Digital Elevation Models (DEM) / DTM (terrain)

Raster DEMs are naturally suited to overlay / combine with raster imagery

Uses in remote sensing: queries and analysis, classification input, visualization

Hololens (Microsoft) https://www.youtube.com/watch?v=xCVuRNc6fWY

1. DEM sources

Almost all DEMs have been created from remote sensing:

a. DEMs from digitising contours: all DEMs pre-1985

Contours created from stereo-photography

b. Digital Stereo photogrammetry: 1985->

Initially from scanned air photos, then digital photos

c. Direct grid DEM data from imagery: 2000->

Stereo <u>Optical</u> imagery and RADAR

d. LiDAR terrestrial and airborne: 2005->

High resolution point cloud, sub-metre

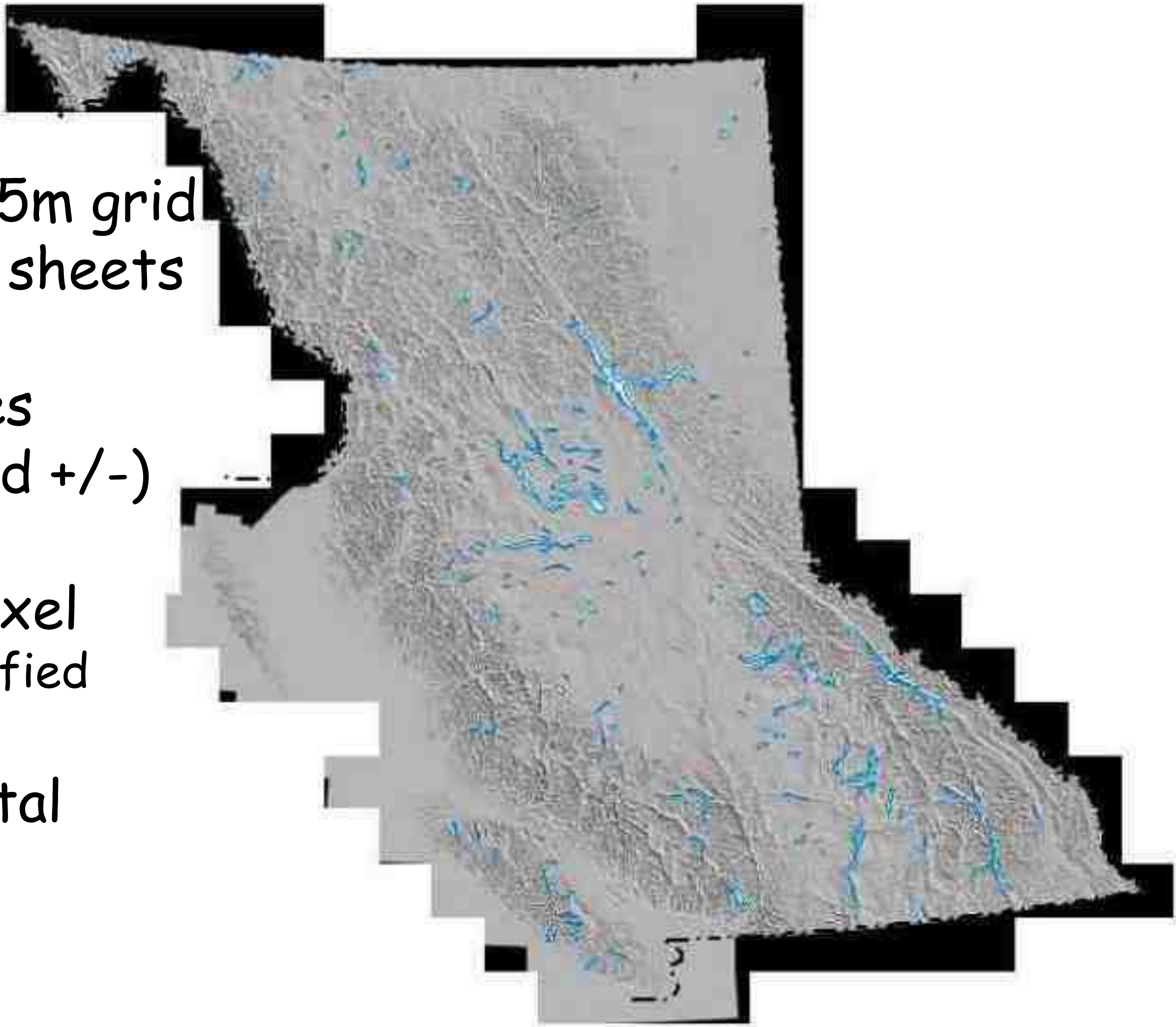
BC provincial TRIM DEM – 25metre grid

Interpolated to 25m grid
by 1:250,000 map sheets

Elevation in metres
= 16 bit DN (signed +/-)

A DN for every pixel
- 32 bit real not justified

created from digital
stereo air photos



DEM sources 2000+

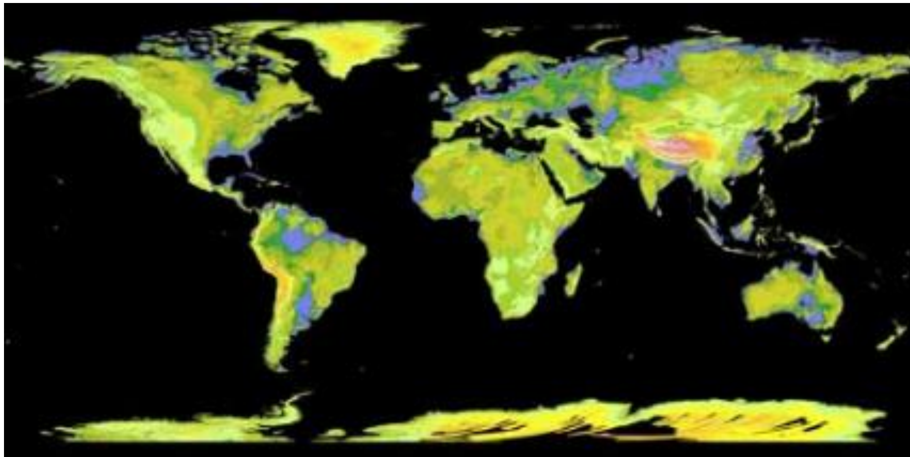
Shuttle Radar Topographic Mission (SRTM) Feb 2000
Data affected by steep slopes,   Download by 5° x 5° area

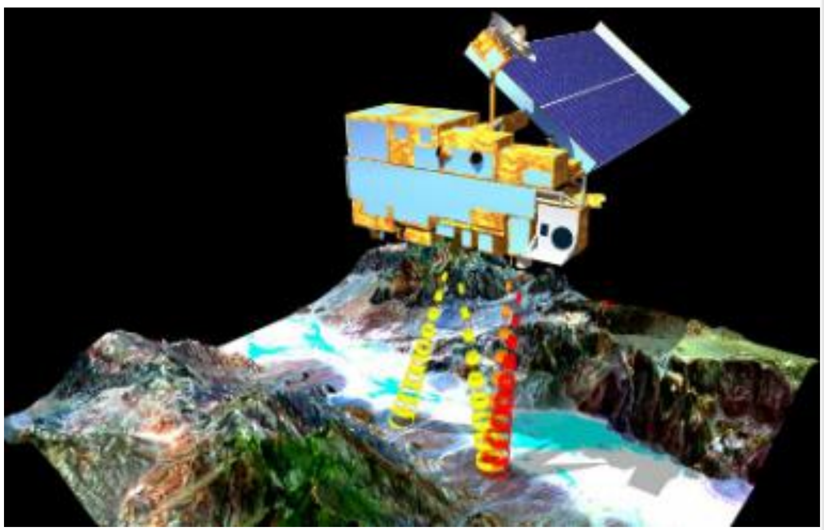
Available for 60°N – 56°S   resolution 3 arc seconds (90m)

Used for most of Google Earth

ASTER DEM

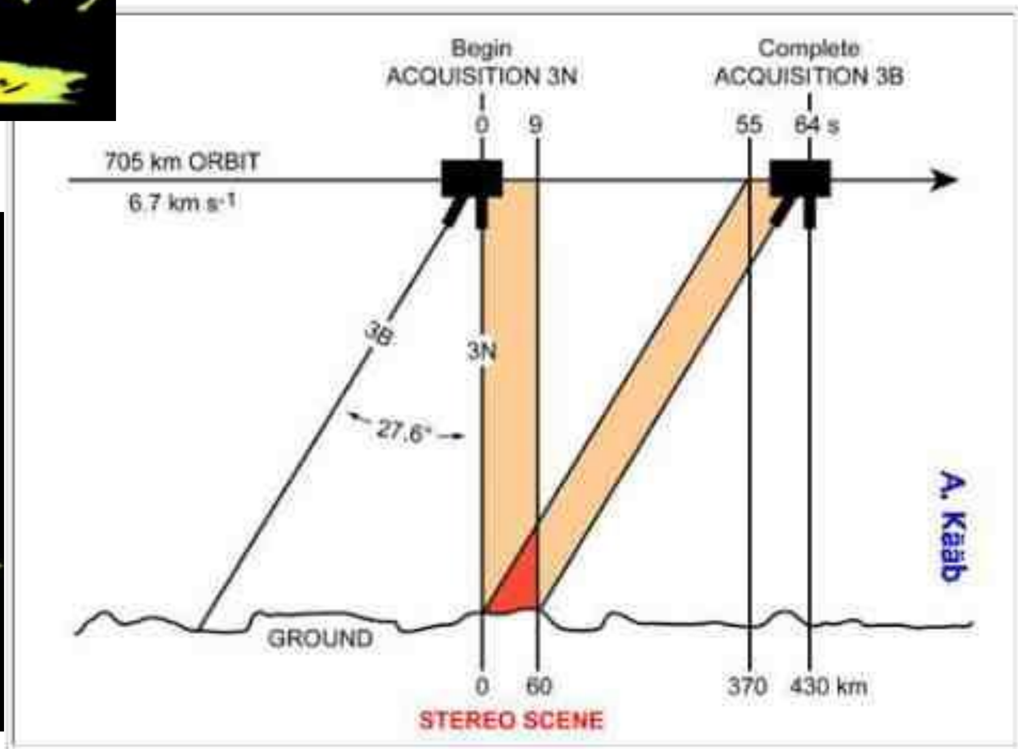
<- global DEM 30m pixels





Global DEM (ASTER)

http://asterweb.jpl.nasa.gov/gdem.asp



ASTER stereo geometry and timing of the nadir-band 3N and the back-looking sensor 3B. An ASTER nadir scene of approximately 60 km length, and a correspondent back looking scene (27.6° off-nadir) acquired about 60 seconds later, form a stereo pair.

ASTER image and DEM : Svalbard, Norway (80N) (15/30 metre resolution)

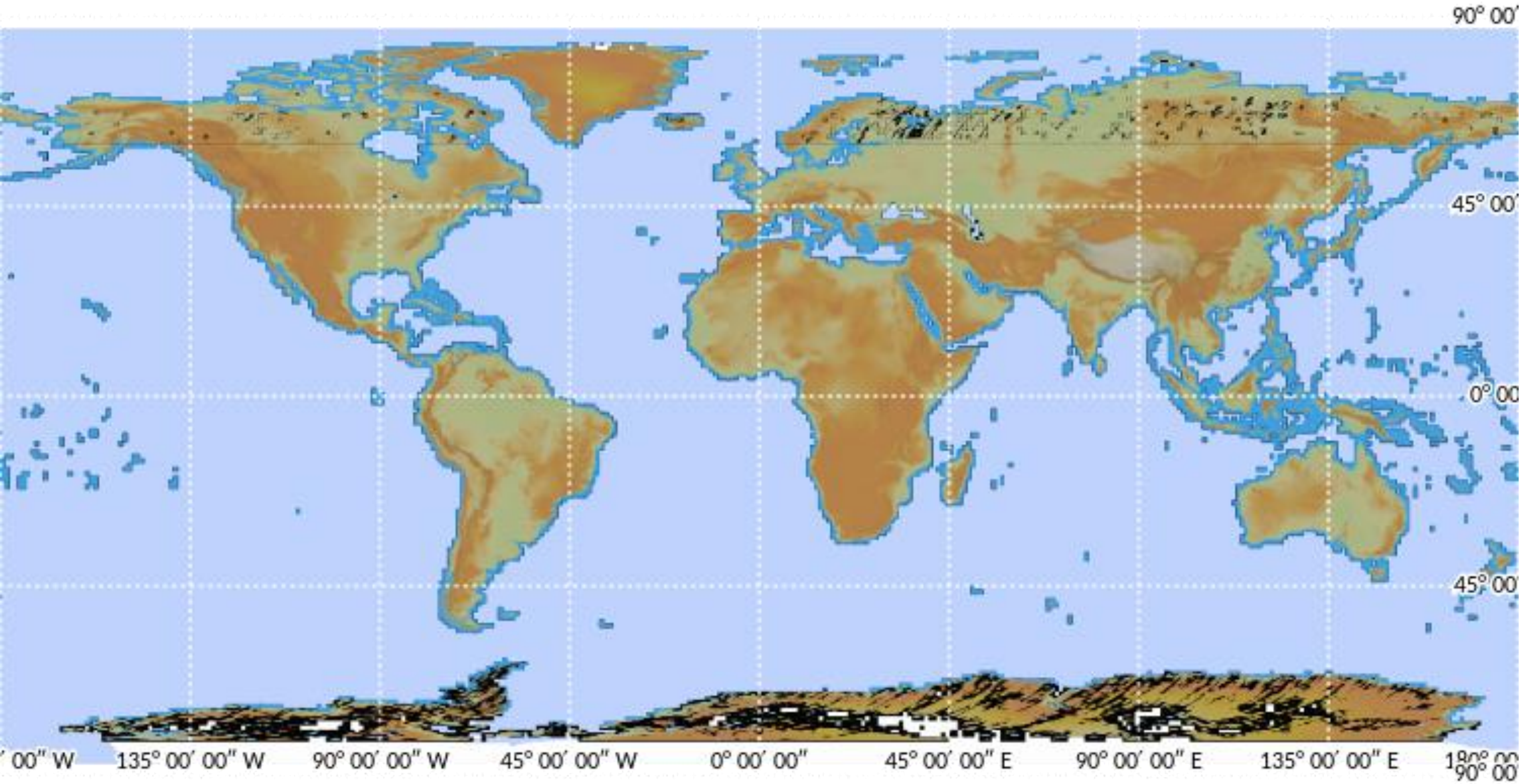
Longyearbyen campus northernmost - UNIS

UNIS courses-upper year/ graduate students

Satellite data receiving stations

ALOS DEM 2006-11

Advanced Land Observing Satellite – stereo imagery 30m



https://www.eorc.jaxa.jp/ALOS/en/index_e.htm

DEM availability

A DEM is a continuous grid of elevation values –
one height value per pixel ..... in a channel (not a band)

Resolutions and datasets available:

NTDB 25m (Canada) 1950-95

TRIM 25m (BC only) 1980-89

ASTER 30m (global) – with holes … 2005

SRTM 90m (near global) 2000

ALOS 30m (global) 2015

Arctic DEM 2m Polar areas

High Resolution Digital Elevation Model (HRDEM) 2m – Canada North

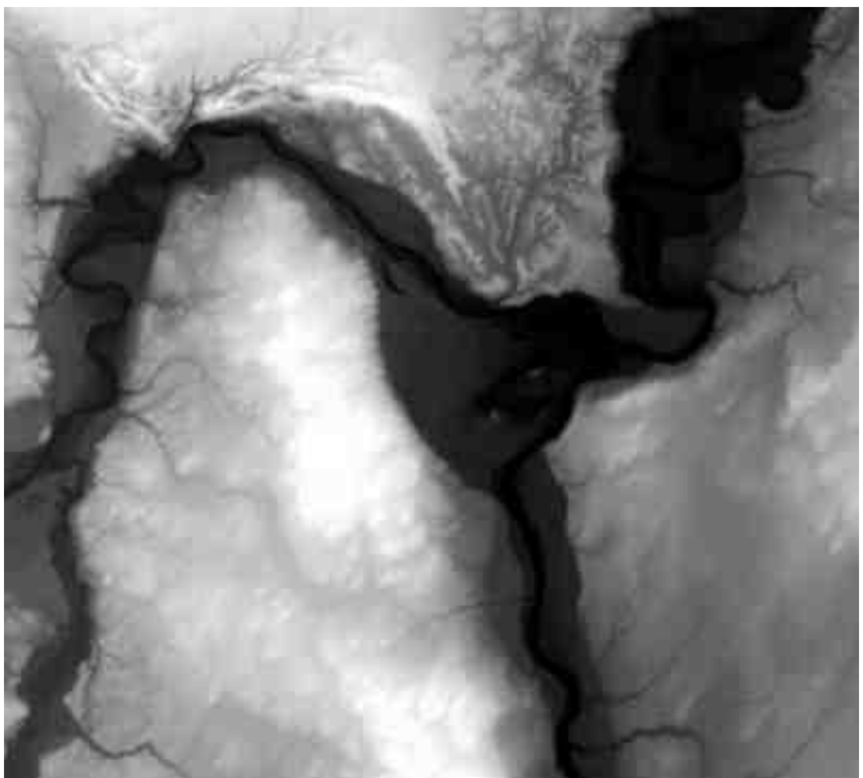
LiDAR: sub-metre- see LiDAR lecture

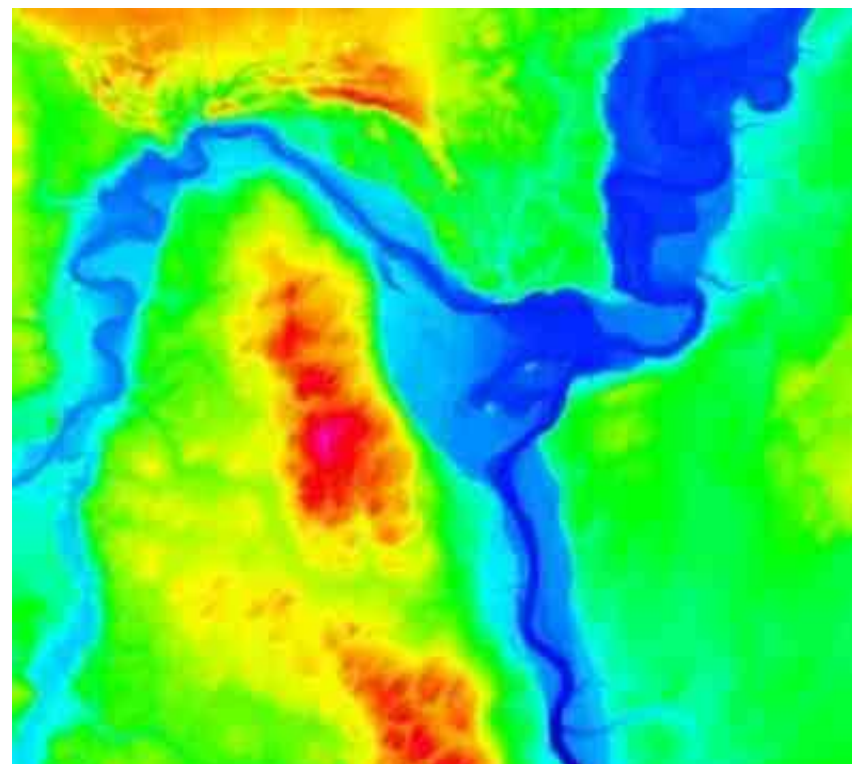
2. DEM - layers

A. Elevation ('DEM')

DN = (metres, 16 bit): onscreen as grayscale/pseudocolour

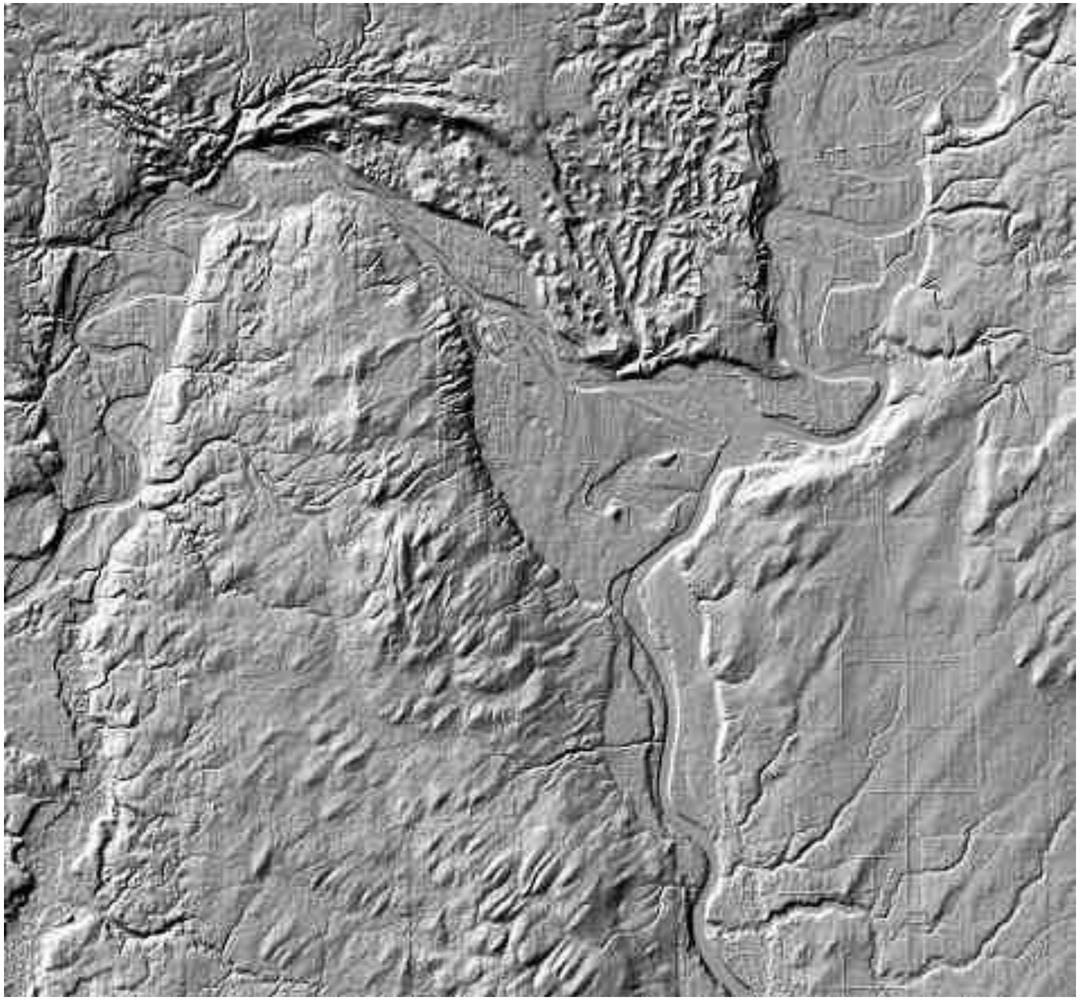
DEMs are stored as integers (metres) or 32 bit (after interpolation)
- 32 bit merited only for LiDAR, NOT for BC TRIM (good to nearest 10metres)





b. Shaded relief (hillshade)

A cartographic layer, DN= 0 - 255 (relative amount of light reflected) as grayscale; light source is selected, usually from the NW.
High values on NW facing slopes, low values on SE facing slopes.



Select light source azimuth and angle
Default = 315, 45

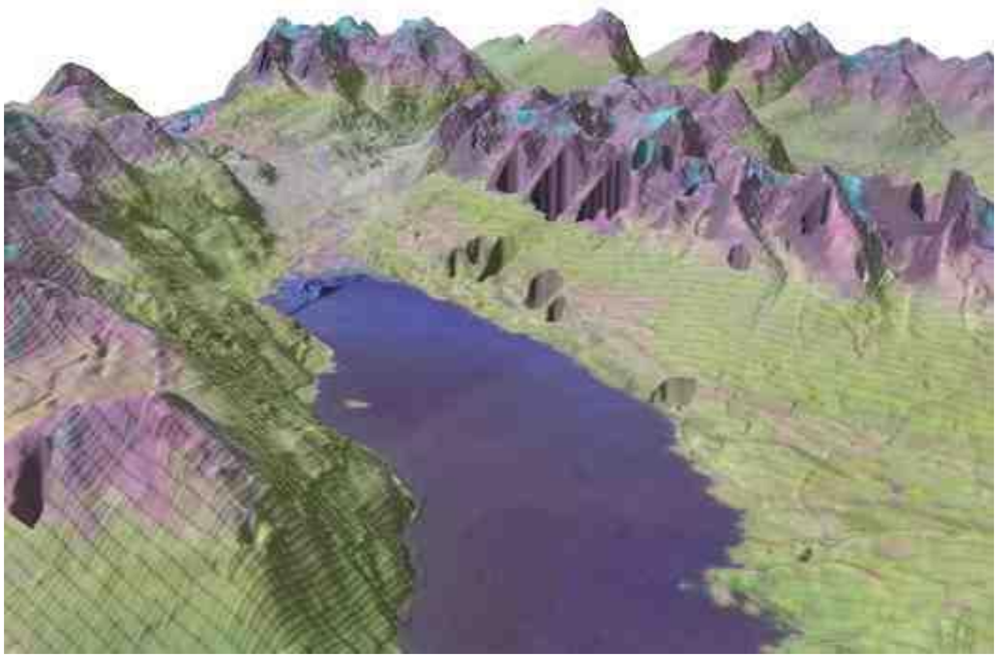
useful / essential to detect errors / assess DEM quality

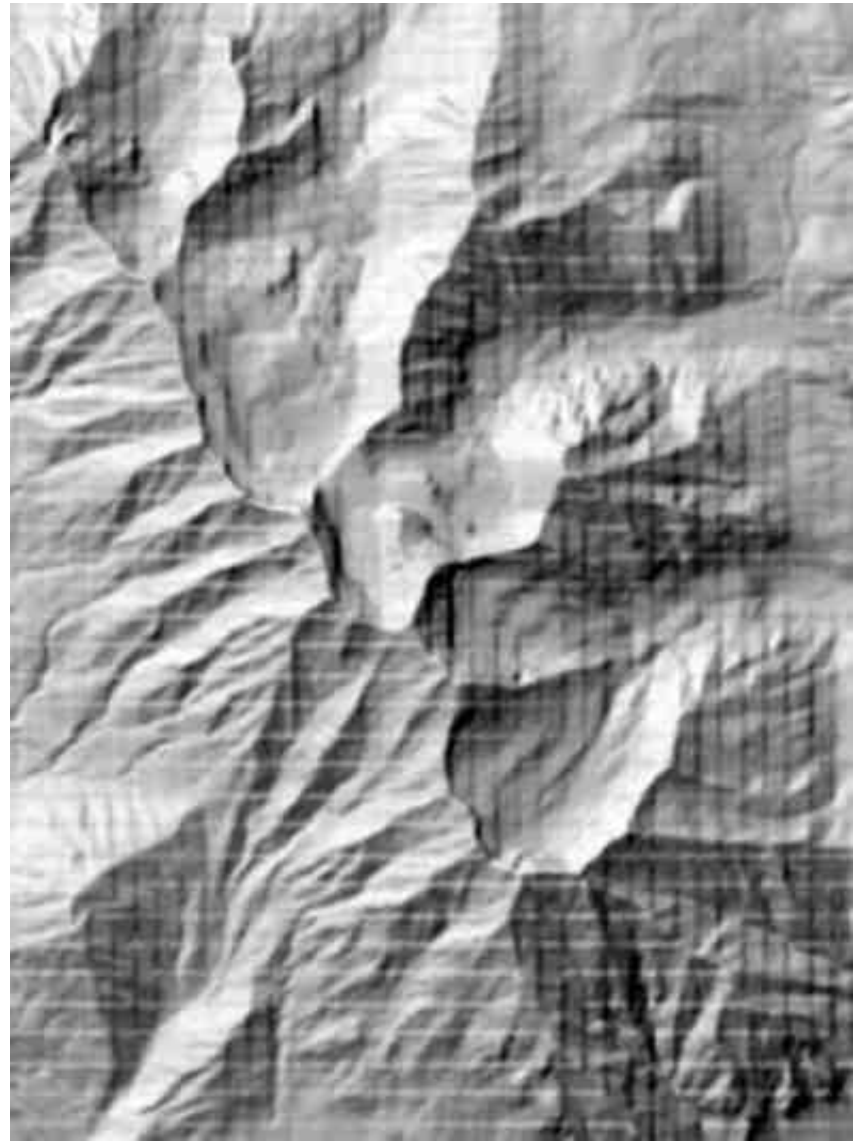
Use of shading to assess DEM

Noooooooooo !!

DEM data often stored in 'geographic' (lat/long) must be 'projected'
Reprojection can cause striping
Avoid reprojecting rasters if possible

Holes due to clouds



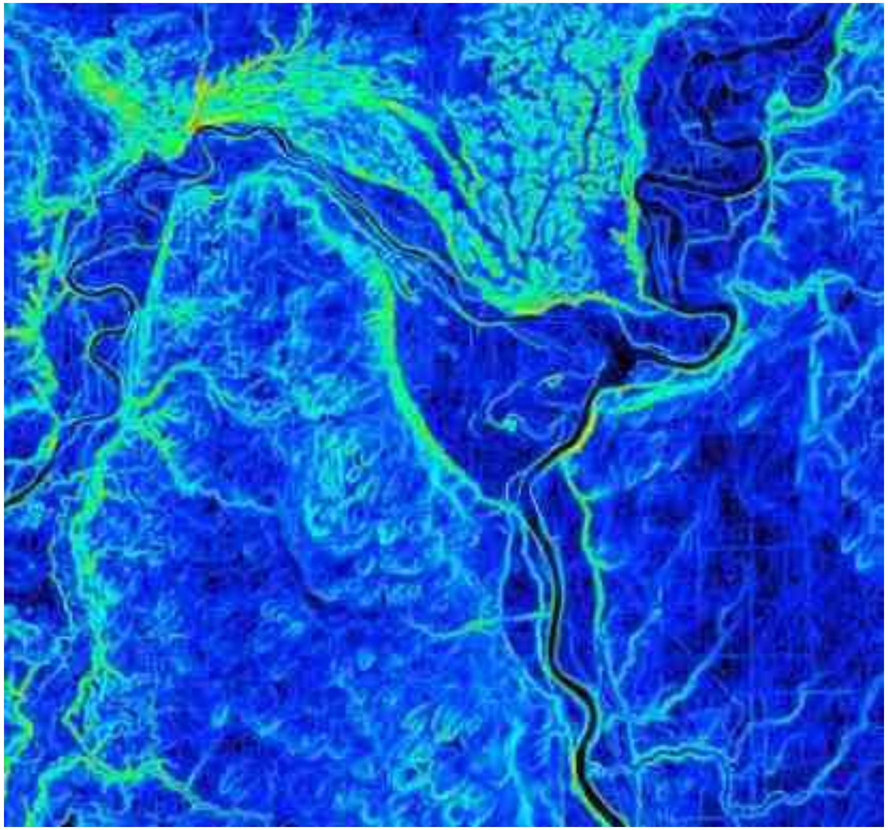


c. Slope (gradient)

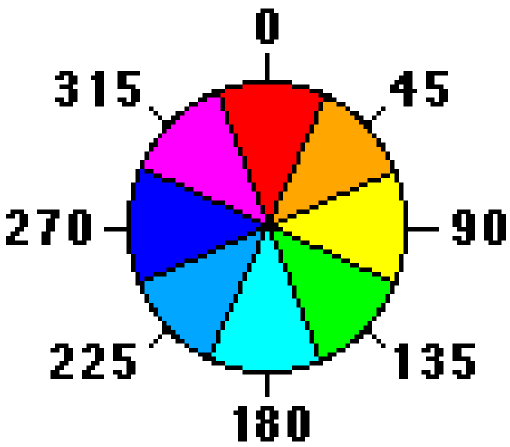
Calculated in degrees (0-90) or % (0 -> infinity = vertical cliff)

slope : rise/run = vertical change over the horizontal distance

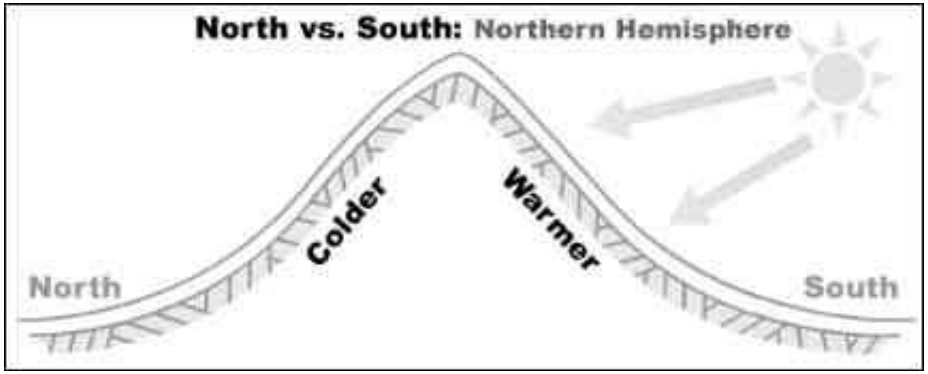
8 bit results (0-255) should be adequate for most purposes



d. Aspect: the compass direction a slope is facing



A circular scale: N = 0 and 360



This raises three questions for analysis:

north facing slope has both extreme values, <u>0 and 360</u> ******

flat slopes have no value (they are given an arbitrary value, e.g. 510)

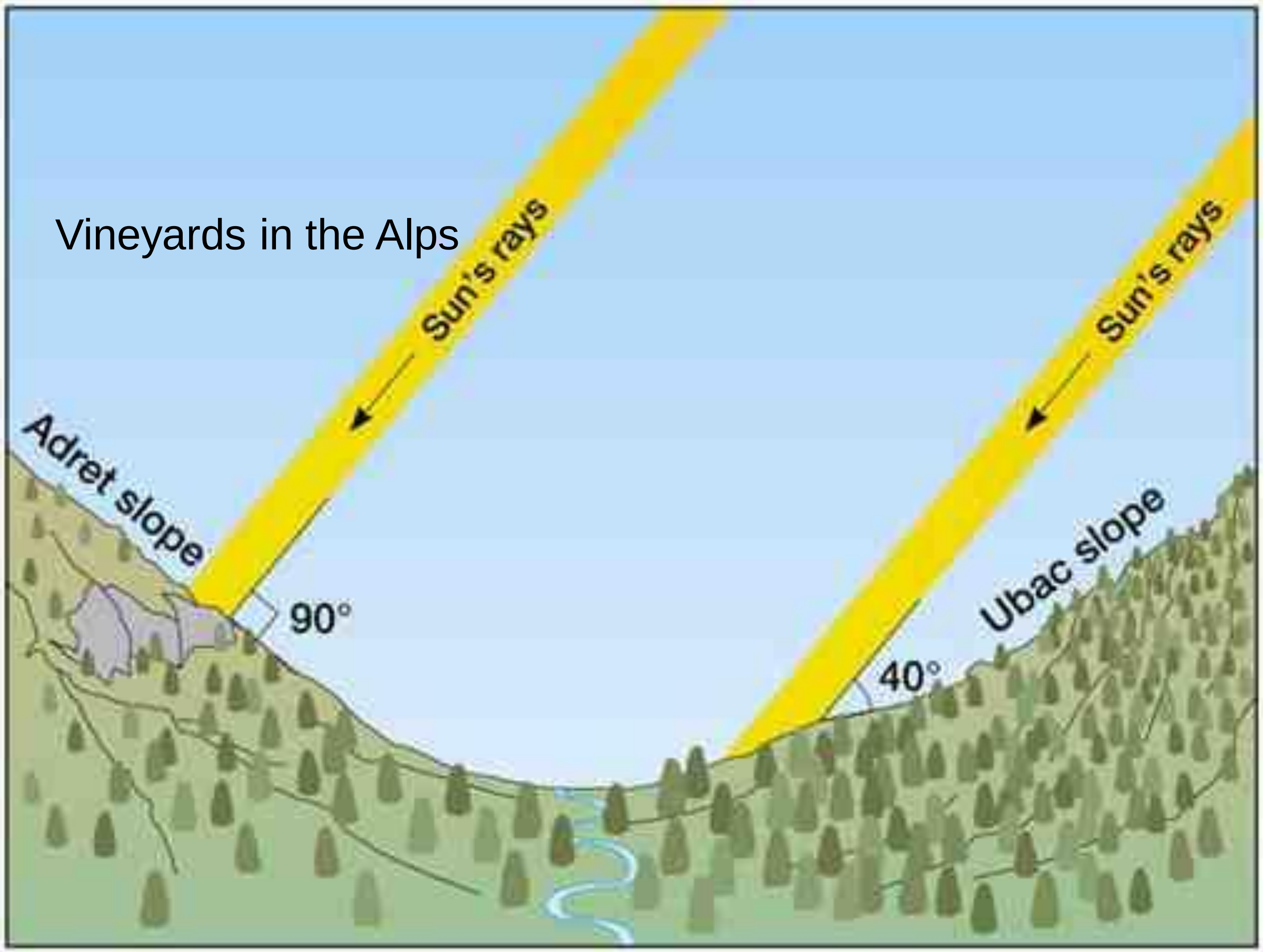
0-360 requires 16 bit data

Aspect has an impact on land use/cover / classification – GIS queries

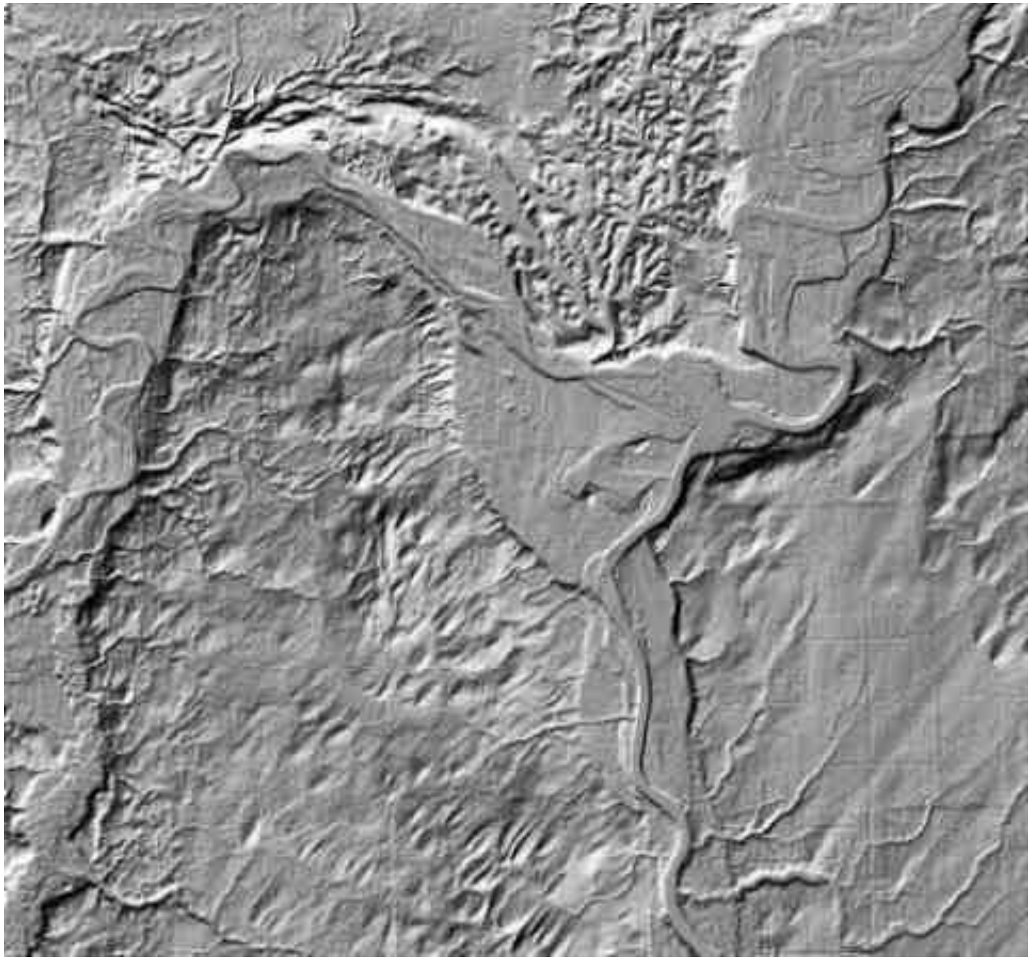
But we can't use it as classification input - Not directly, instead we use:

e. Incidence

- DN is related to the reflection based on sun angle (0-90)
- Known from the sun - satellite geometry (included with image data)



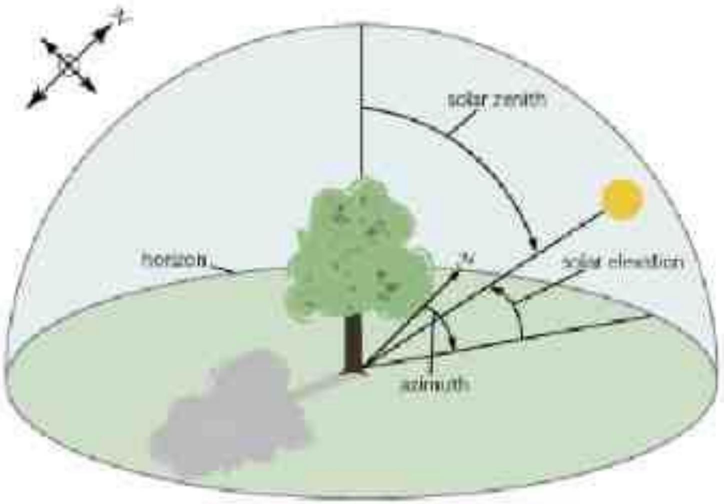
- **Incidence** looks similar (inverted!) to shaded relief, with DN 0-90
- the angle (degree) of light incidence, is based on the sun position
- Requires metadata for sun elevation and azimuth for the scene



Azimuth = sun’s compass direction

Elevation = height of sun

Solar zenith = 90 - elevation



3. DEMs in Digital Image Classification

strategies for reducing mountain shadows effect

Input channels for classification:

Raw bands e.g. TM 3,4,5 / OLI 6,5,4 <u>PLUS</u>

Ratios / Indices
Transform components (e.g. Tassel Cap greenness, wetness)

DEM Elevation
Slope (gradient)
Incidence (not aspect)

Other: e.g. Curvature (concavity/convexity), texture
- generation of watersheds in RS / GIS

Utilization of Landsat TM and Digital Elevation Data for the Delineation of Avalanche Slopes in Yoho National Park (Canada)

K. Wayne Forsythe and Roger D. Wheate

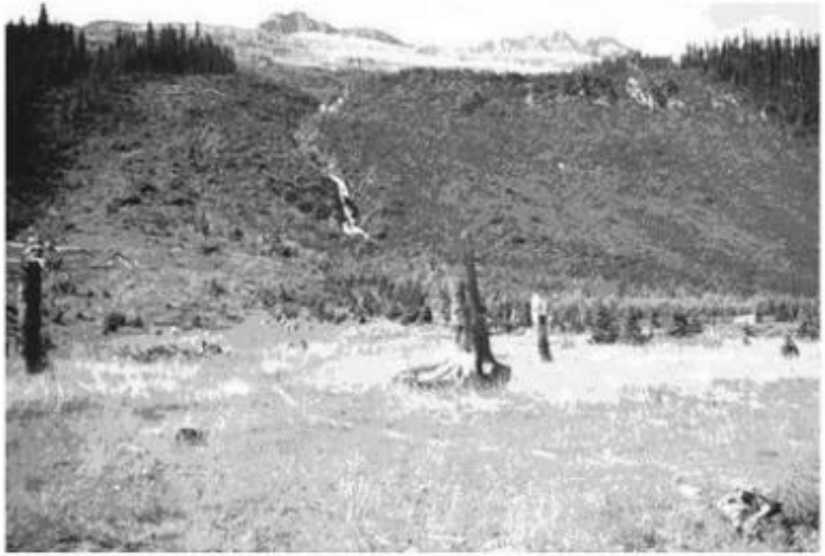


Fig. 1. Avalanche Slope at Takakkaw Falls, Yoho National Park. Looking west, slope is approximately 500 metres wide.

Avalanche slopes : 25-45°

Avalanche slopes : 25-45°

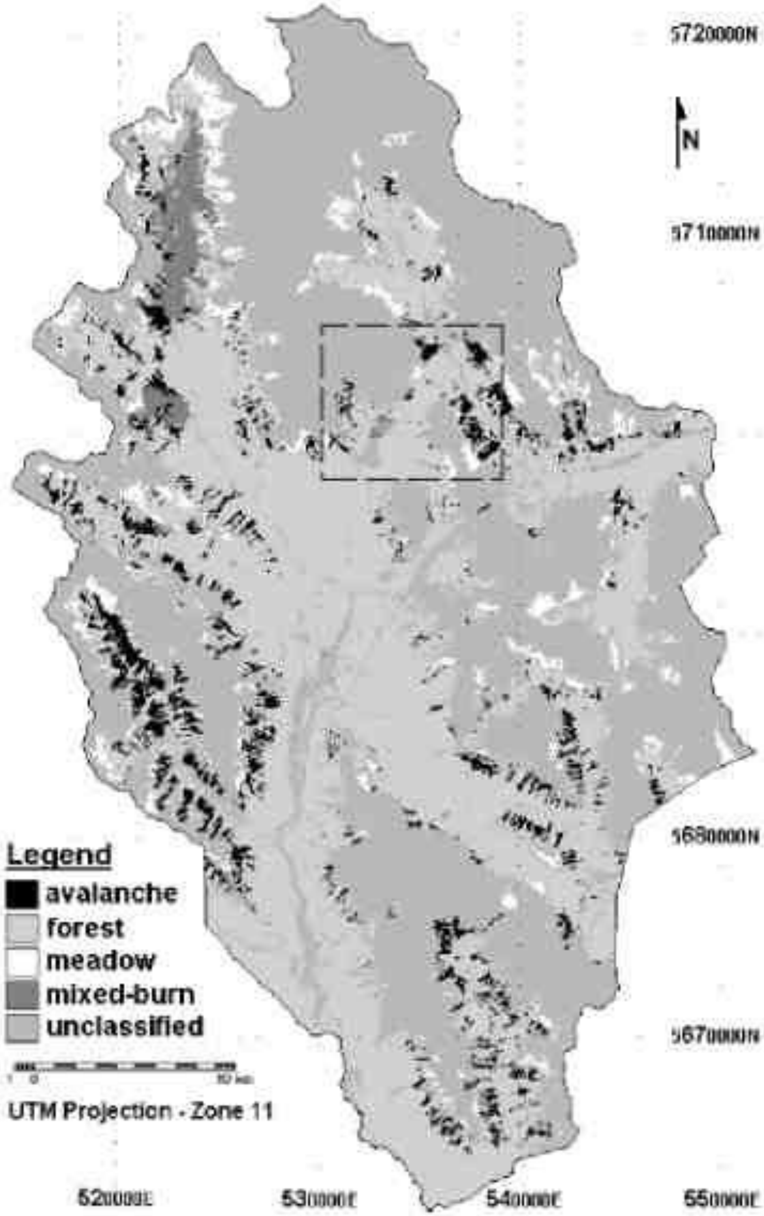


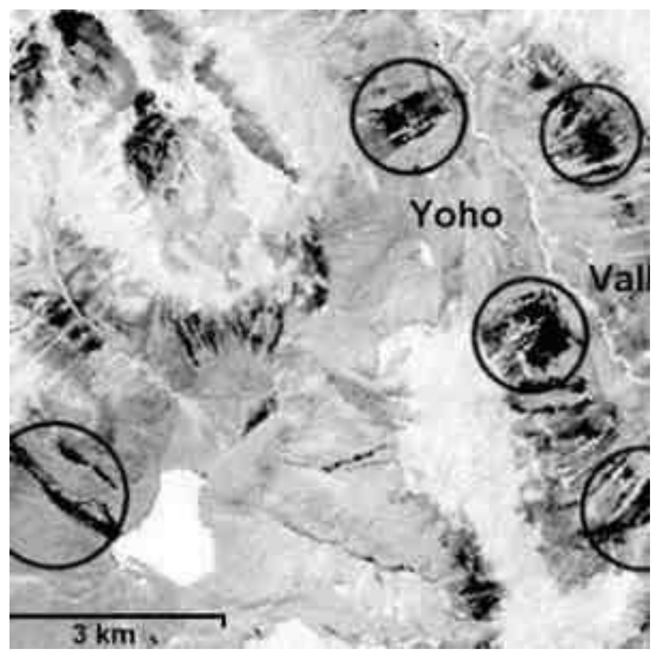
Fig. 6. Classification Results after the 3x3 filter. Dashed box indicates the area featured in Figs. 4 and 5)

Classifications and channel inputs

a. TM bands 3, 4, 5, and 7 alone
b. TM bands 3, 4, 5, and 7 plus elevation
c. TM bands 3, 4, 5, and 7 plus elevation and slope
d. TM bands 3, 4, 5, and 7 plus elevation, slope, and incidence
e. TM bands 3, 4, 5, and 7 plus elevation, slope, incidence, NDVI, and PC3.

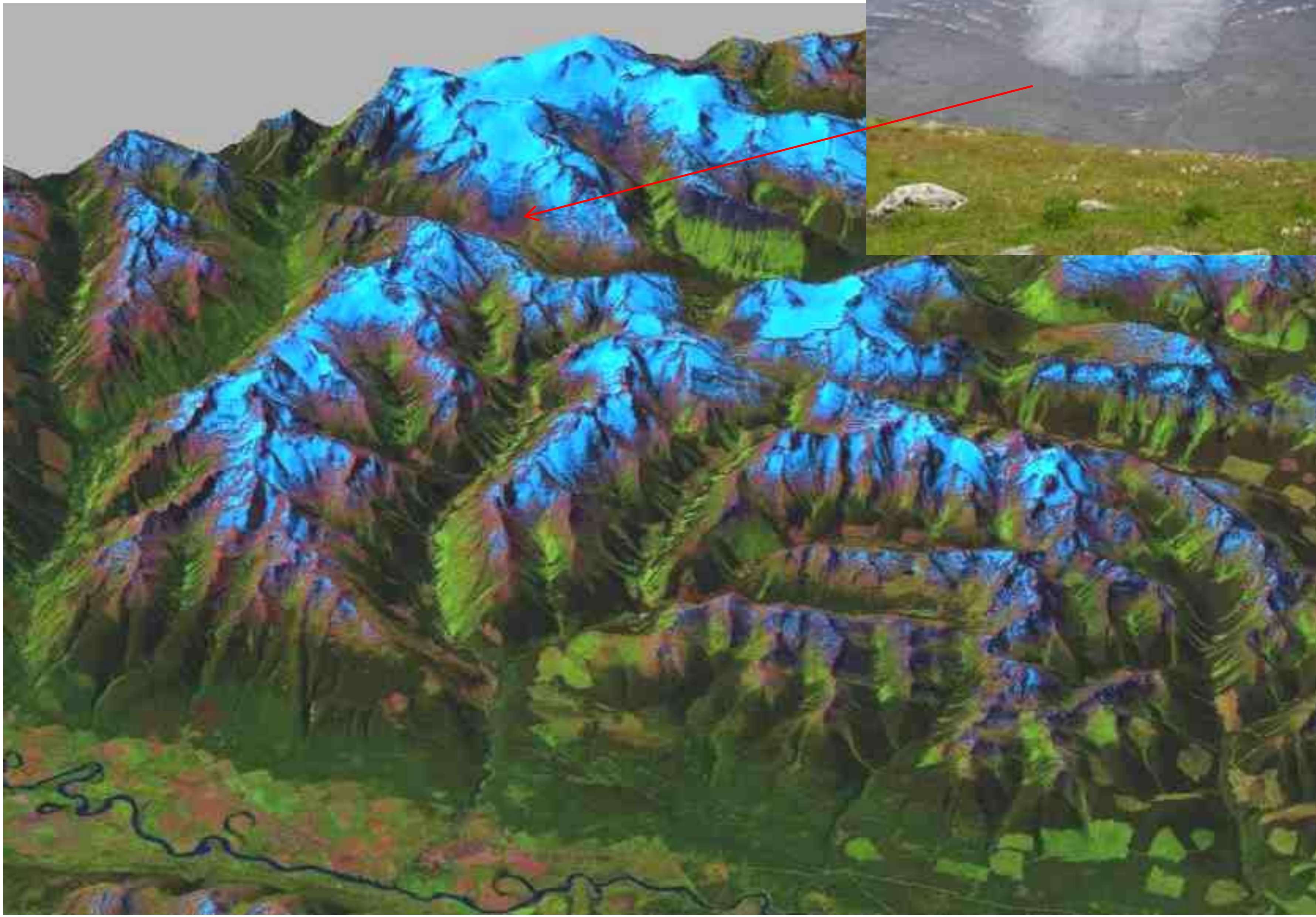
TABLE III
CLASSIFICATION ACCURACY RESULTS (PERCENT)

Classification	Avalanche	Forest	Meadow	Mixed	Overall
a. bands 3,4,5,7	79.0	99.0	69.8	78.0	79.75
b. a + elev	78.9	98.3	100.0	88.2	84.50
c. b + slope	76.8	99.0	99.5	94.1	91.75
d. c + incidence	80.6	100.0	99.4	88.2	92.25
e. d + NDVI, PC3	81.7	95.4	99.0	94.4	90.00



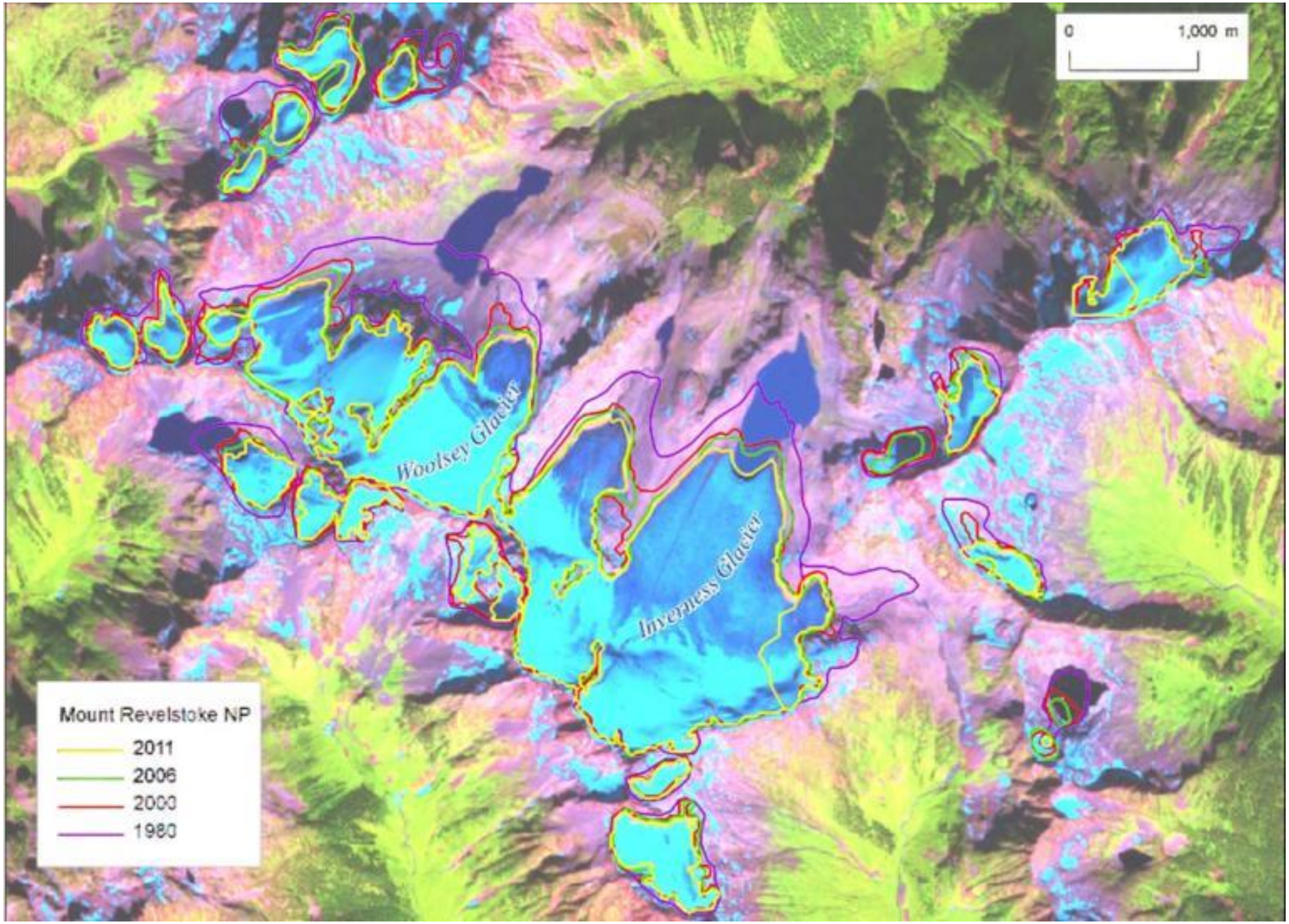
DEM:
1:250,000
100m pixels

4. Visualisation – perspectives
e.g. Google Earth, ArcScene etc..

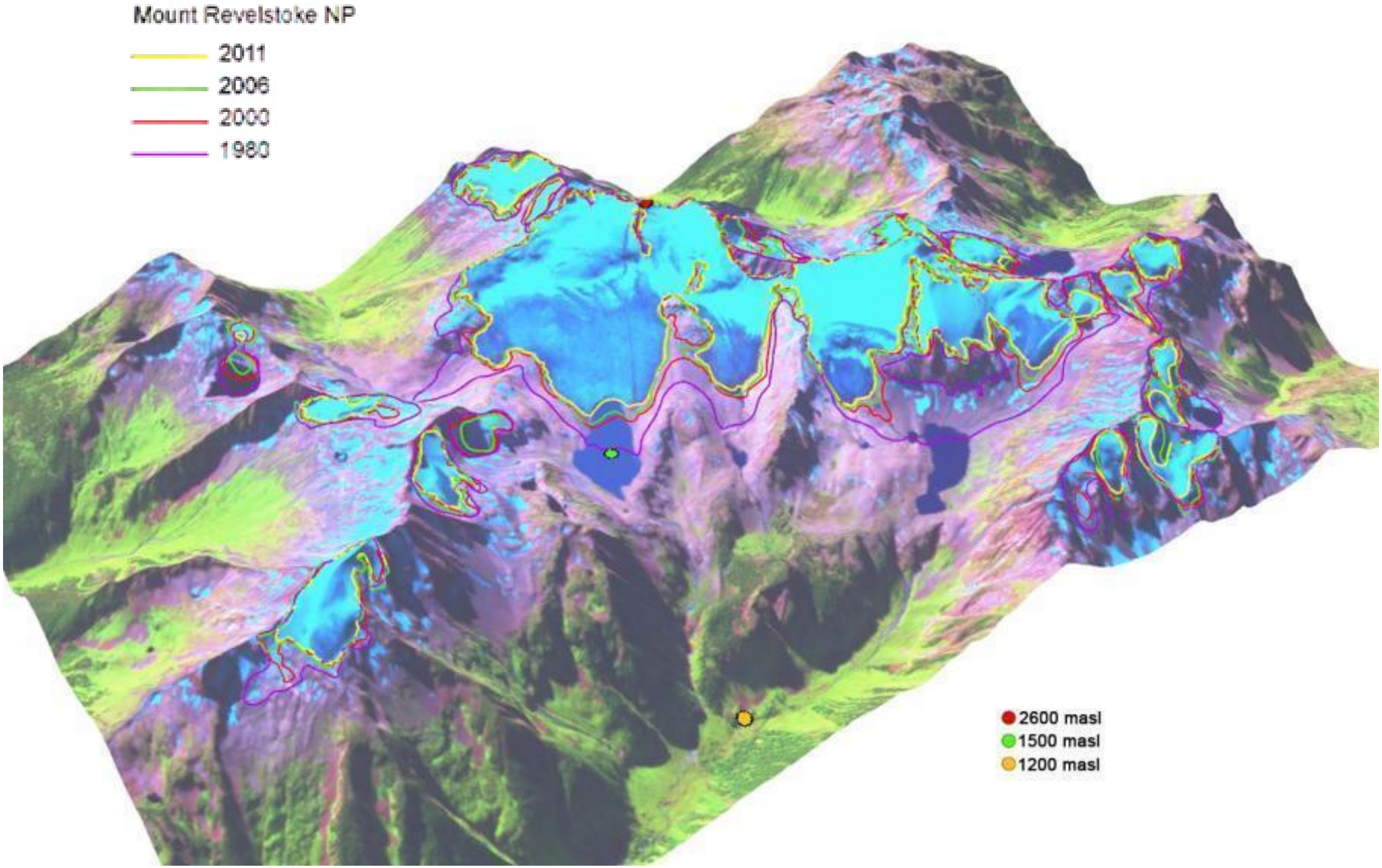


Robson Valley/McBride and Dore valley – Castle Glacier

2012: Update for Glacier and Mt. Revelstoke Parks using new imagery (SPOT)



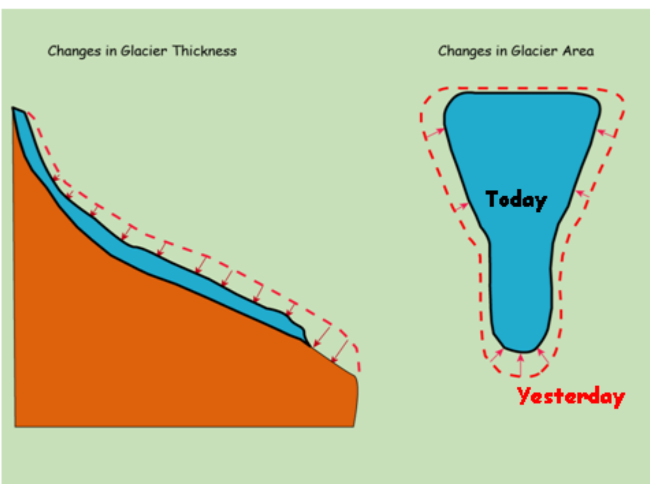
Planimetric view



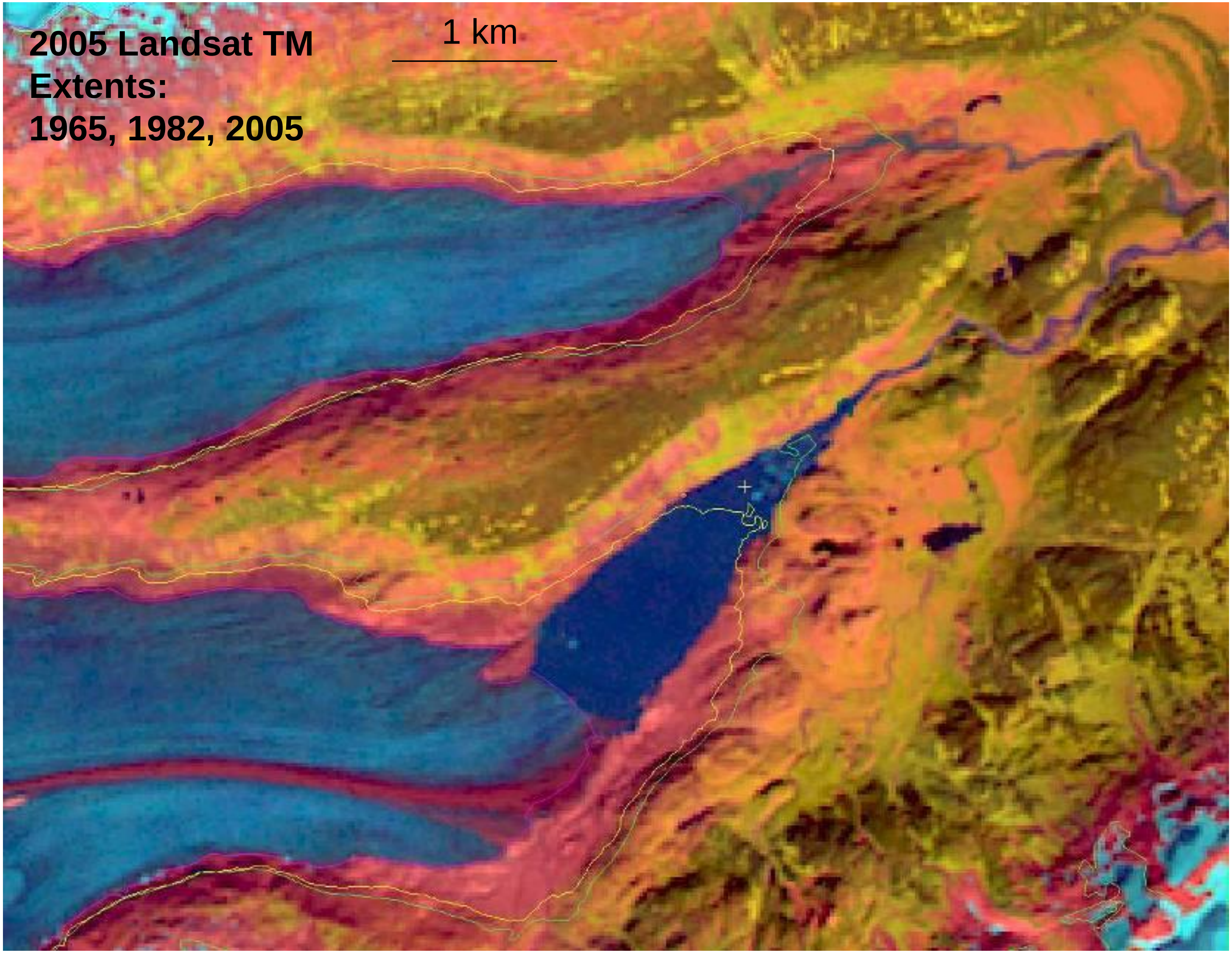
Perspective view

5. DEM differencing – to show glacier downwasting

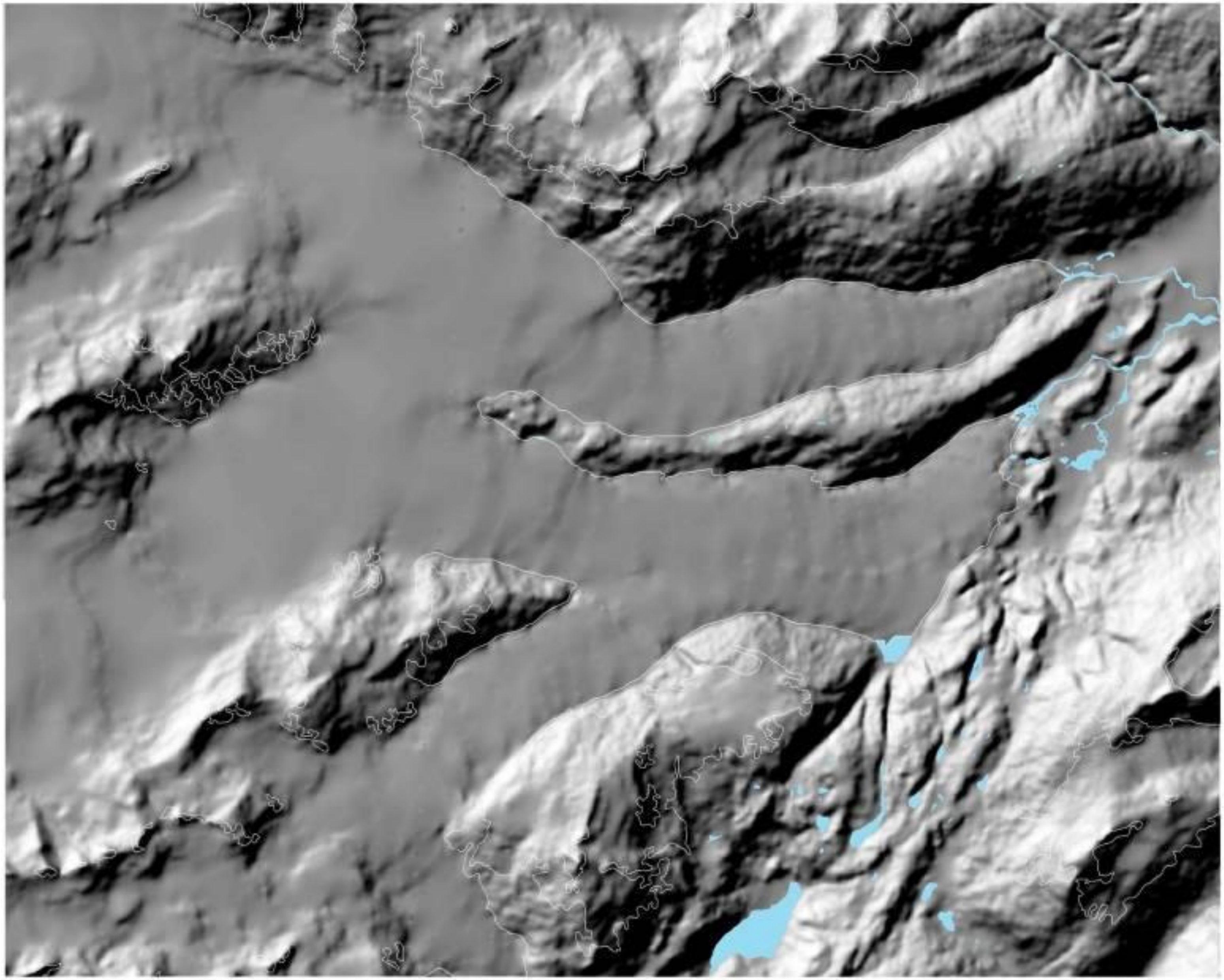
Athabasca Glacier
1919 - 2005



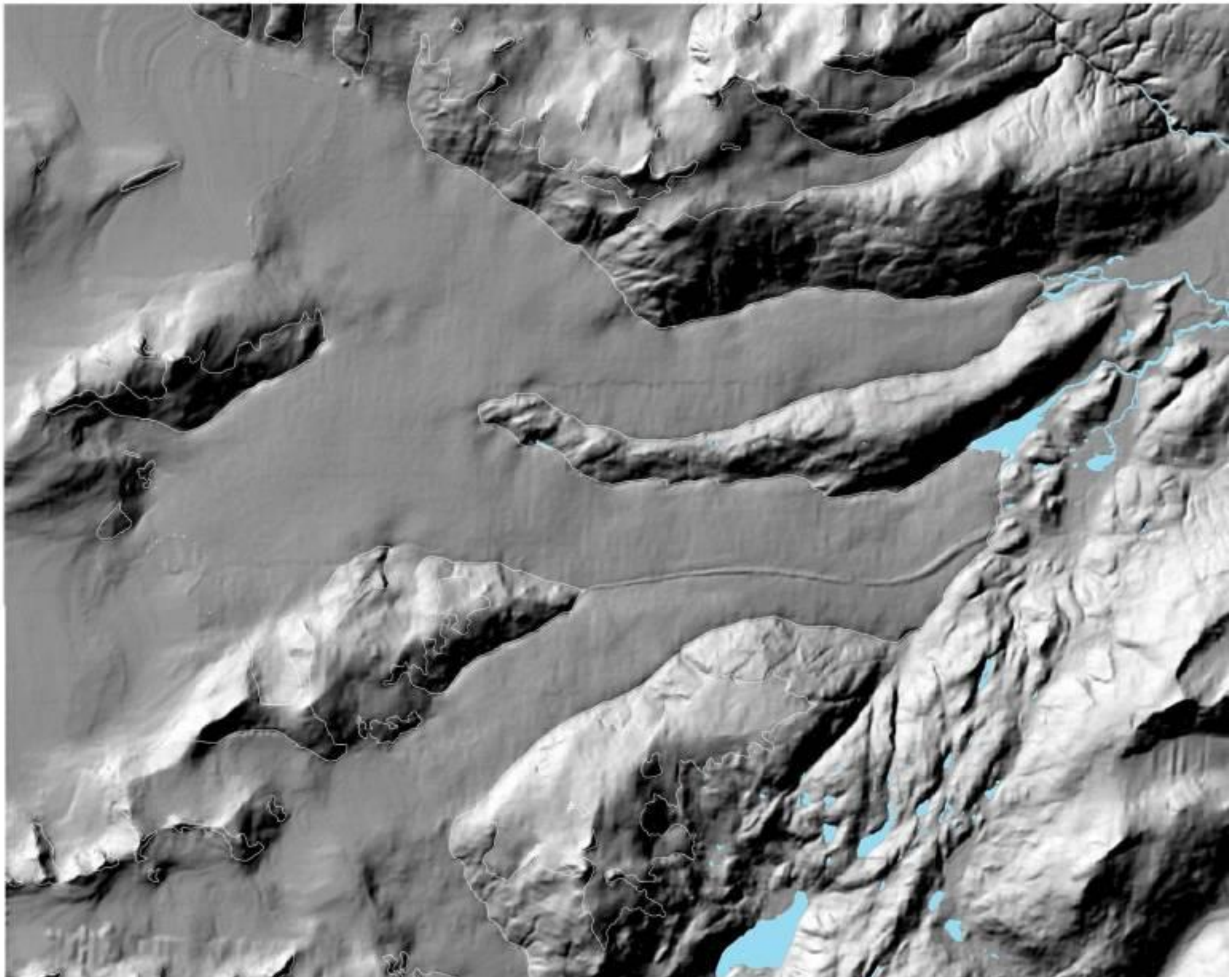
Andrei / Forrest Kerr Glaciers - Northern Coast Mountains



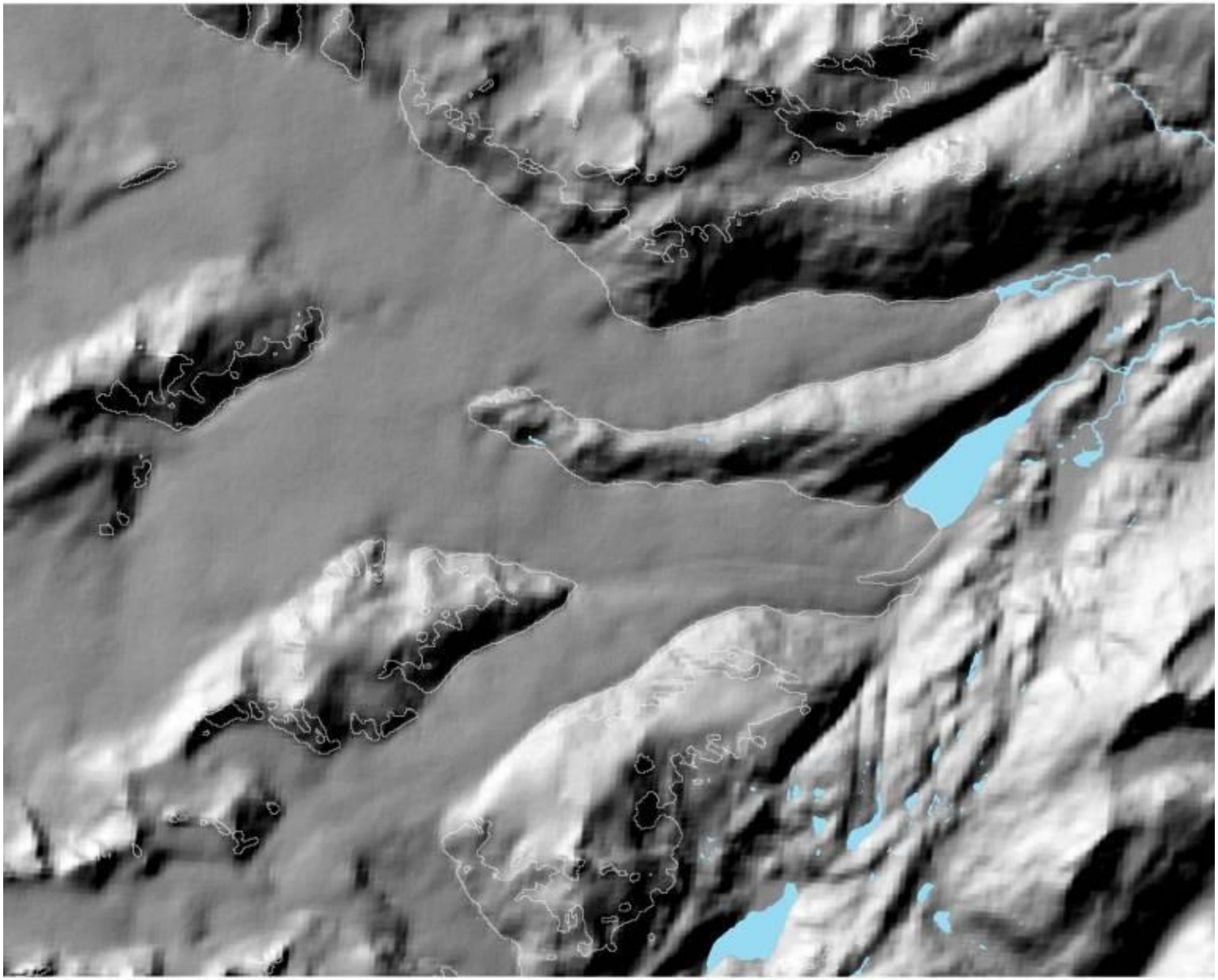
Federal mapping 1965



BC provincial 'TRIM' 1982



Shuttle Radar Topography Mission (SRTM) 2000

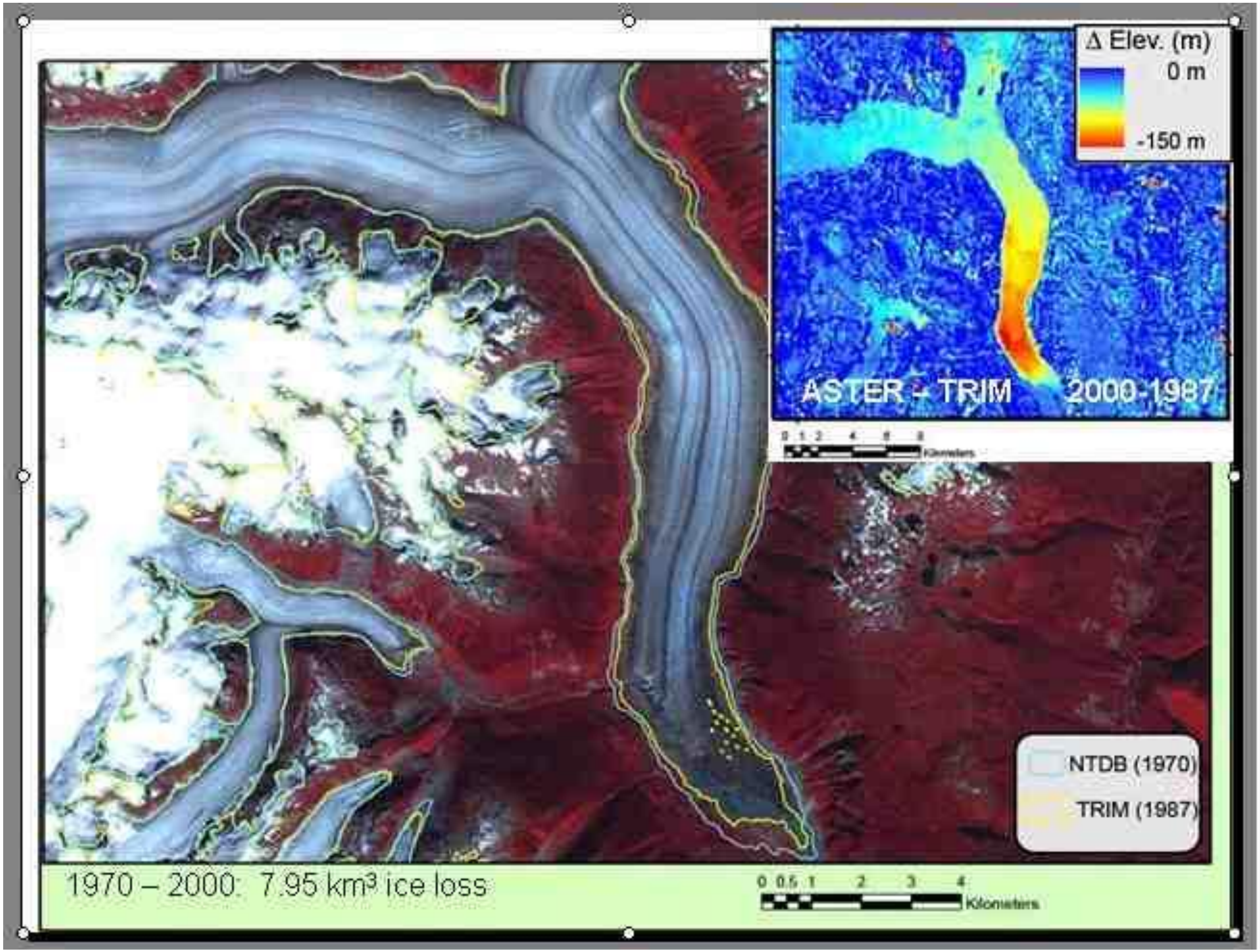


Animation series, implying elevation change: Klinaklini Glacier


2006

Thickness loss and volume estimates from DEMs

Klinaklini Glacier = subtracting temporal DEMs gives an estimate of depth lost



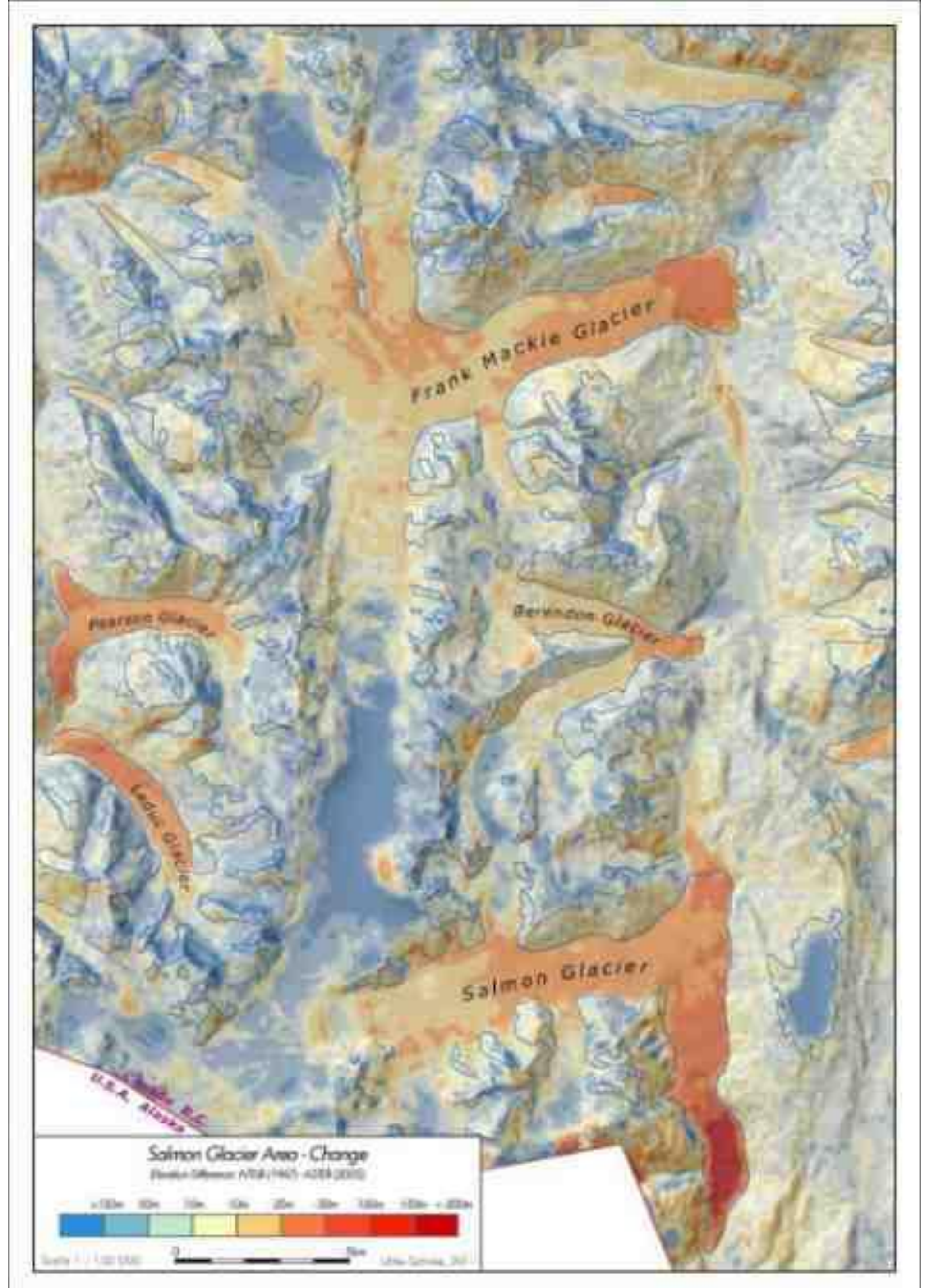
Salmon Glacier
North of Prince Rupert

Glacier downwasting

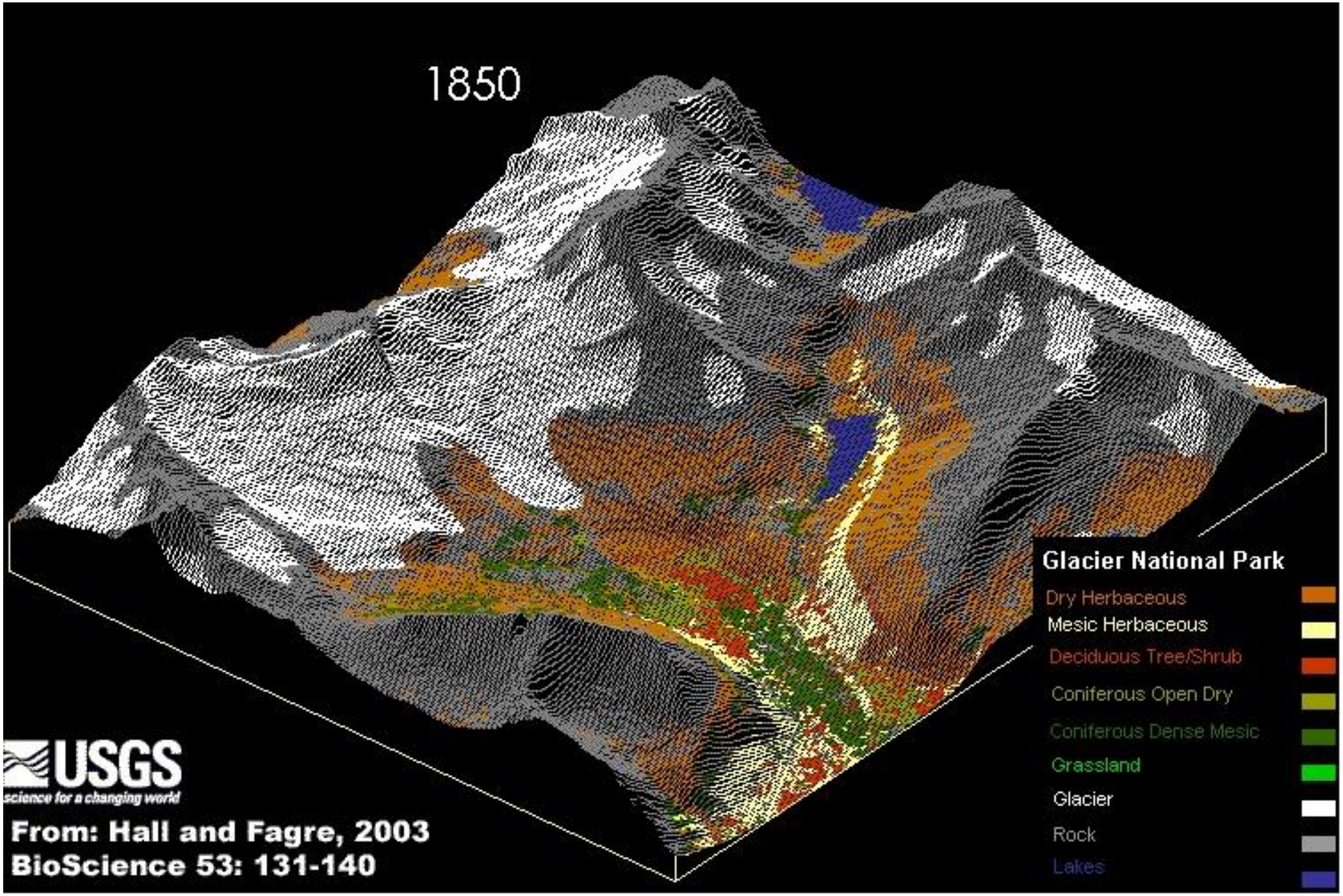
Subtraction of two DEMs:
2008 minus 1965

Red shades show
increased loss

Blue shades slight gain



Glacier National Park, MT : modelled glacier change animation



https://academic.oup.com/bioscience/article/53/2/131/254976

https://en.wikipedia.org/wiki/File:Glac_modelled_glacier_change_animation.gif