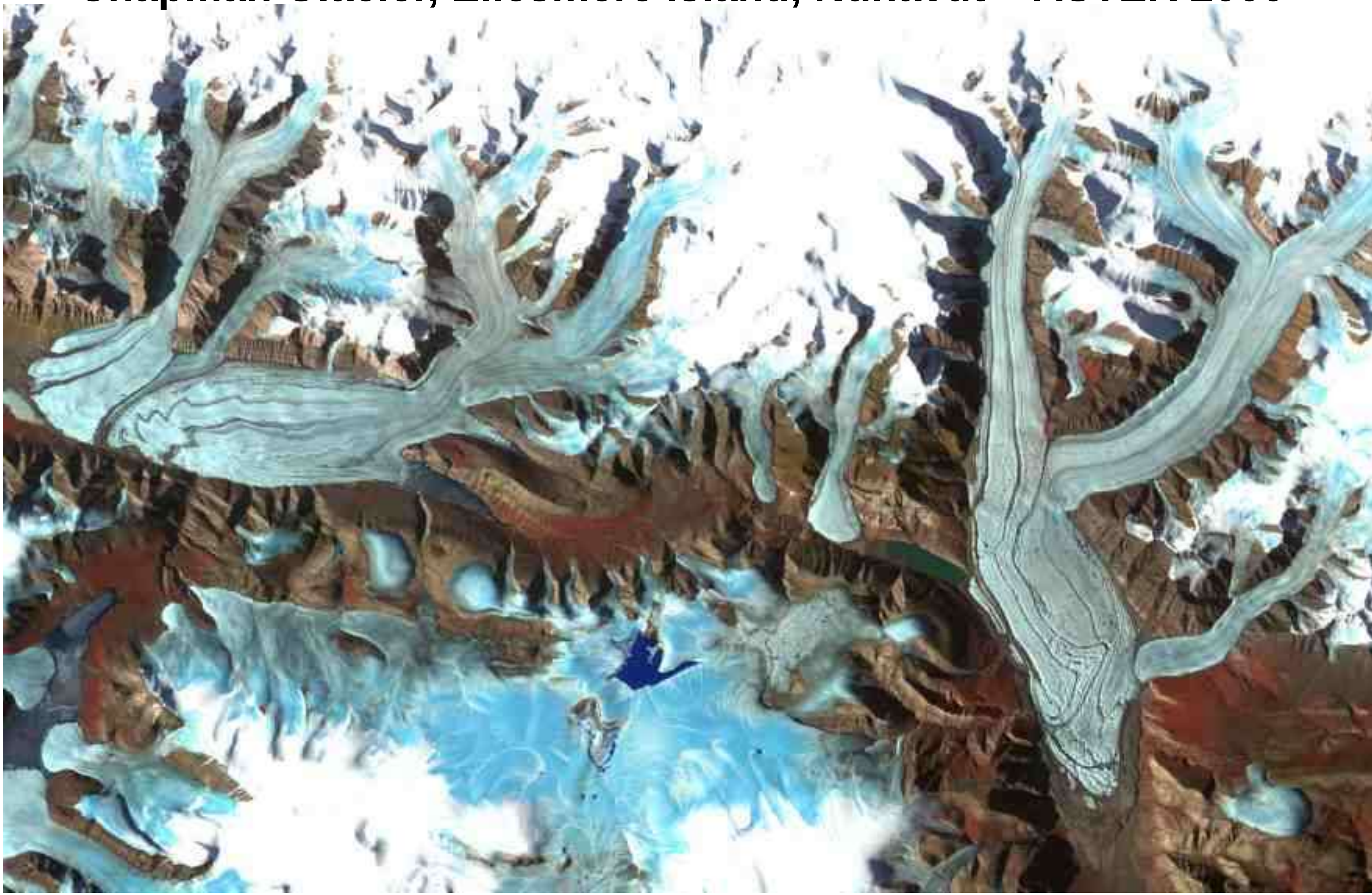
Remote Sensing of Glaciers

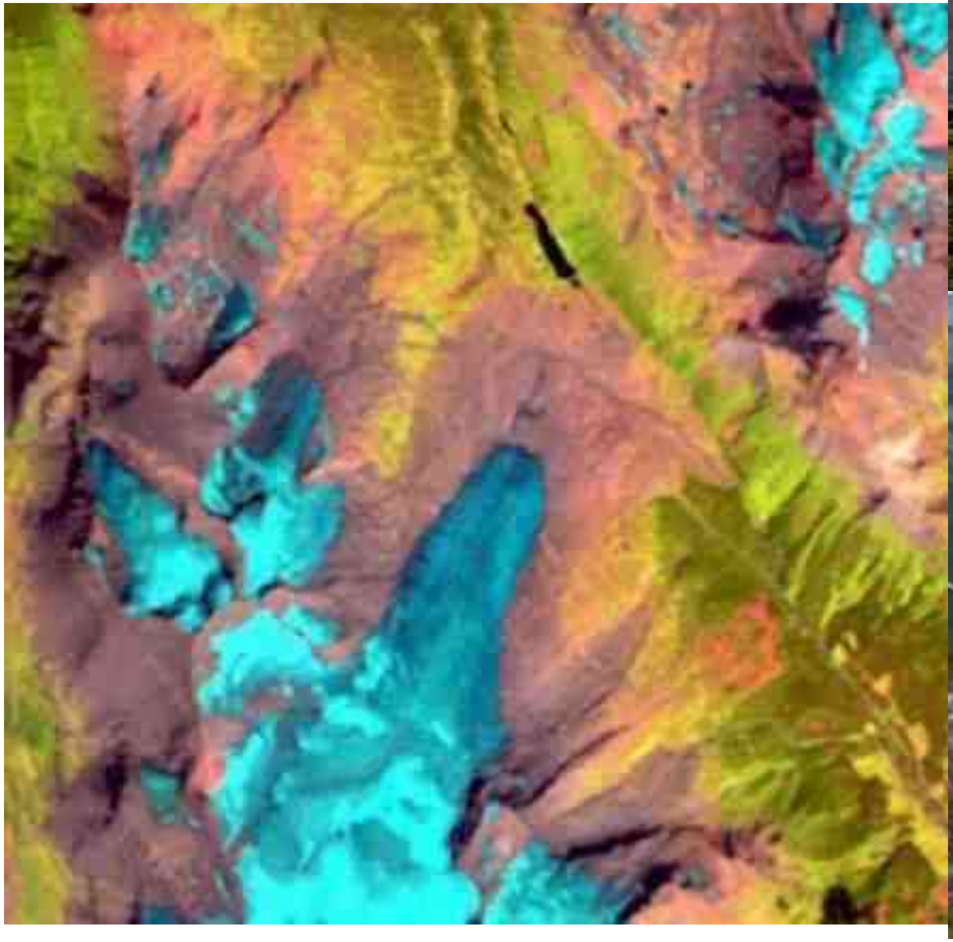
Chapman Glacier, Ellesmere Island, Nunavut – ASTER 2000

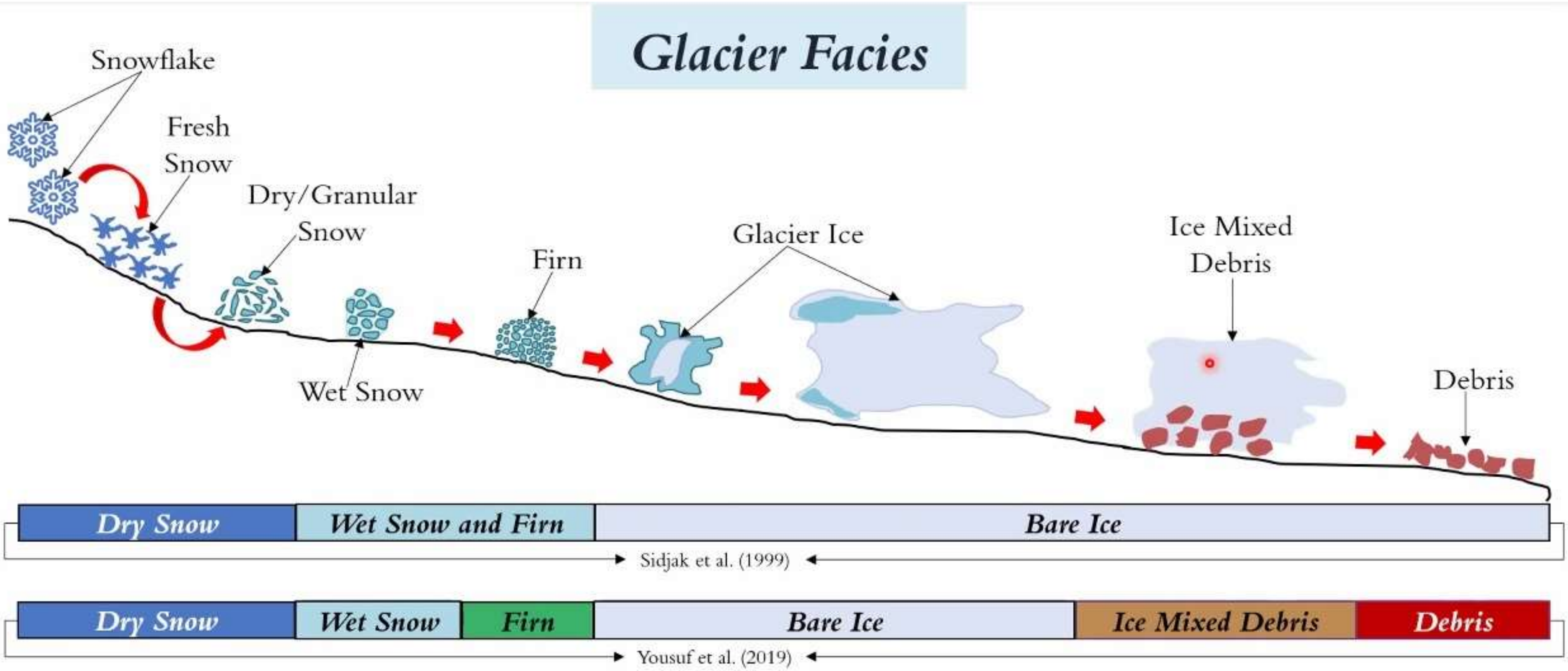


Landsat Images (since 1972 / 1984)
Most glaciers are remote ….

Note mark of Little Ice Age ~ 1850
LIA: ~ 1450-1850

Note late lying snow cover





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.

Accumulation Ablation

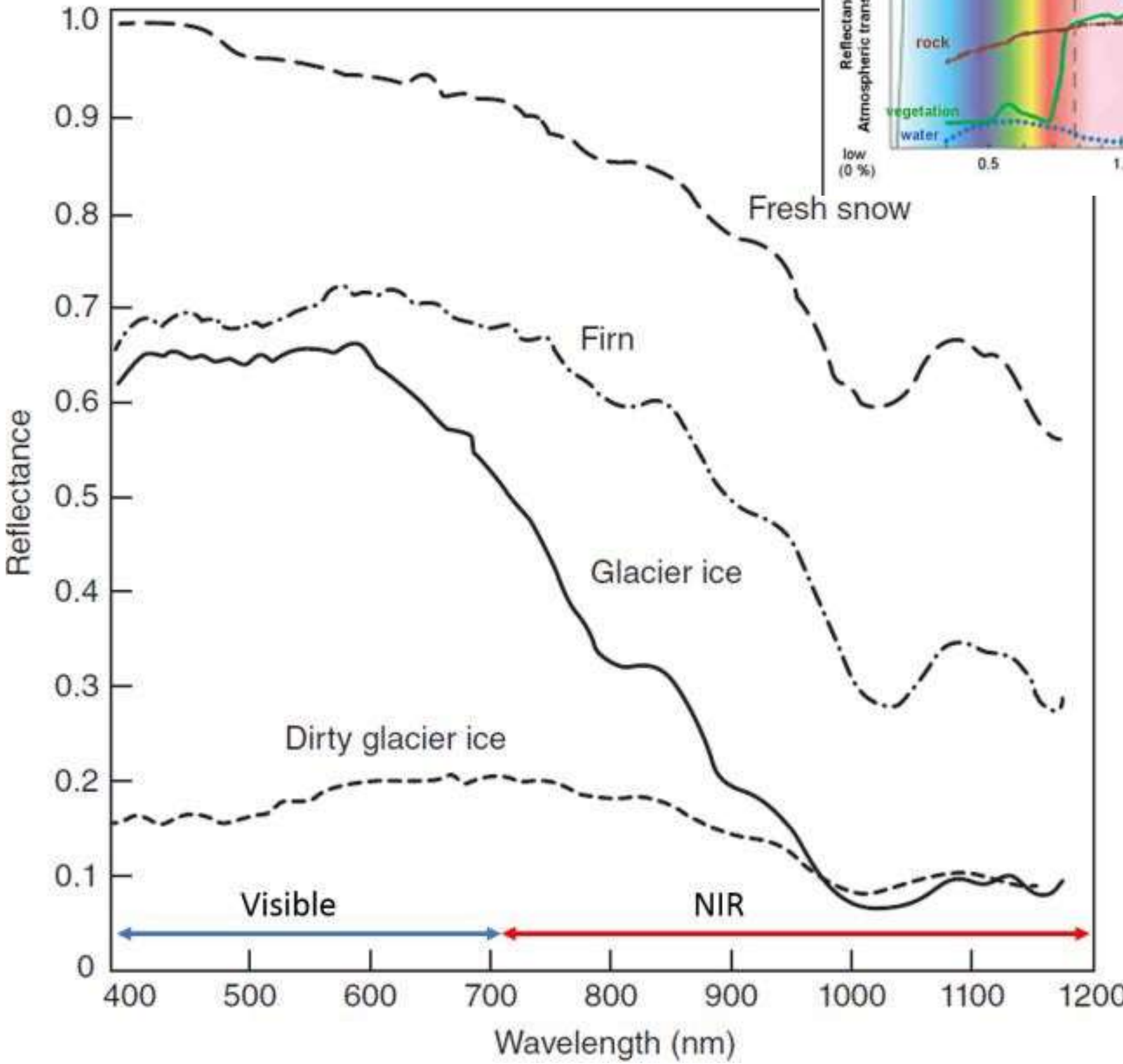
Hudson Bay Glacier 1912-2000

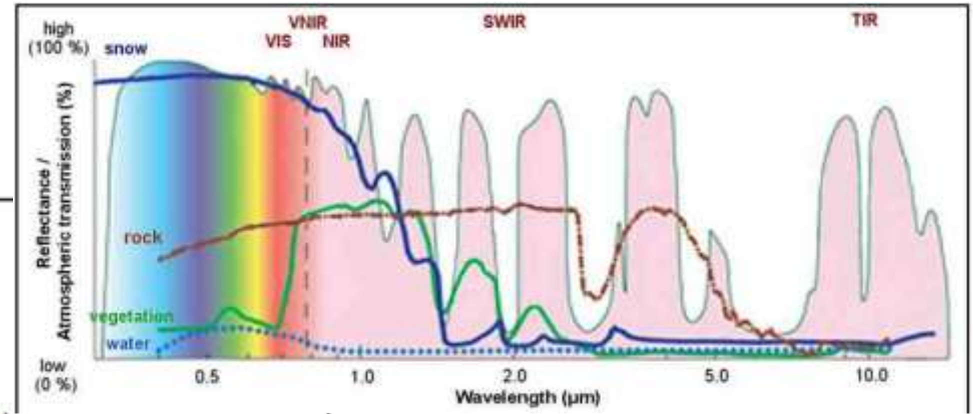
Robson Glacier 1911-2010

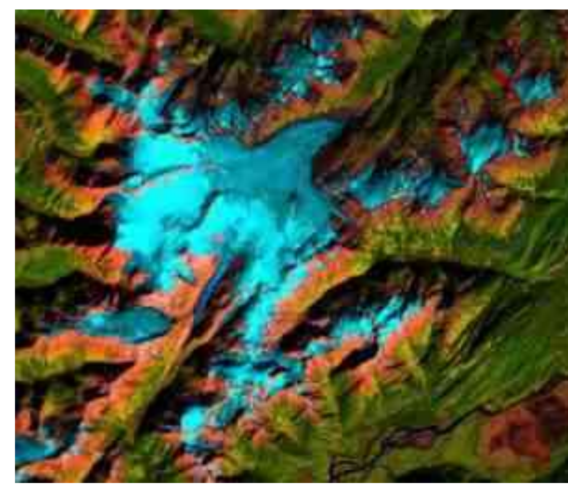
Robson Glacier 1911 – Byron Harmon

Robson Glacier 2010 – Robin Draper

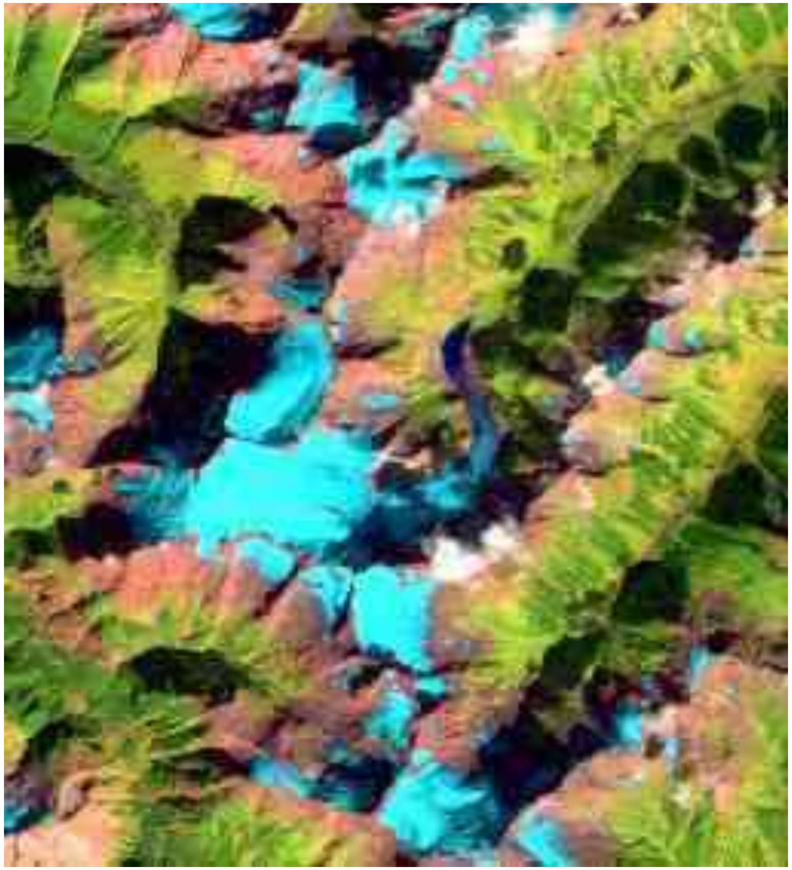
Spectral characteristics of snow and ice







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?)

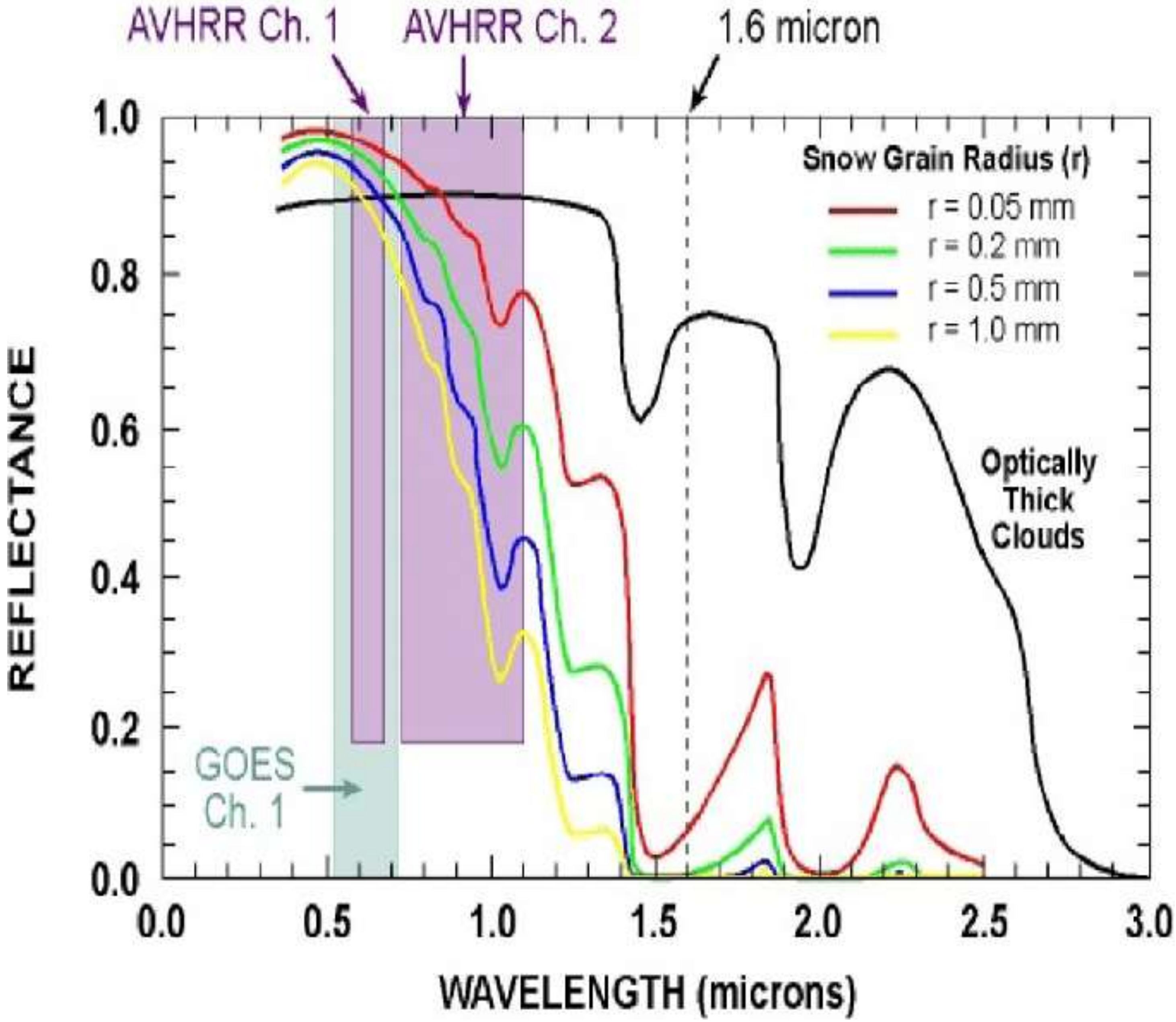


Mid-IR/Near-IR-Red

Red-Green-Blue

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

Snow versus clouds



1. Image classification - supervised

Accumulation area (snow); Ablation (ice) ... and firn (wet snow)

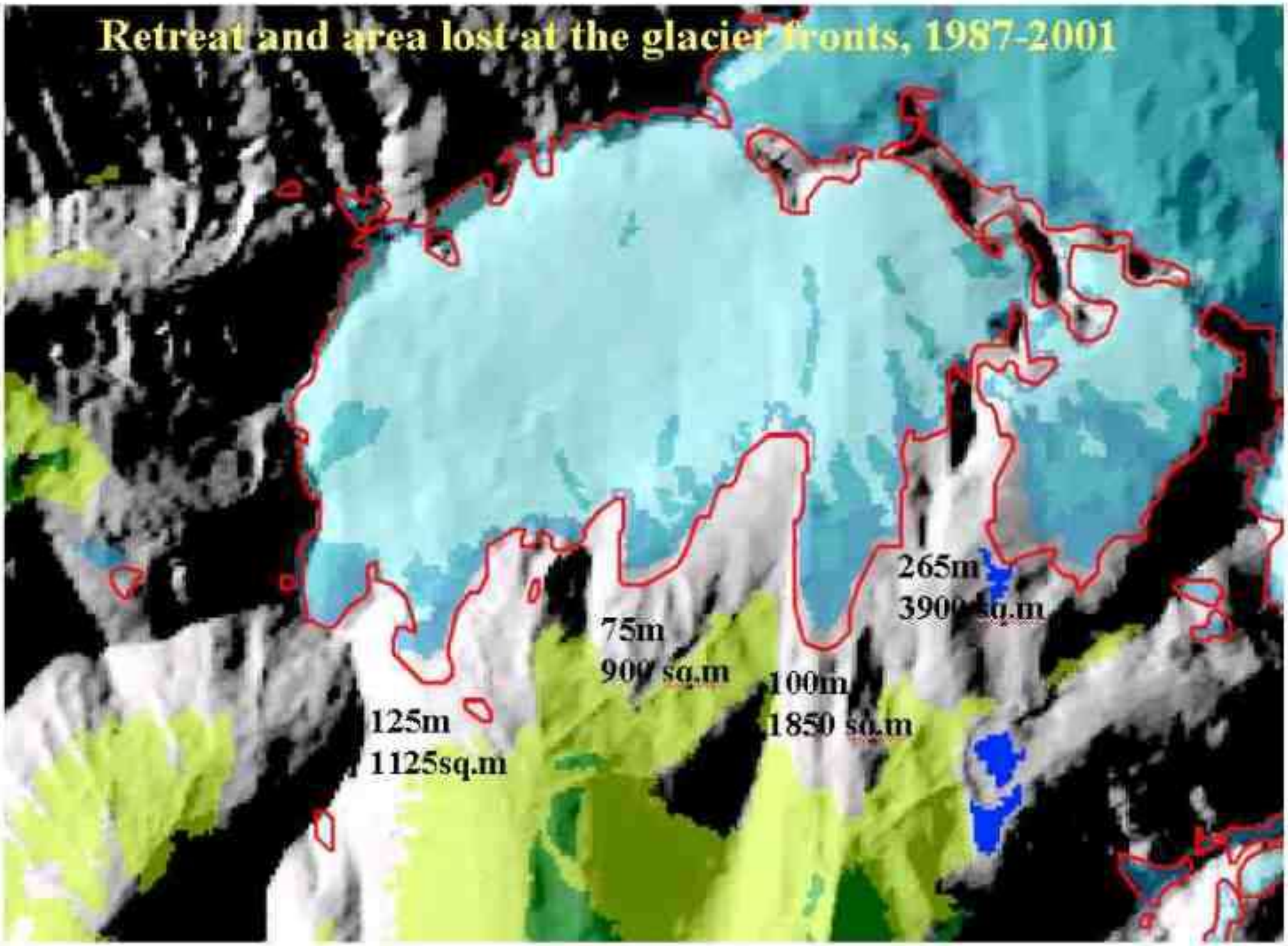
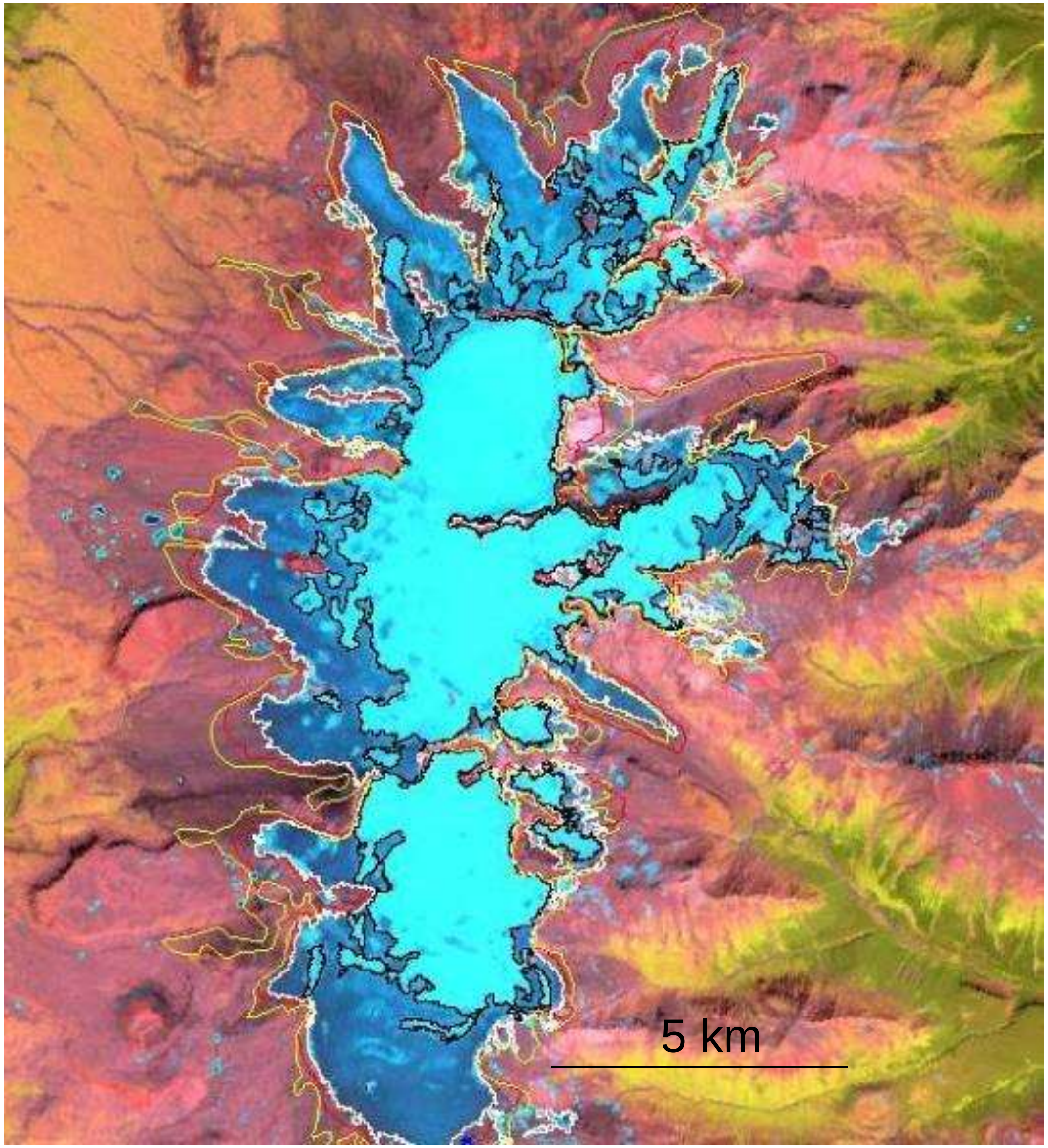


Image processing

1. Classification: 2000 areas produced by supervised classification

Edziza: extents from NTDB 1966, BC TRIM 1985, Landsat 2000

Training on ablation / accumulation areas



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

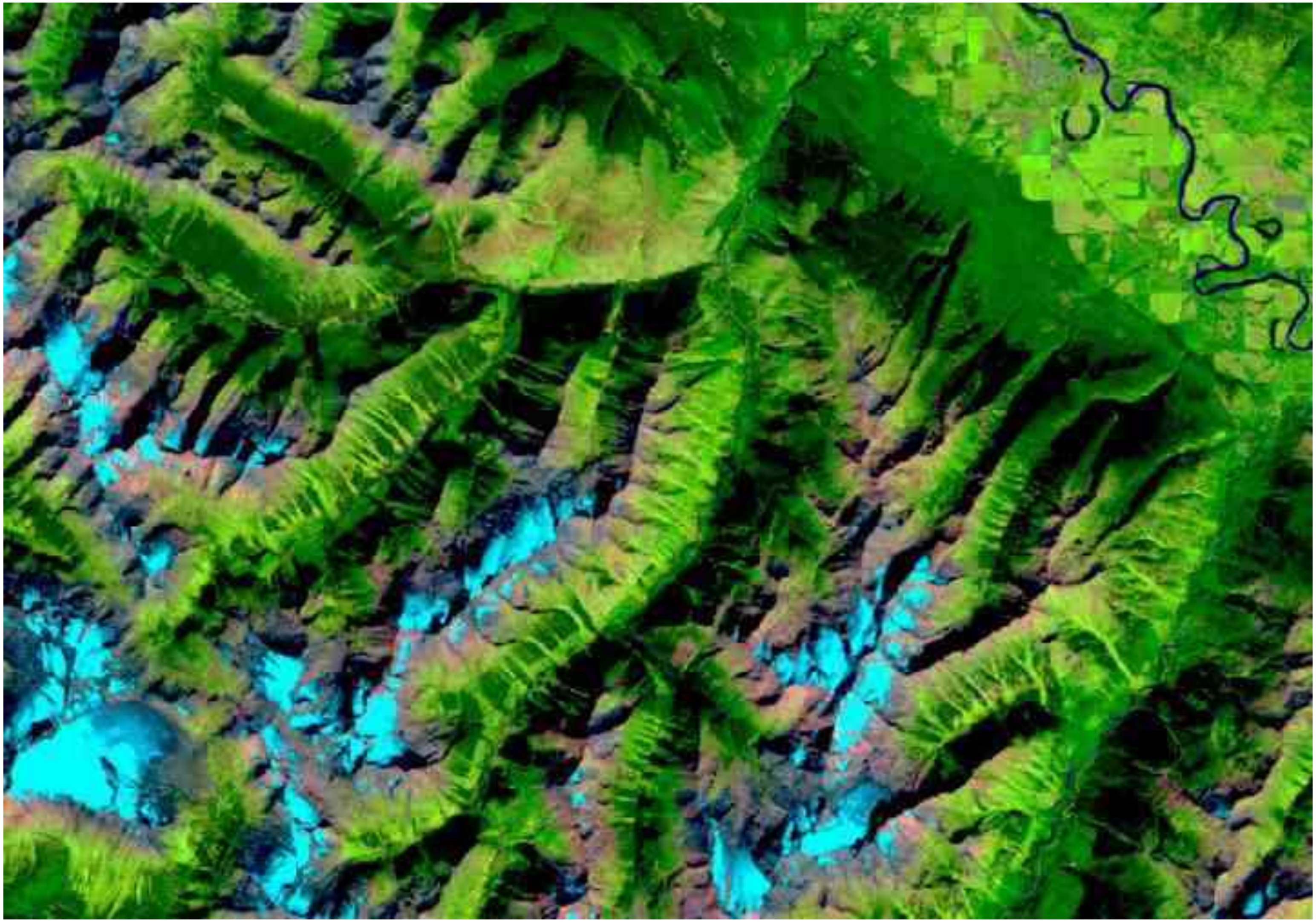
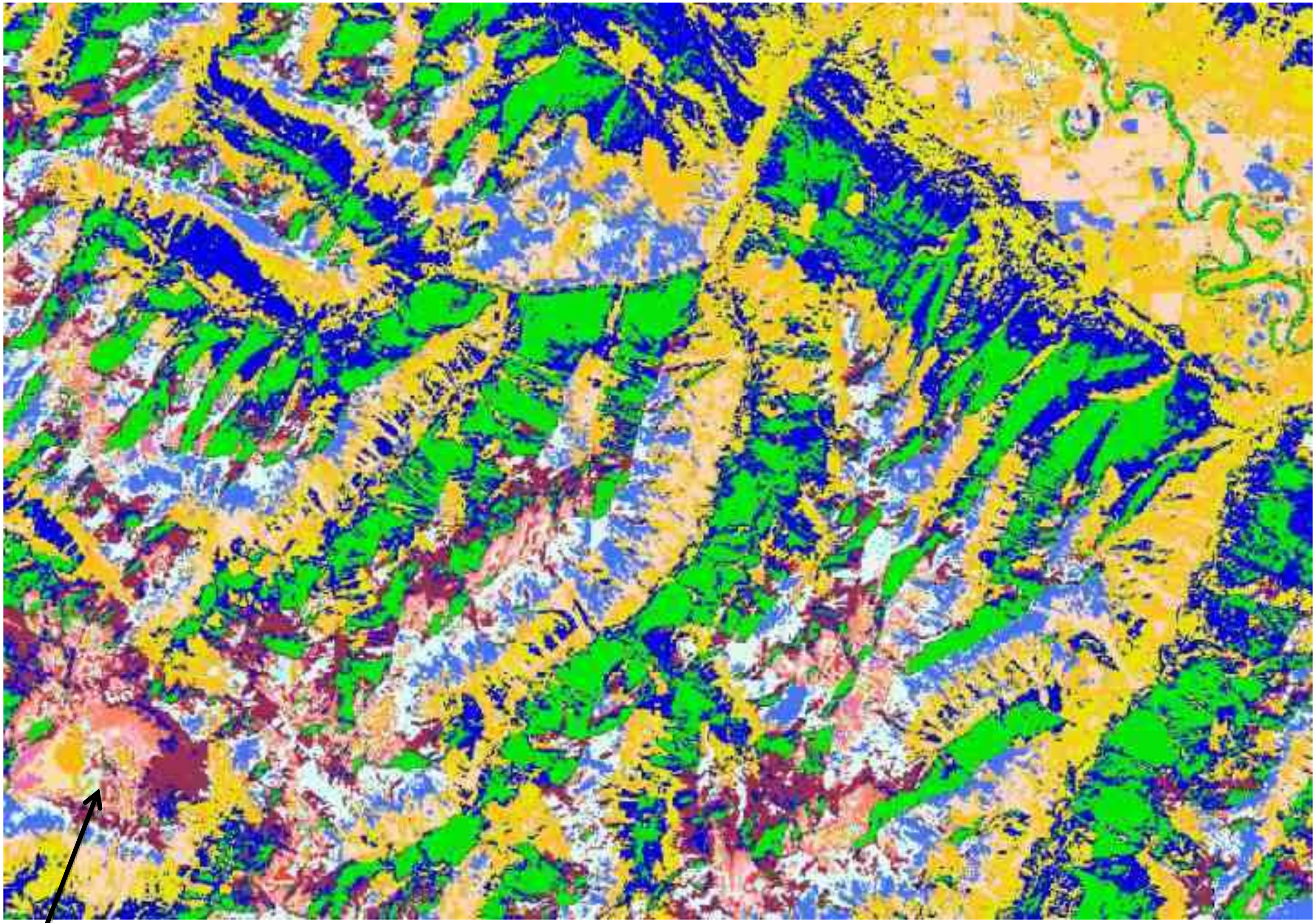


Image classification - Unsupervised



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

2. Normalised Difference Snow Index

(NDSI): green-SWIR / Green + SWIR

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

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

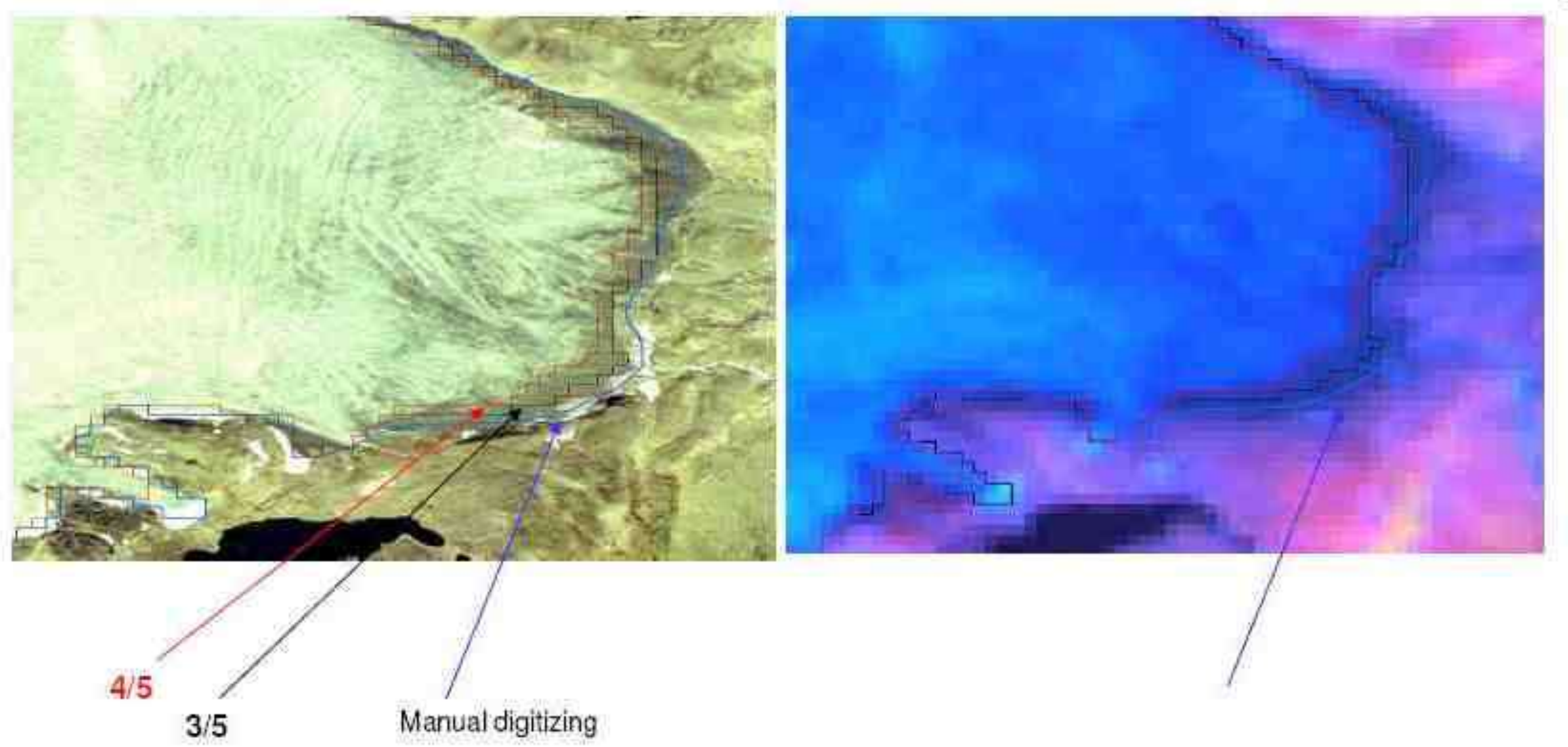
Method: use as threshold or input in classification

Note: its impossible 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/MIR band ratio TM 4 / 5 (snow/ice >1.0)

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

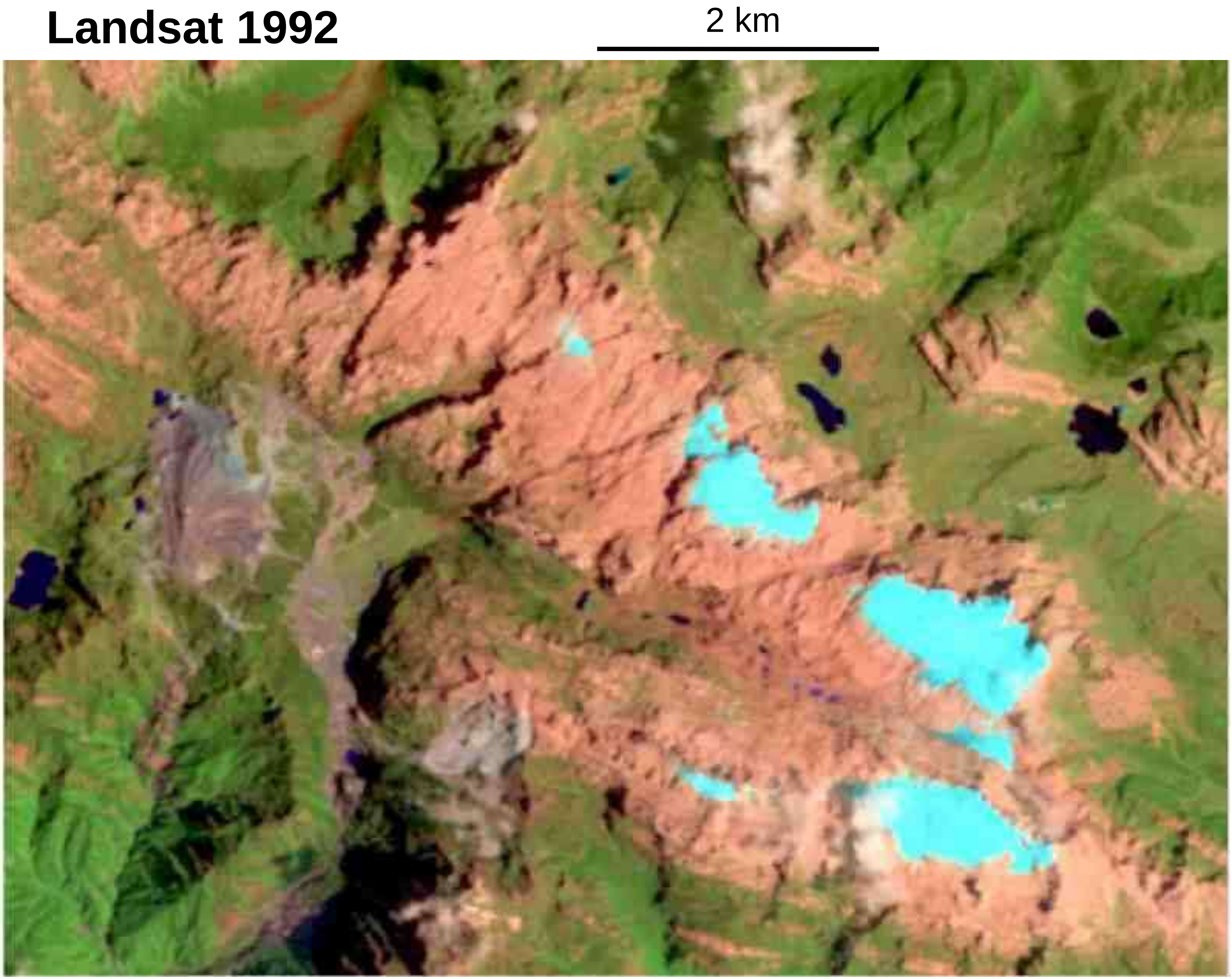


Snow and ice: very high in visible, very low in Mid-Infrared (‘SWIR’)

Ratio - Visible (Red) to SWIR captures snow/ice ‘almost’ exclusively

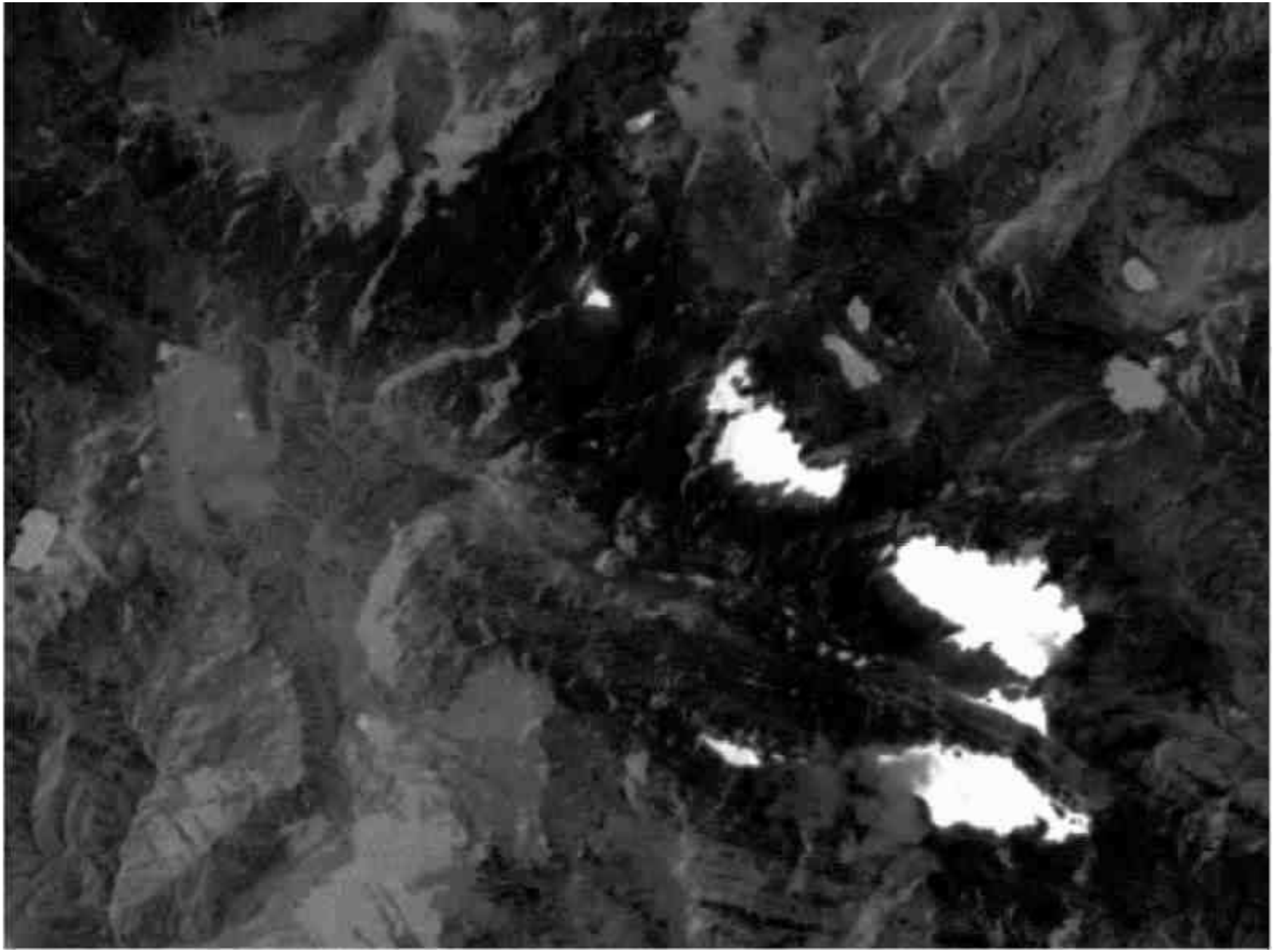
- Some issues with silt-laden water, shadowed glaciers and debris cover

Landsat 1992

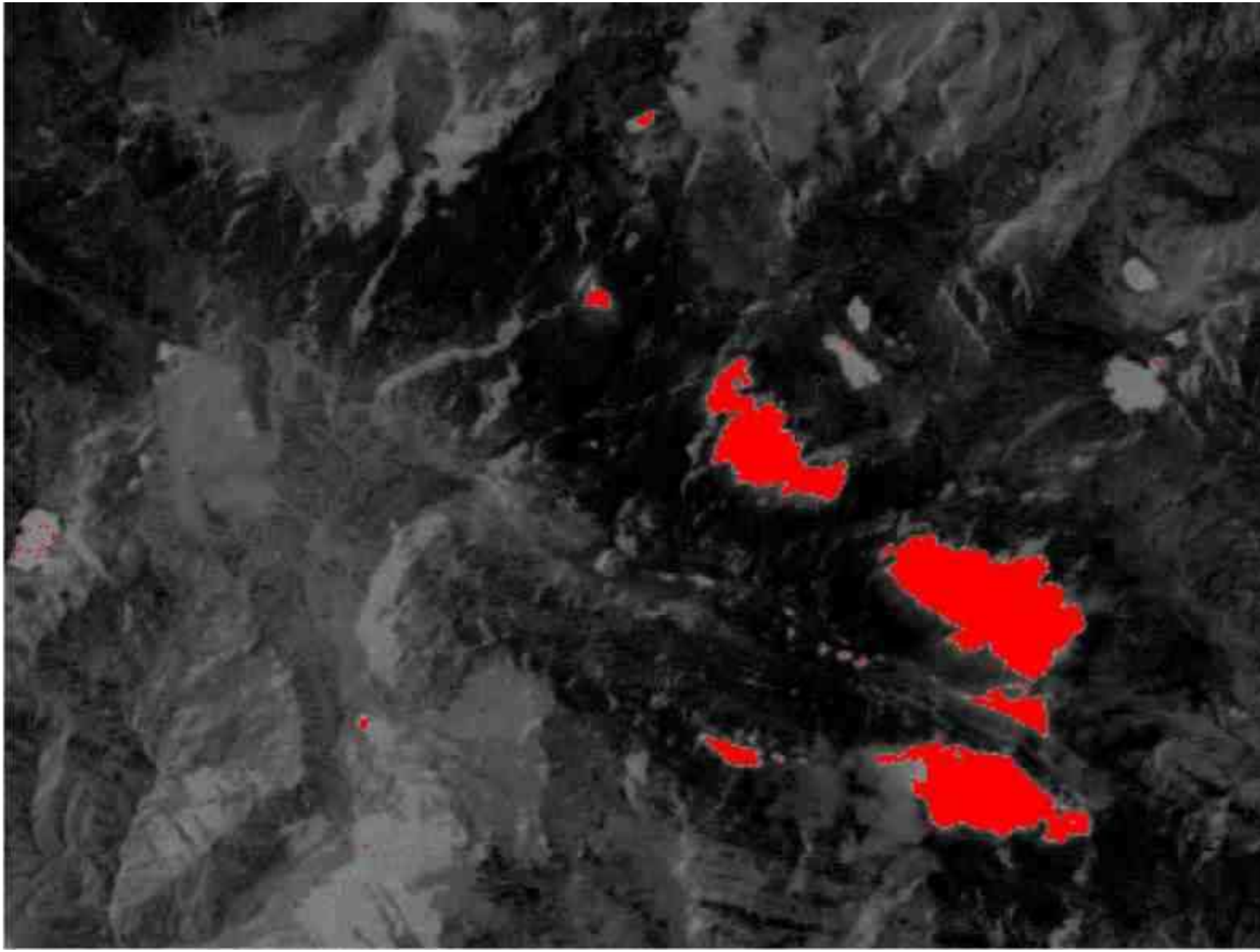


Carstenz Icefield, Indonesia, 4 S – no shadows, 5000m elevation

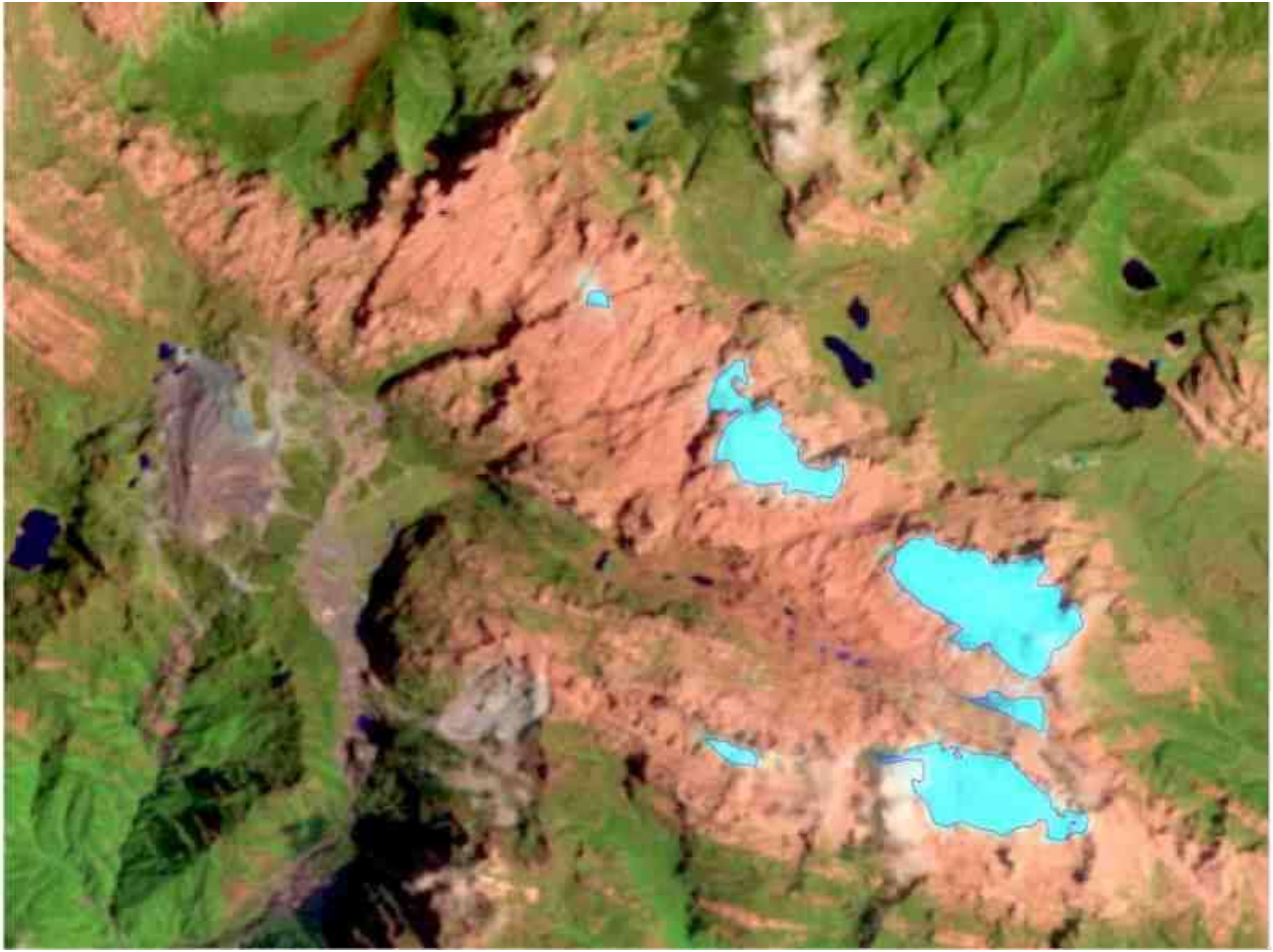
Red/SWIR ratio



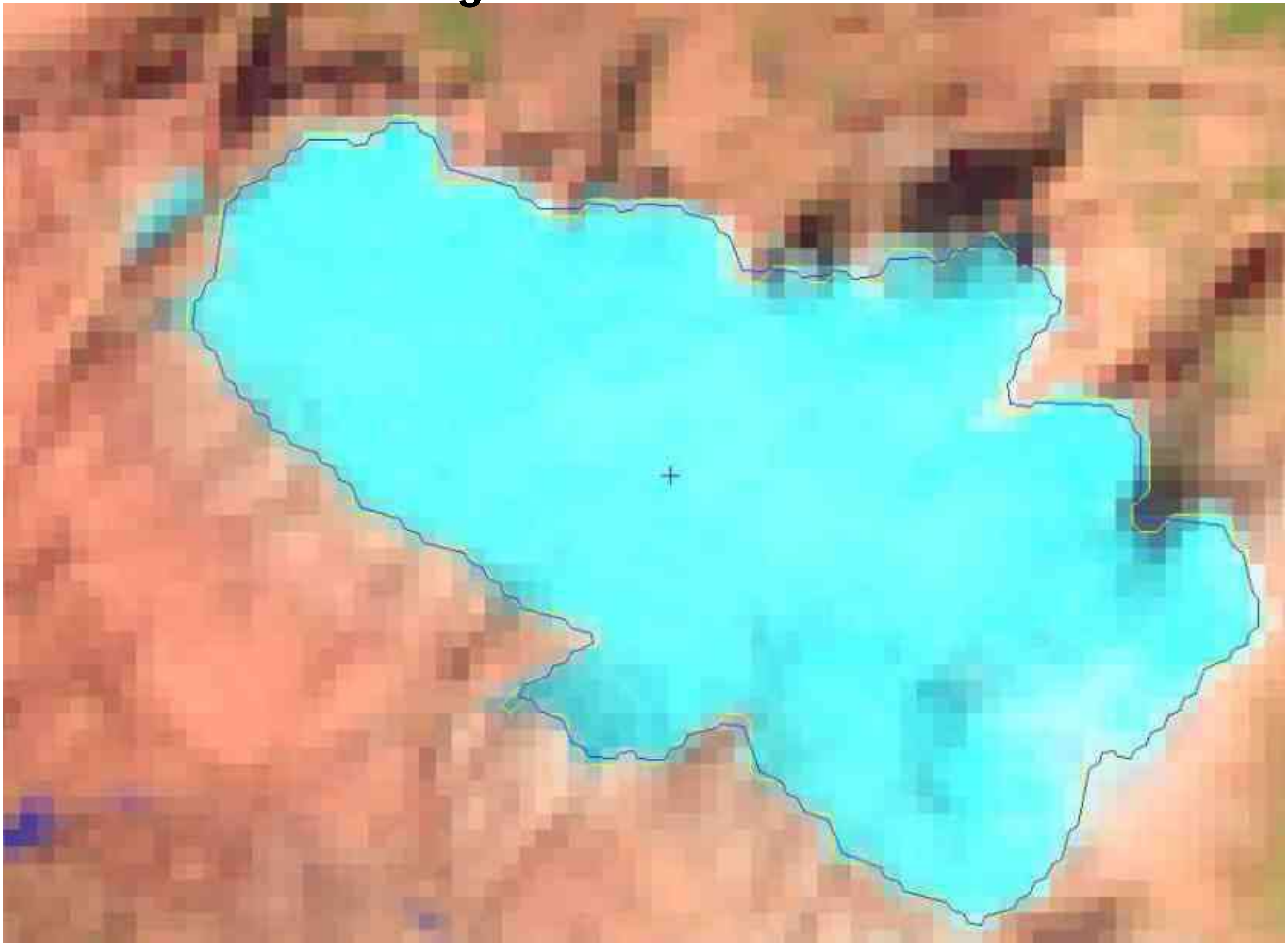
Threshold value 2.0



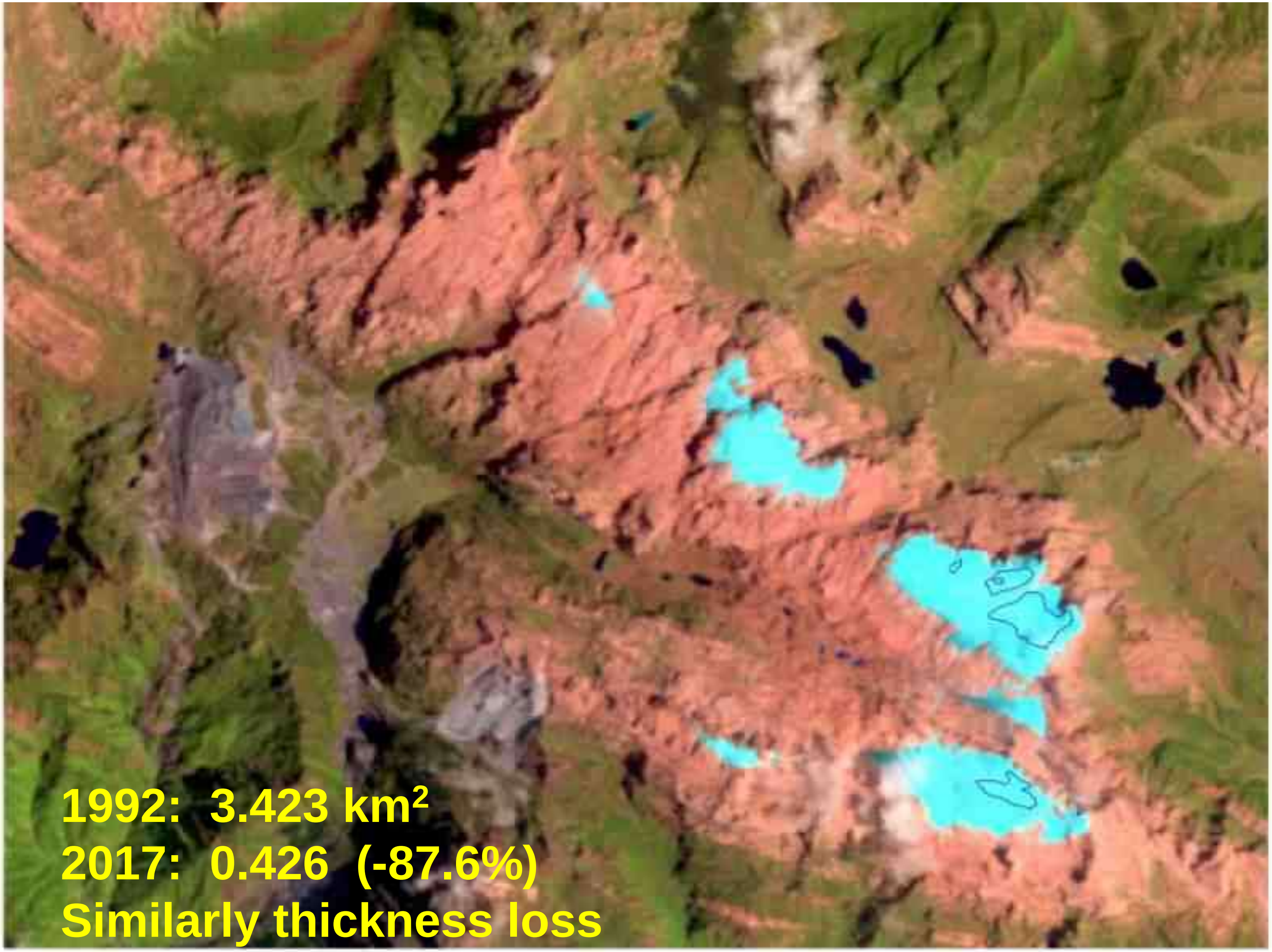
Convert bitmap to polygon



Vector smoothing



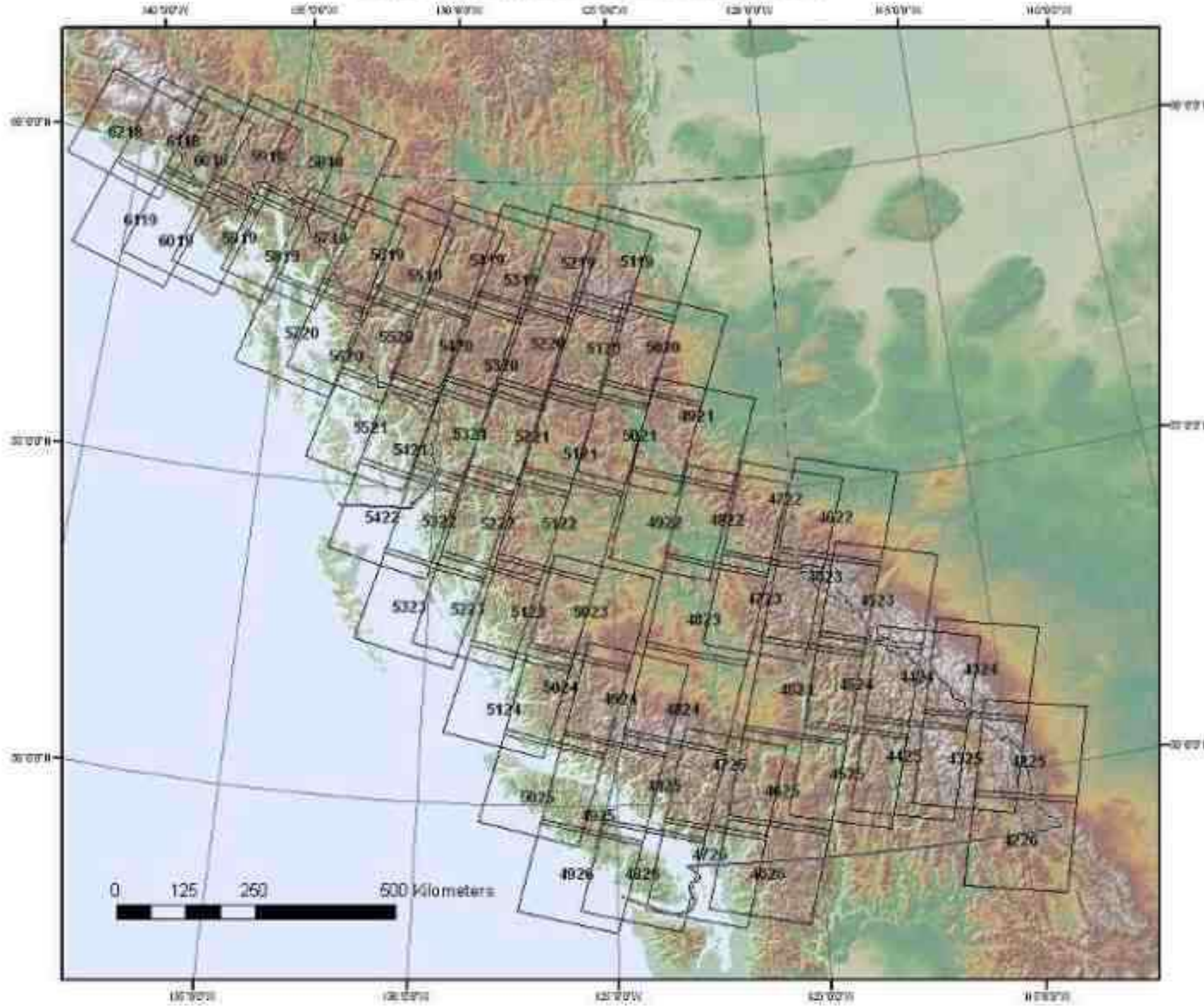
Overlay of 2017 polygons on 1992 image showing ice loss



2 km

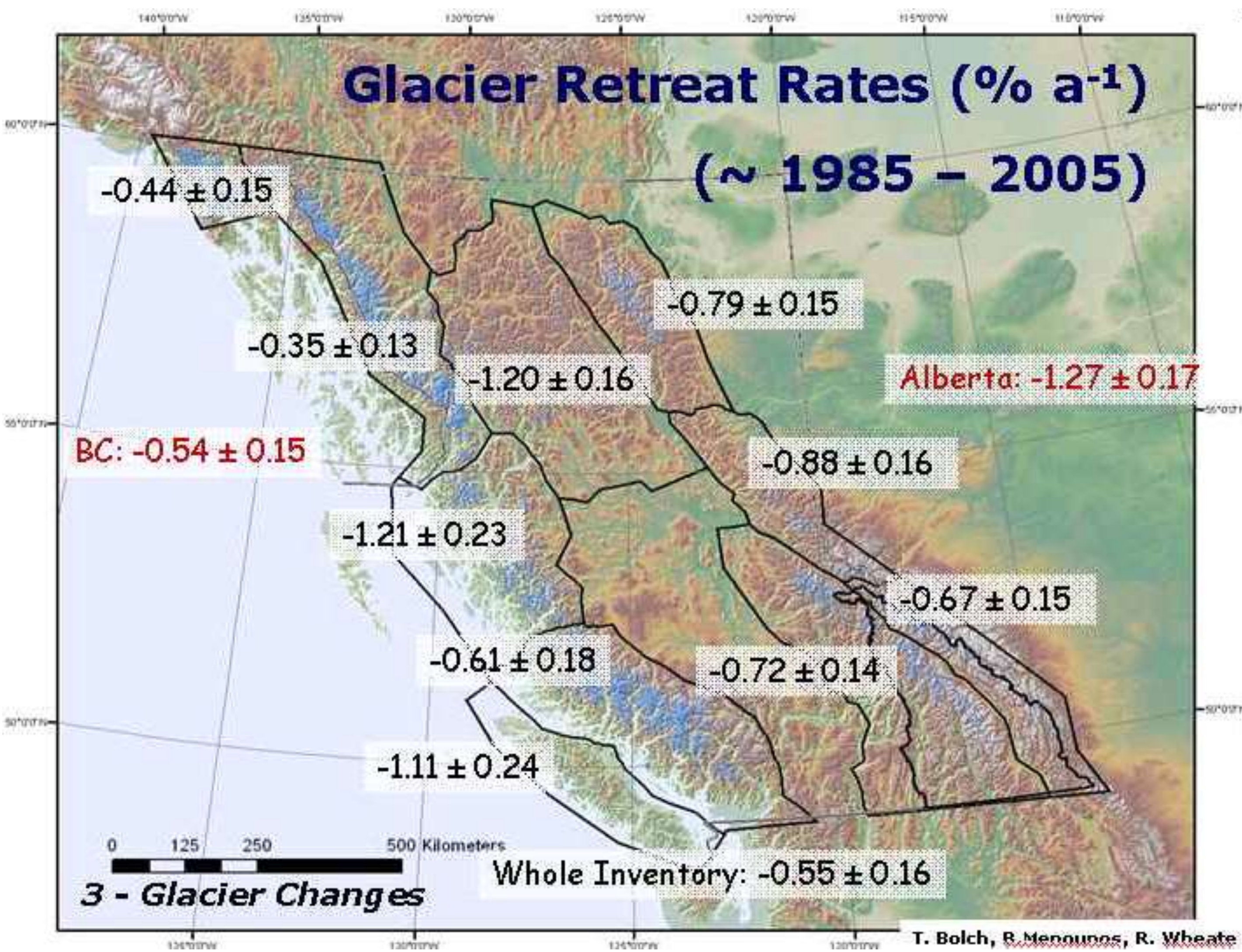
The cordilleran glaciers of western Canada

British Columbia: Landsat Path and Row

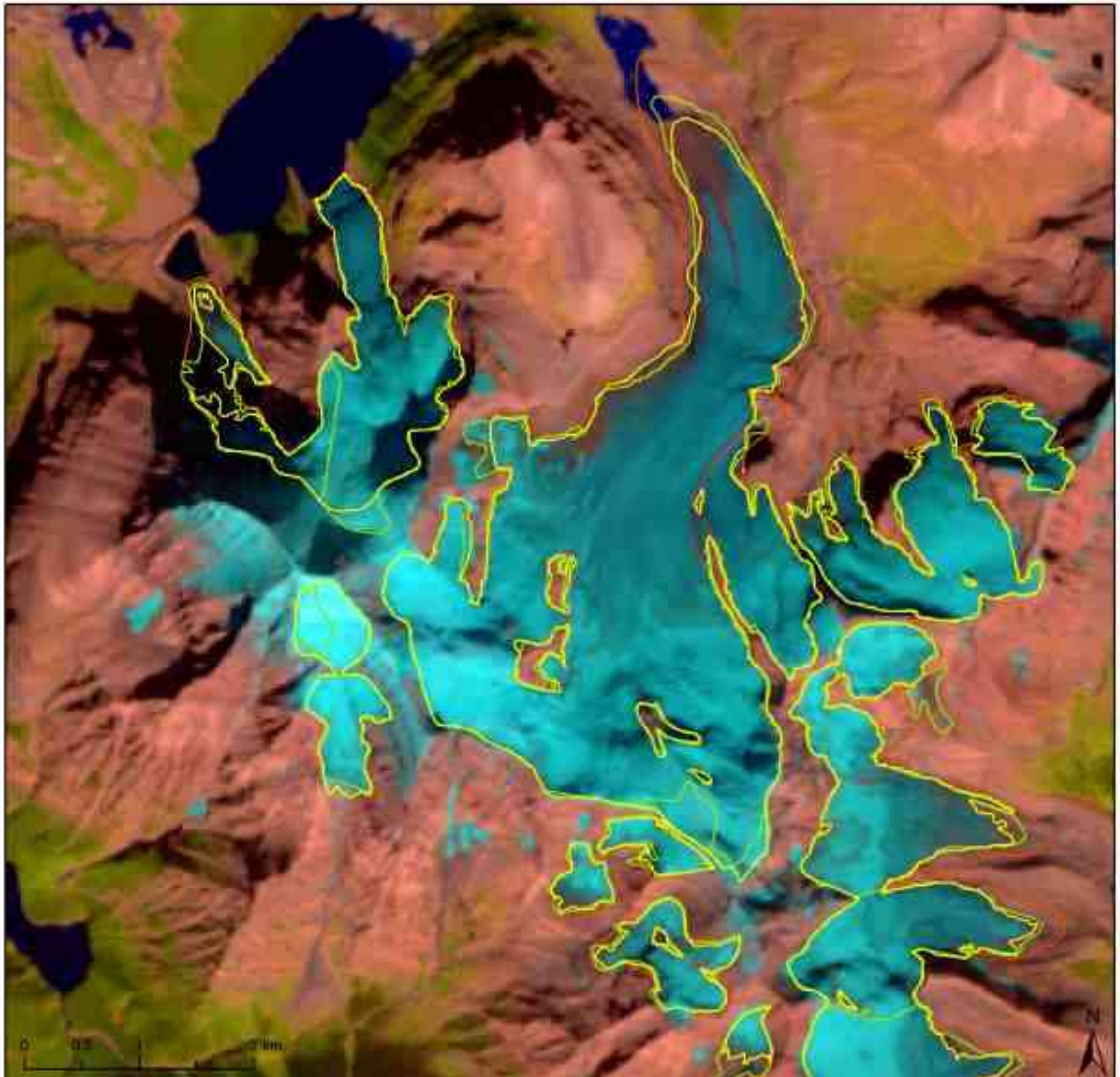


2007-08: We used 50 Landsat scenes and applied the Landsat 5 TN 3/5 ratio, with threshold >2.0 ~15,000 glaciers covering ~ 25,000 km^2 **('we' = Tobias Bolch !)**

Change per year (%) …. More glacier mass in the Coast Mountains



Glacier retreat 1985 - 2015 at Mount Robson

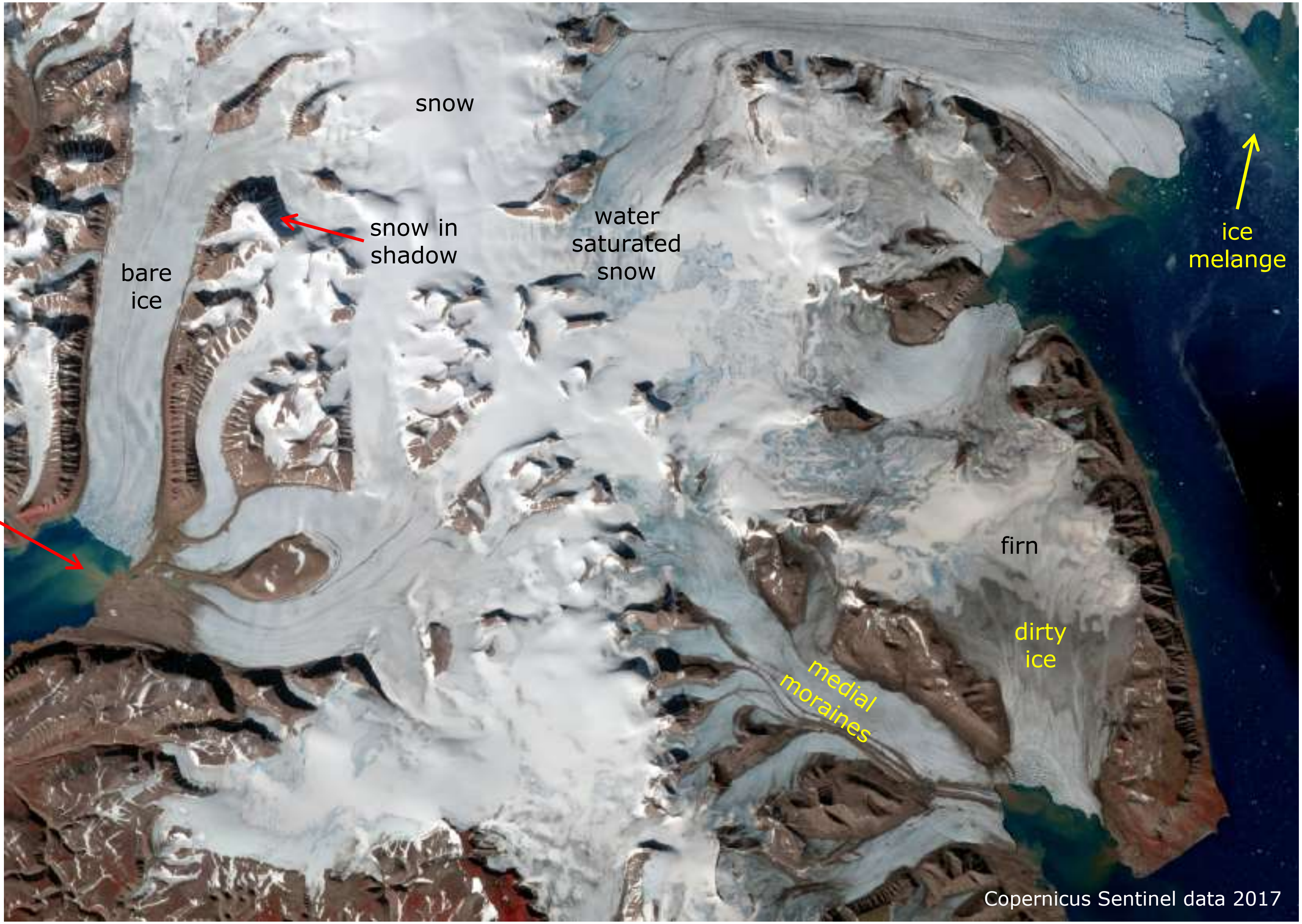


Glacier outlines

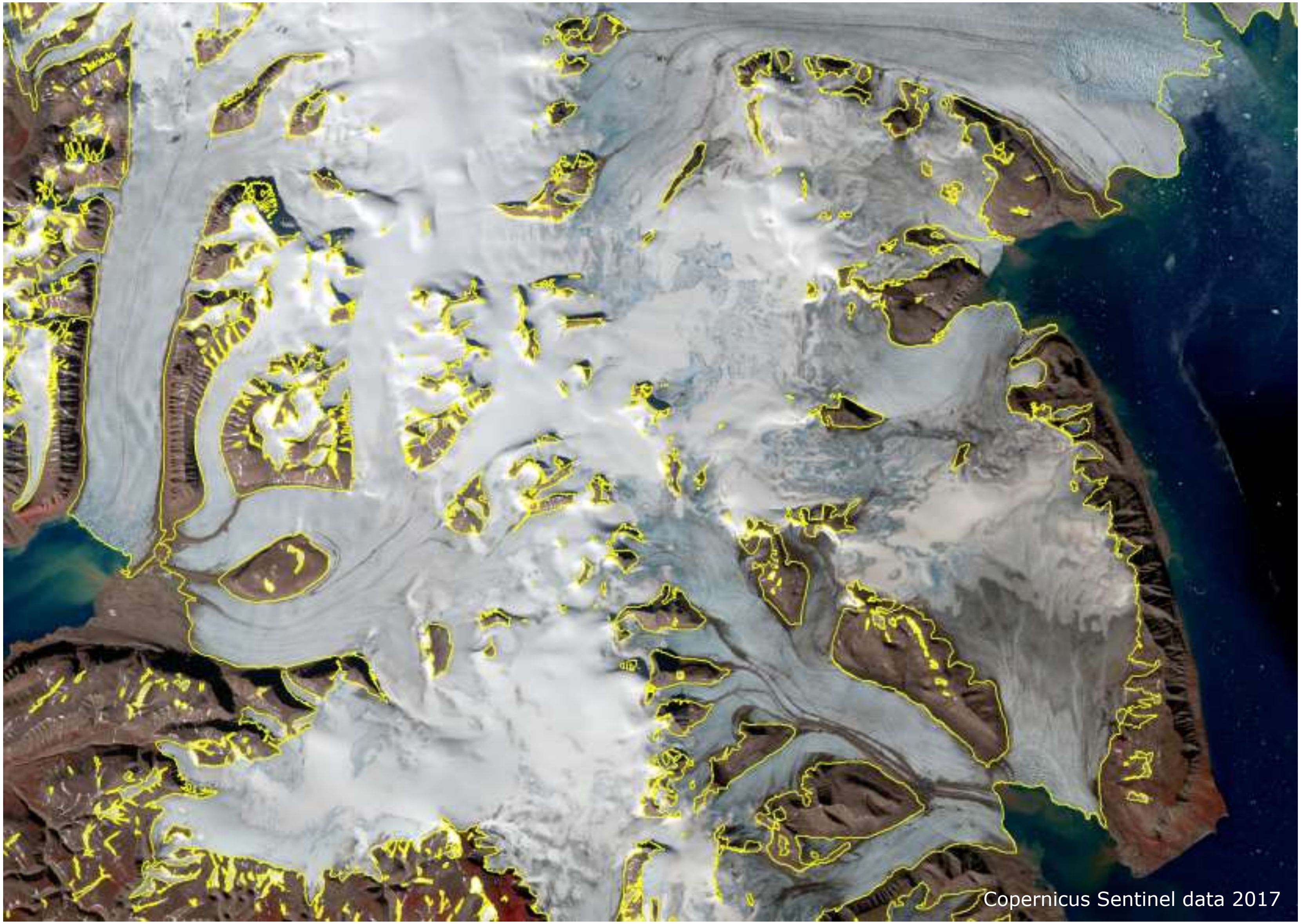
2015
2005
1985

Image data: Landsat 8 (NASA)
Outline data: T. Bolch (2005)
and TRIM (BC Govt.) (1985)
Projection: WGS 84 UTM Zone 10N
Cartography: Sophie Goertz
Date: 10.09.2018

Svalbard subset overview (bands 8 4 3) (Frank Paul)



Resulting corrected outlines (Frank Paul)



Ongoing Challenges

1. mixed pixels → lower threshold

2. shadows → lower threshold

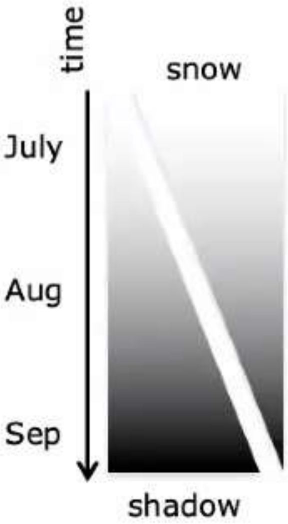
… view in visible bands or Panchromatic

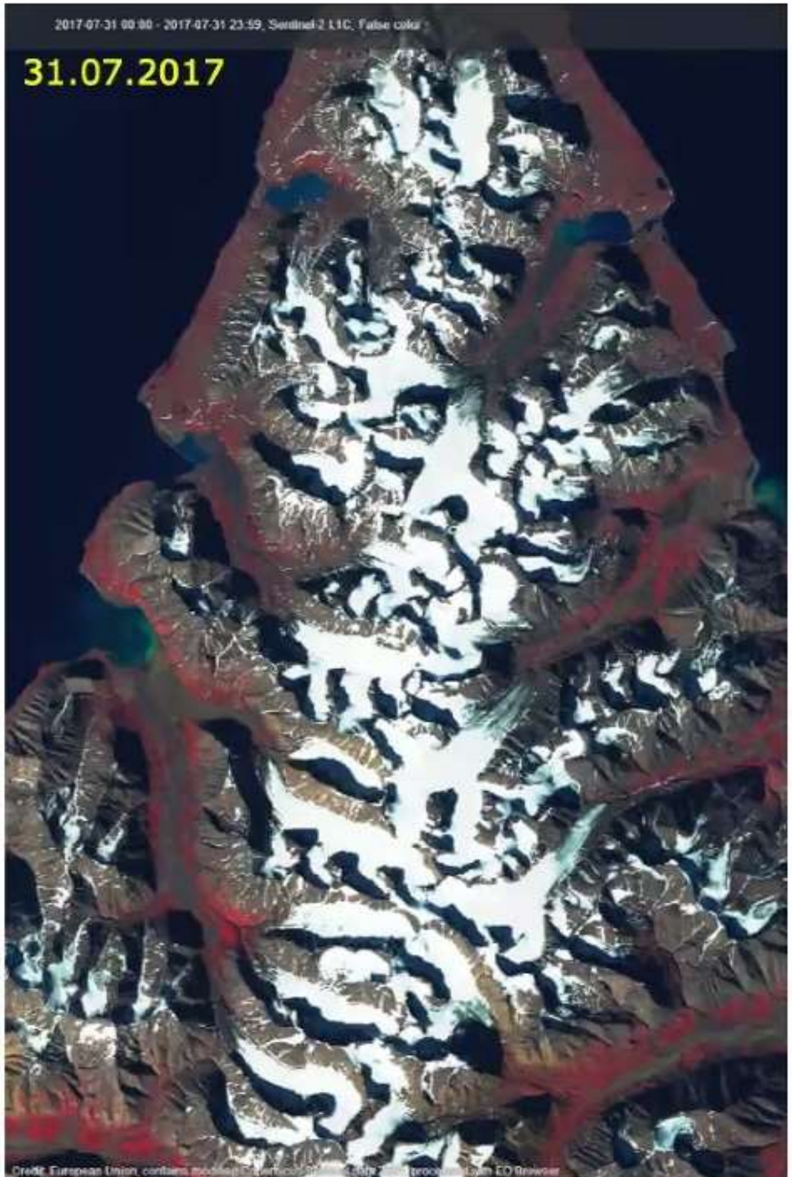
3. Misclassified lakes → higher threshold

4. Debris Cover

DEM? Thermal?

Later in the year: less snow, more shadow





Approach:
map with July scene, correct with September

Svalbard: 80 N

Remote Sensing of Glaciers

Image processing can be used to map:

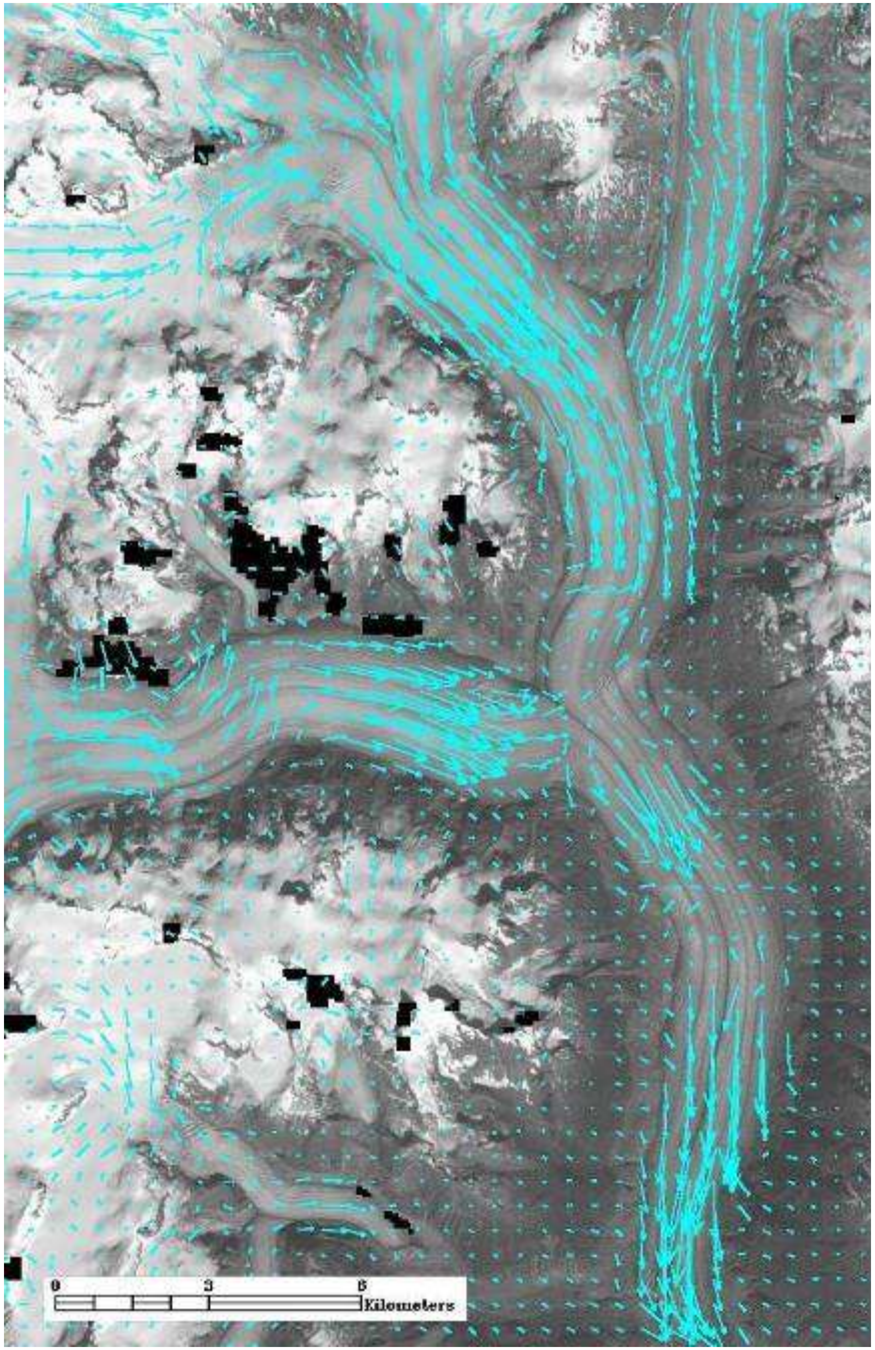
a. Glacier extents (compare with map vectors)

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

c. Animation – image series

d. Glacier movement /velocity

e. Elevation / volume change with DEMs (see next lecture)



d. Glacier velocity

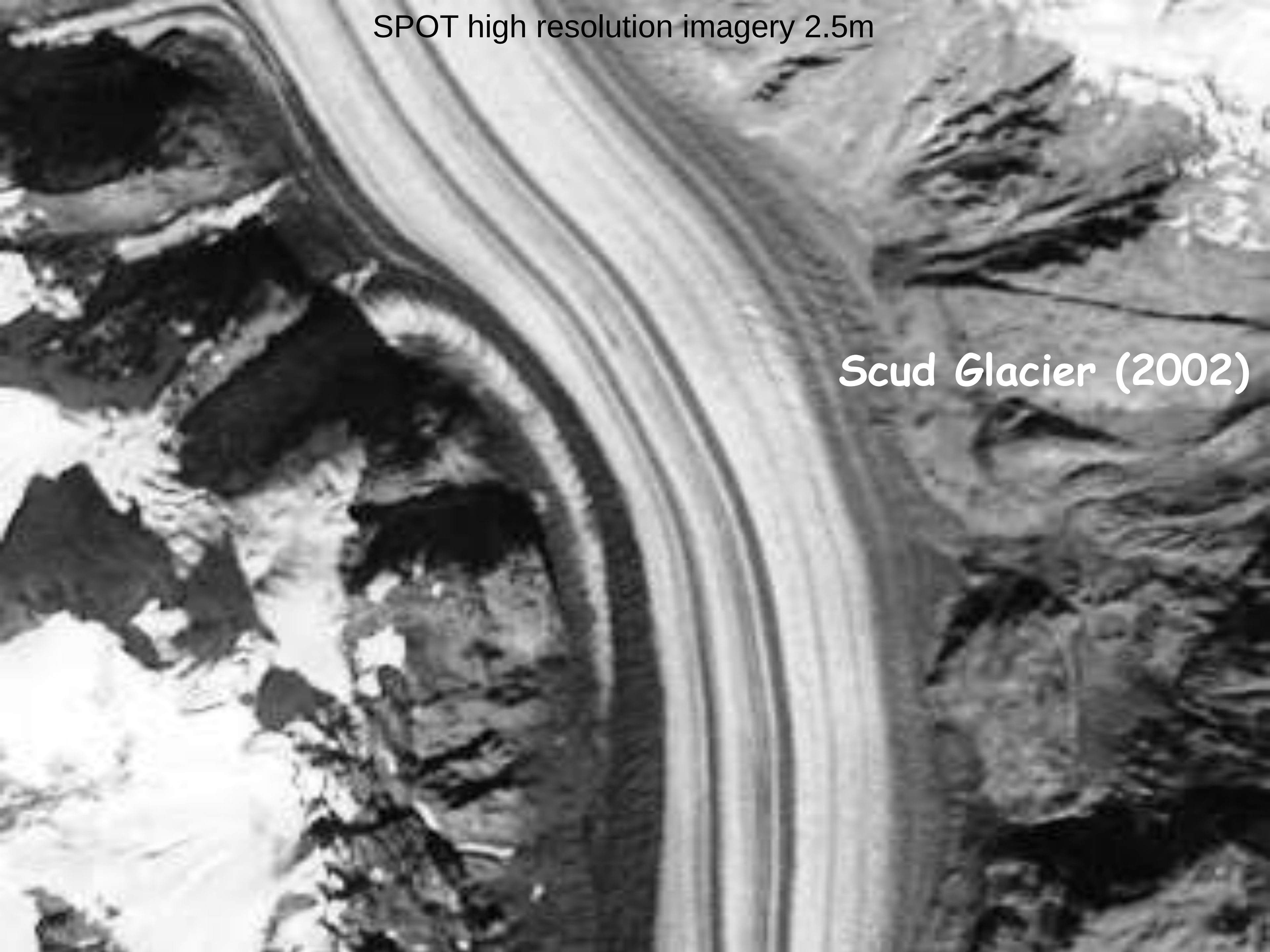
Klinaklini Glacier

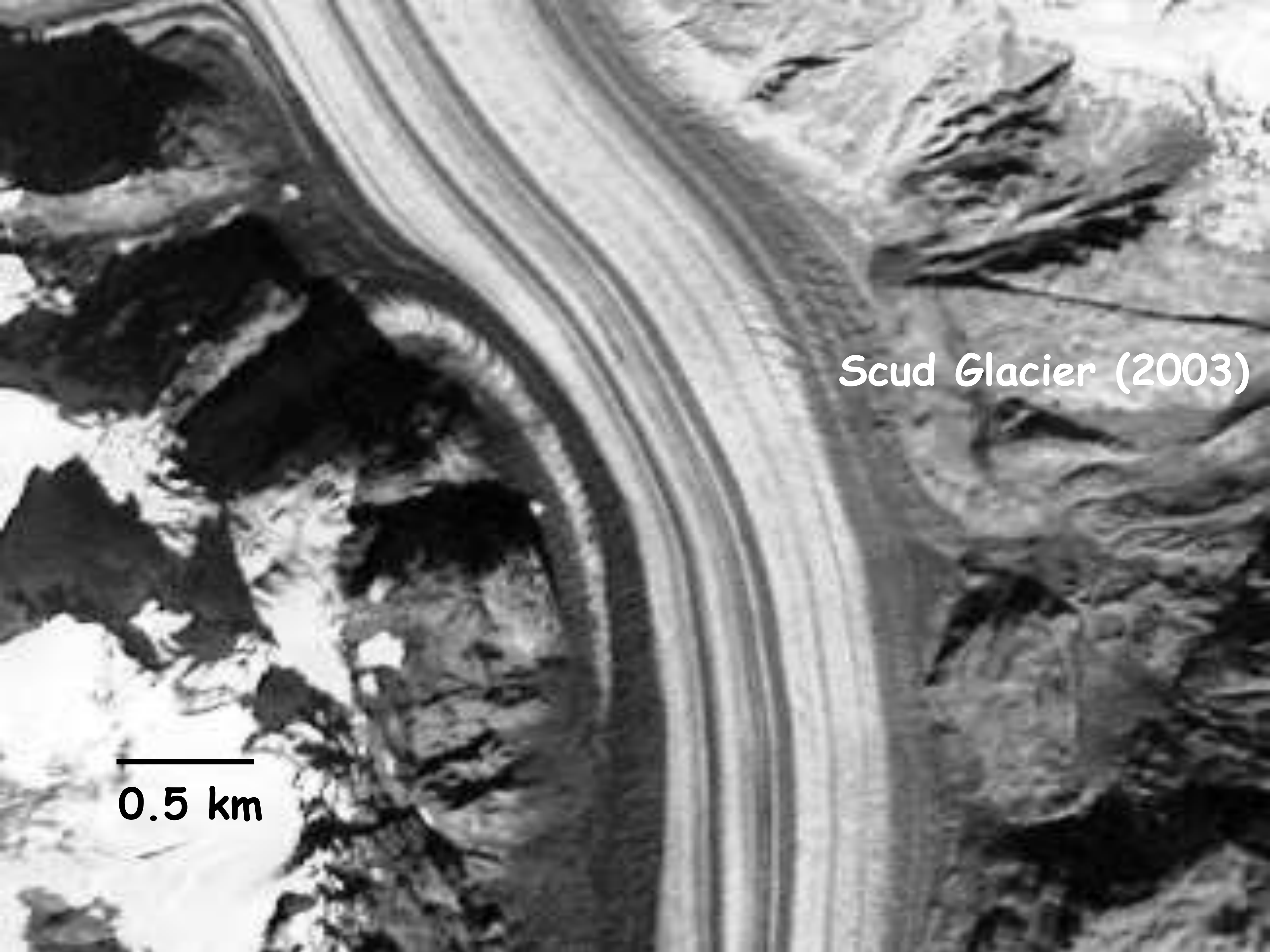
Annual movement ranges 30 – 500m
(mostly summer) ~ 1m per day (summer)

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

ENVI COSI-CORR software

SPOT high resolution imagery 2.5m




Scud Glacier (2003)
0.5 km

e. **DEMs** – more next lecture

Image processing can be used to map and measure :

Elevation change / Volume loss from DEMs