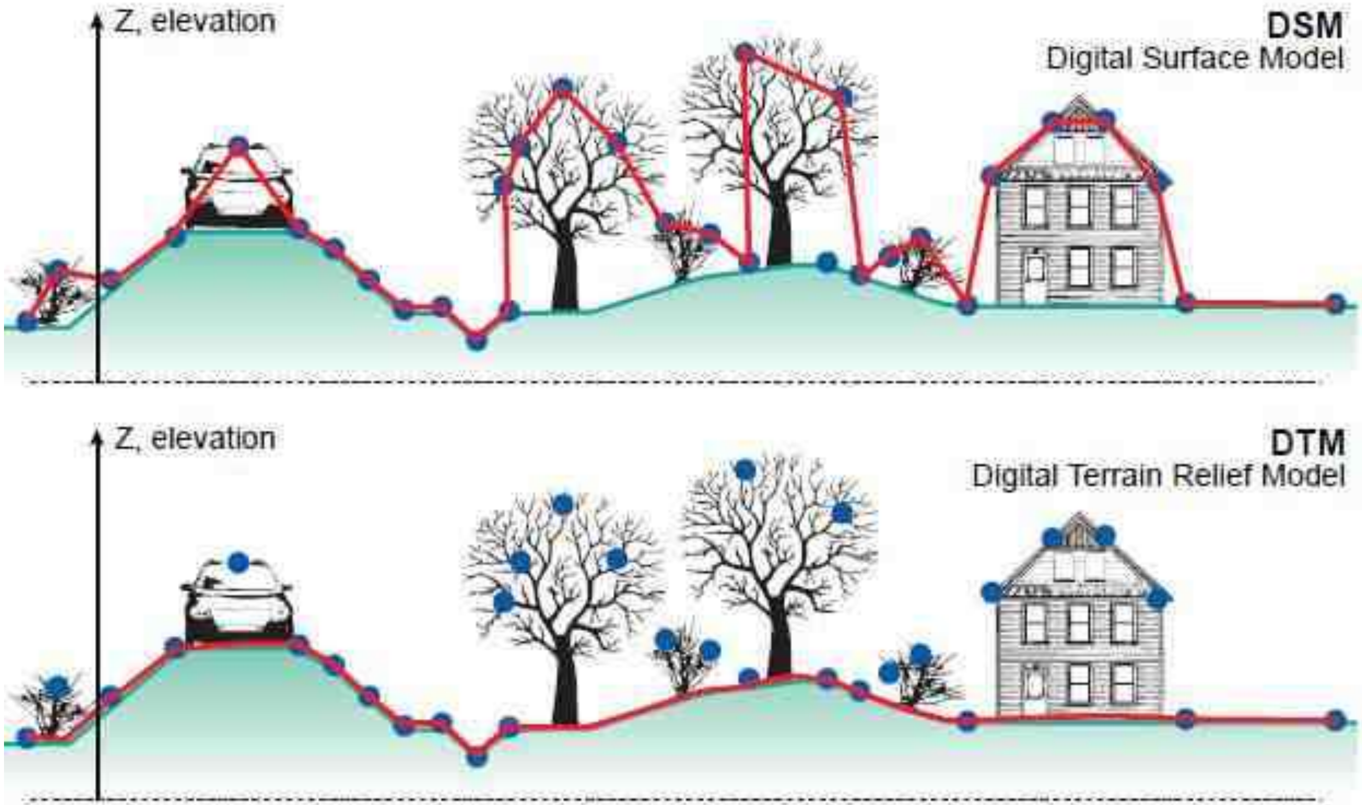
Digital Elevation Models (DEM) / DTM (terrain)

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

Uses in remote sensing:

queries and analysis, classification input, visualisation

DEM, DTM and DSM



Digital Surface Models

Spaceborne / LiDAR

Digital Terrain Models

Photogrammetric / LiDAR

= 'Bare Earth'

http://www.satimagingcorp.com/svc/dem.html

Almost all DEMs have been created from remote sensing:

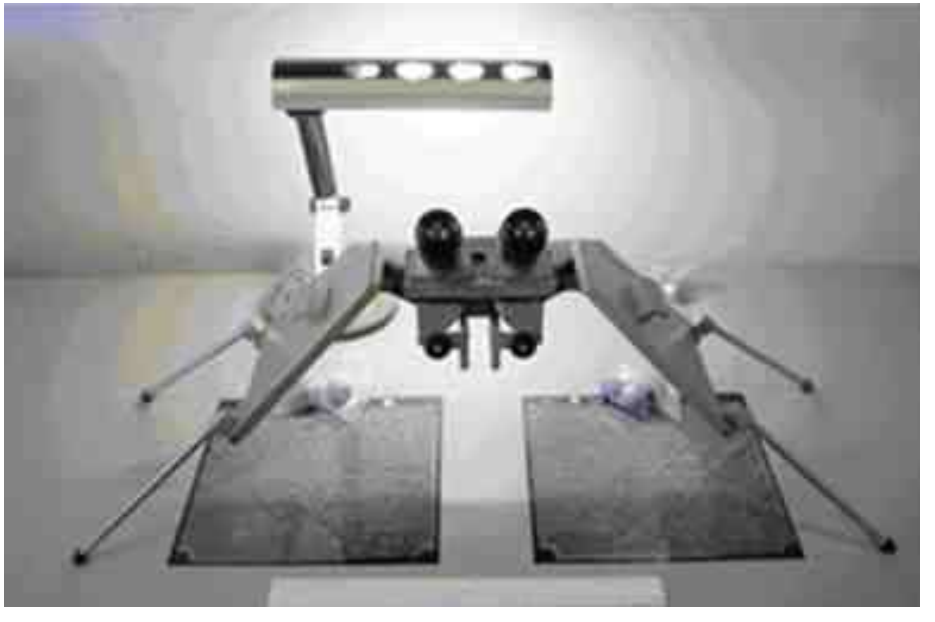
1. DEM sources

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

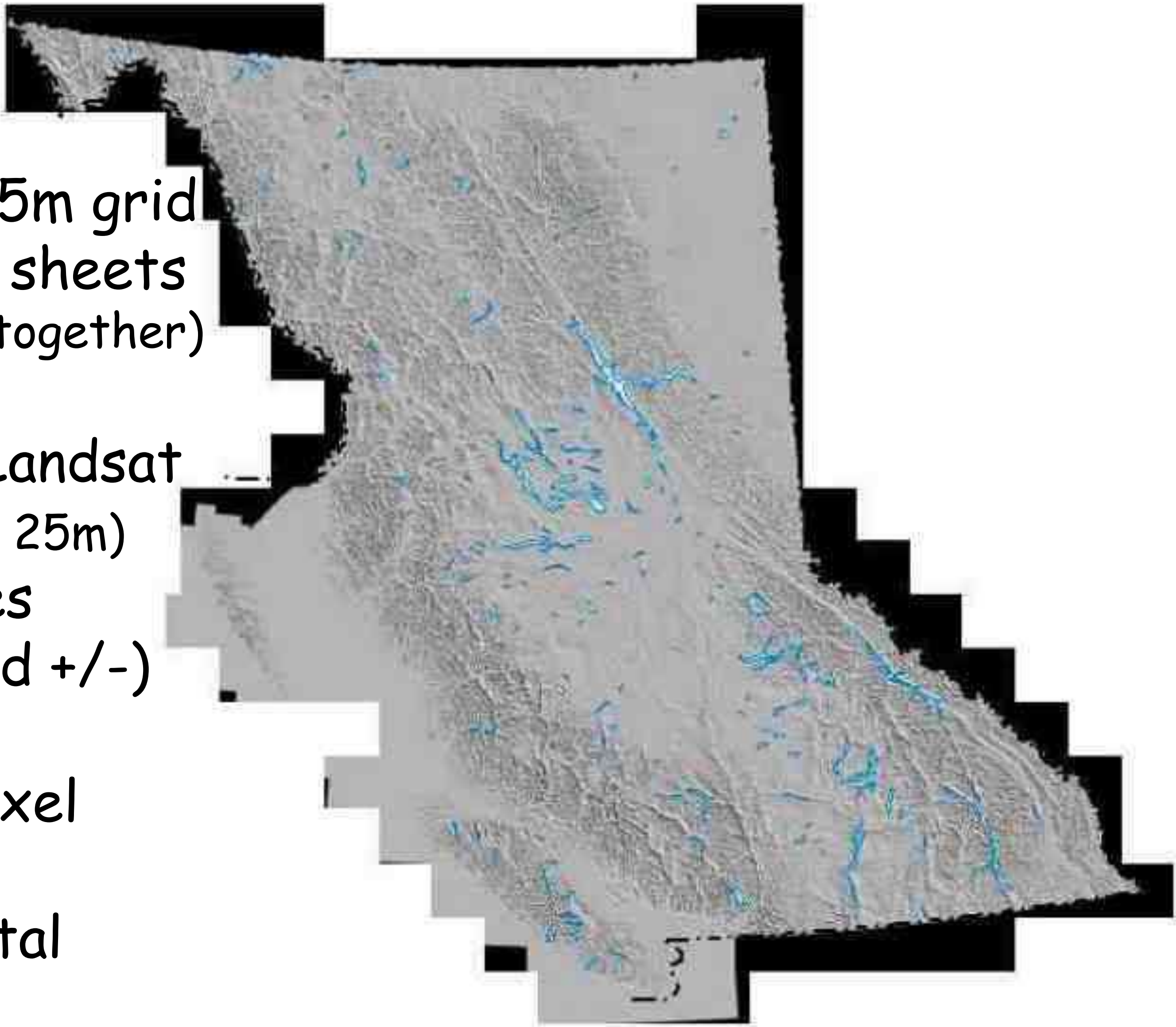
Contours created from stereo-photography

b. Digital Stereo photogrammetry: 1985->

Initially from scanned air photos, then digital photos



BC provincial TRIM DEM – 25metre grid



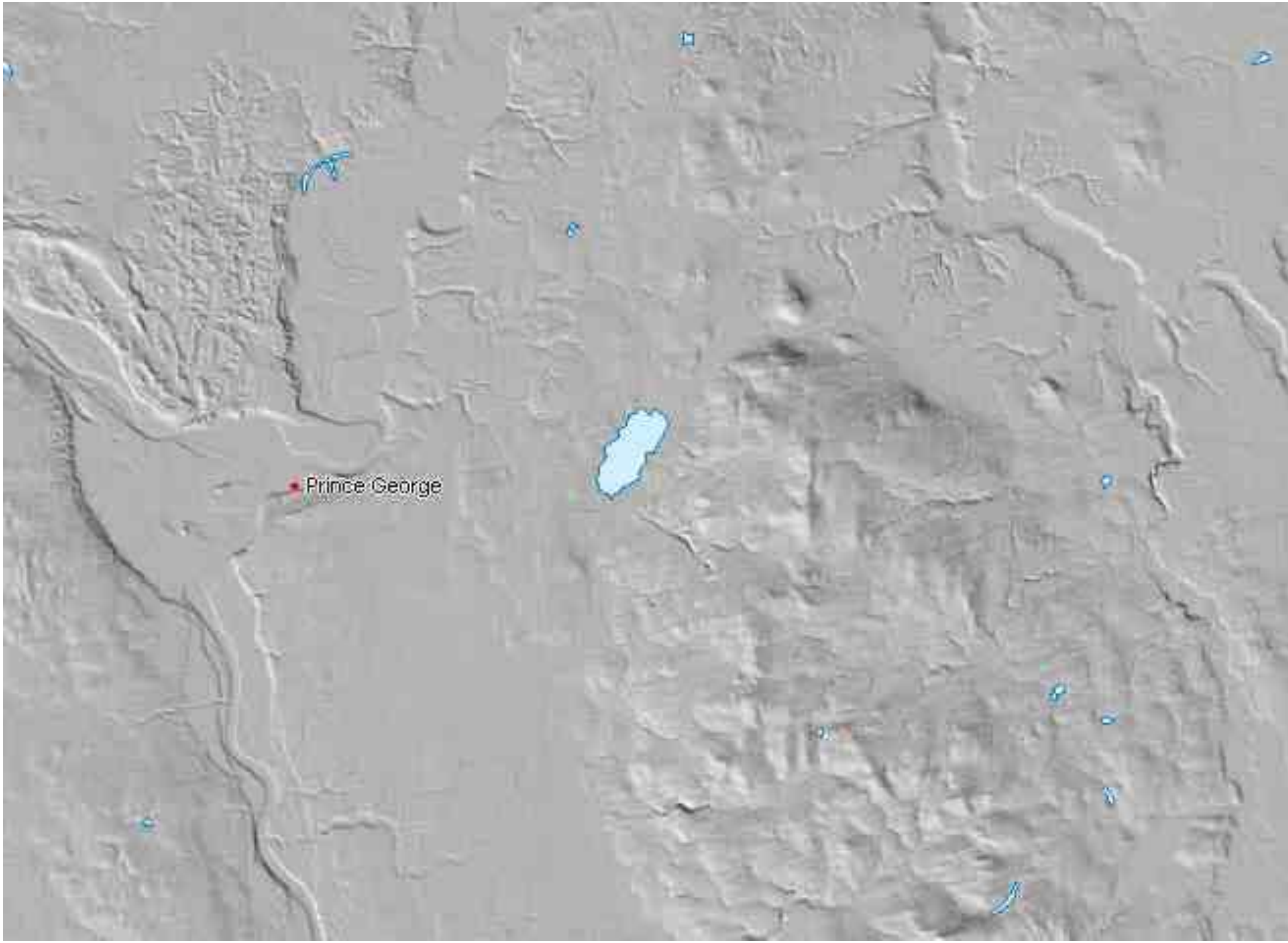
Interpolated to 25m grid
By 1:250,000 map sheets
(100 tiles assembled together)

- designed to fit Landsat
Pixels (resampled to 25m)
Elevation in metres
= 16 bit DN (signed +/-)

A DN for every pixel

created from digital
stereo air photos

BC: federal and provincial data – TRIM DEM (25m)



Almost all DEMs have been created from remote sensing:

DEM sources (continued)

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

Non- RS sources: ??

Post 2000 methods

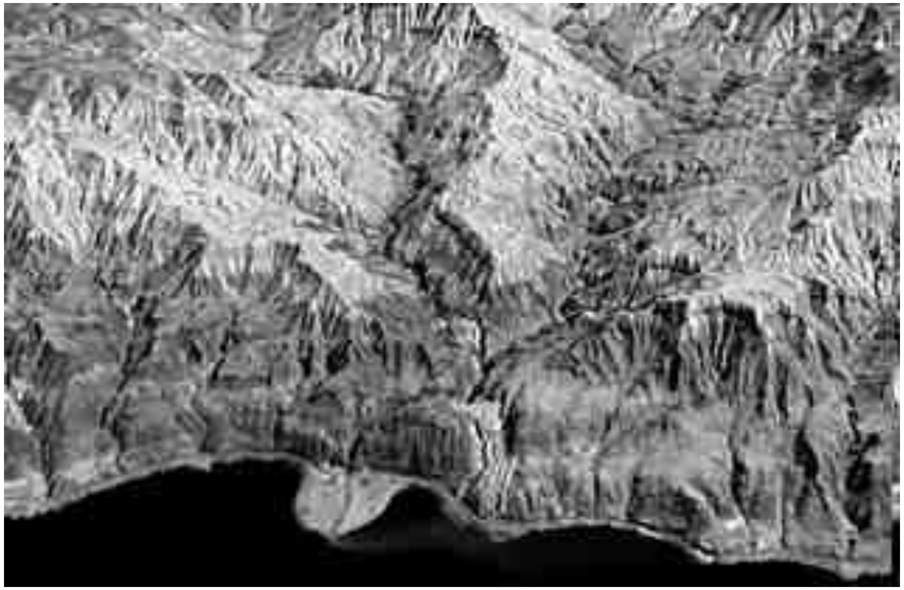
Direct grid DEM data from imagery

- RADAR e.g. Shuttle Radar Topographic Mission (SRTM)
- Stereo digital optical satellite imagery (adjacent / directed tracks)

Issues: cloud cover (optical) and missing data (RADAR)

ASTER (optical)

SPOT



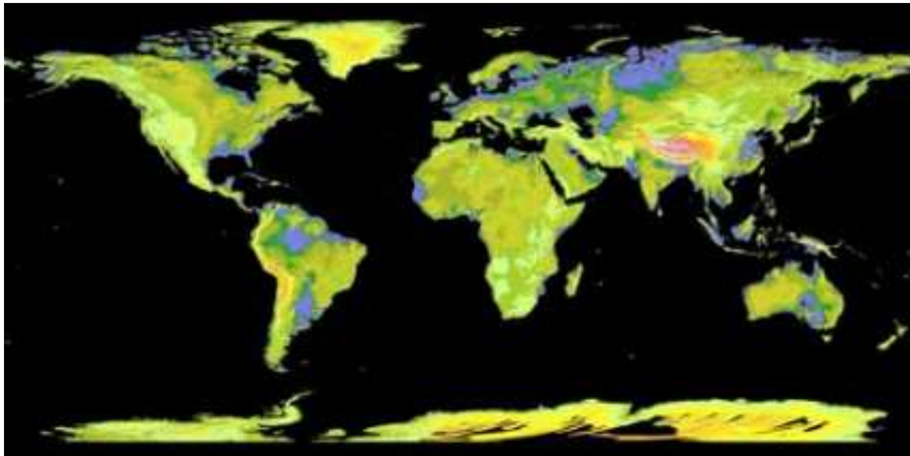
DSM sources 2000+

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

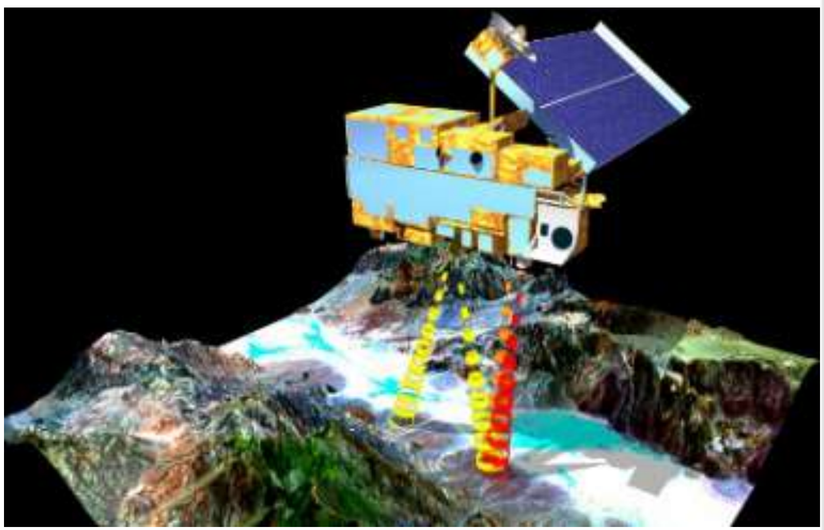
Available for 60°N – 56°S resolution 3 arc seconds (90m)

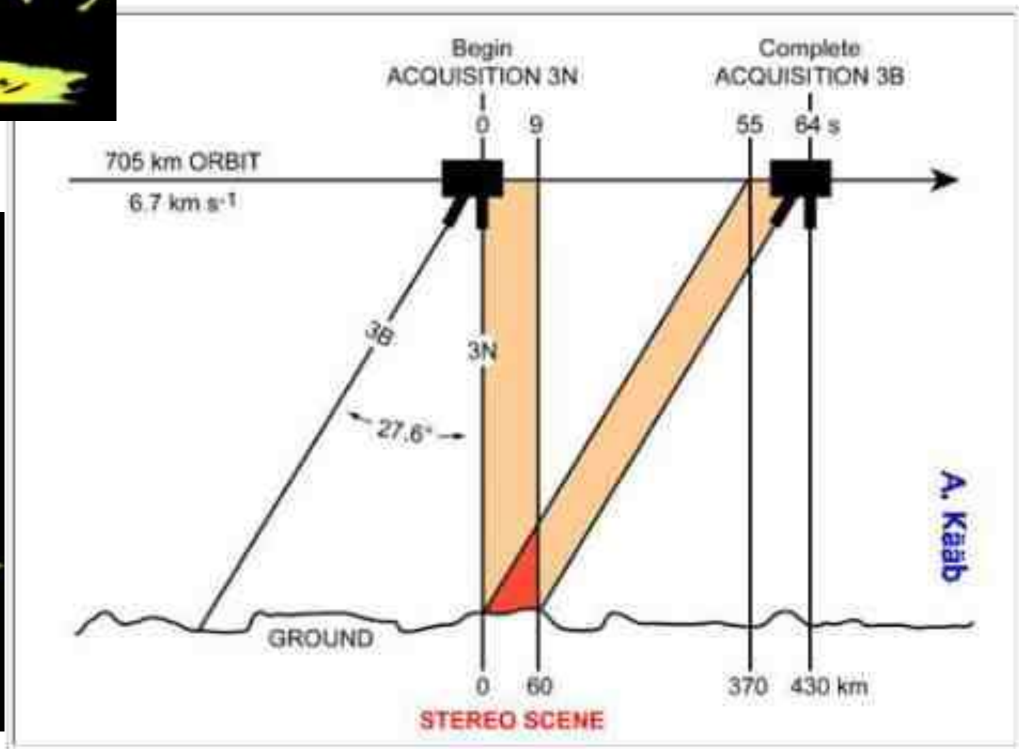
Used for most of Google Earth

ASTER DEM



<- global DEM 30m pixels





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.

Global DEM (ASTER)
http://asterweb.jpl.nasa.gov/gdem.asp

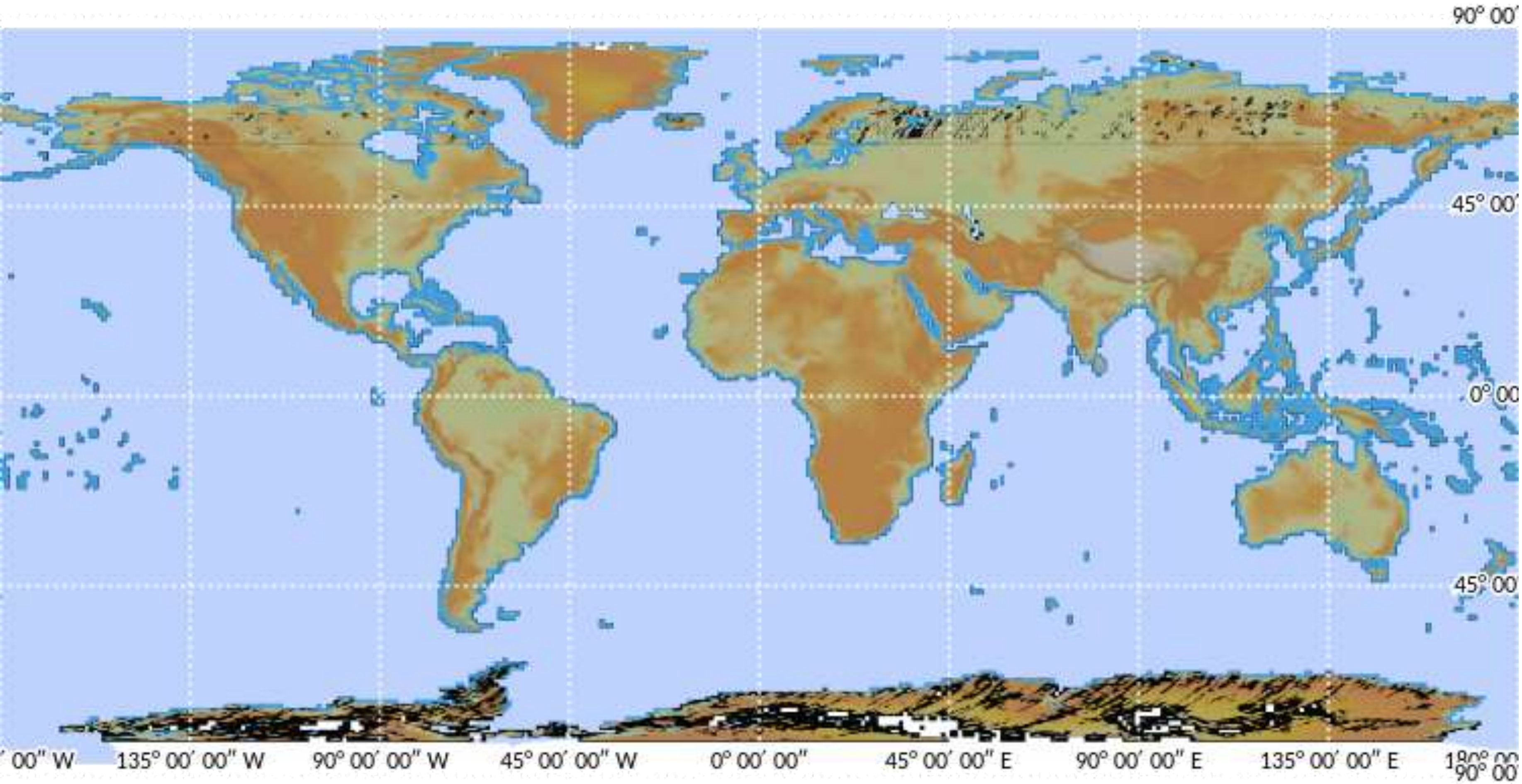
ASTER image and DEM : Svalbard, Norway (80N) (15 metre resolution)

Longyearbyen campus northernmost - UNIS

UNIS courses-upper year/ graduate students

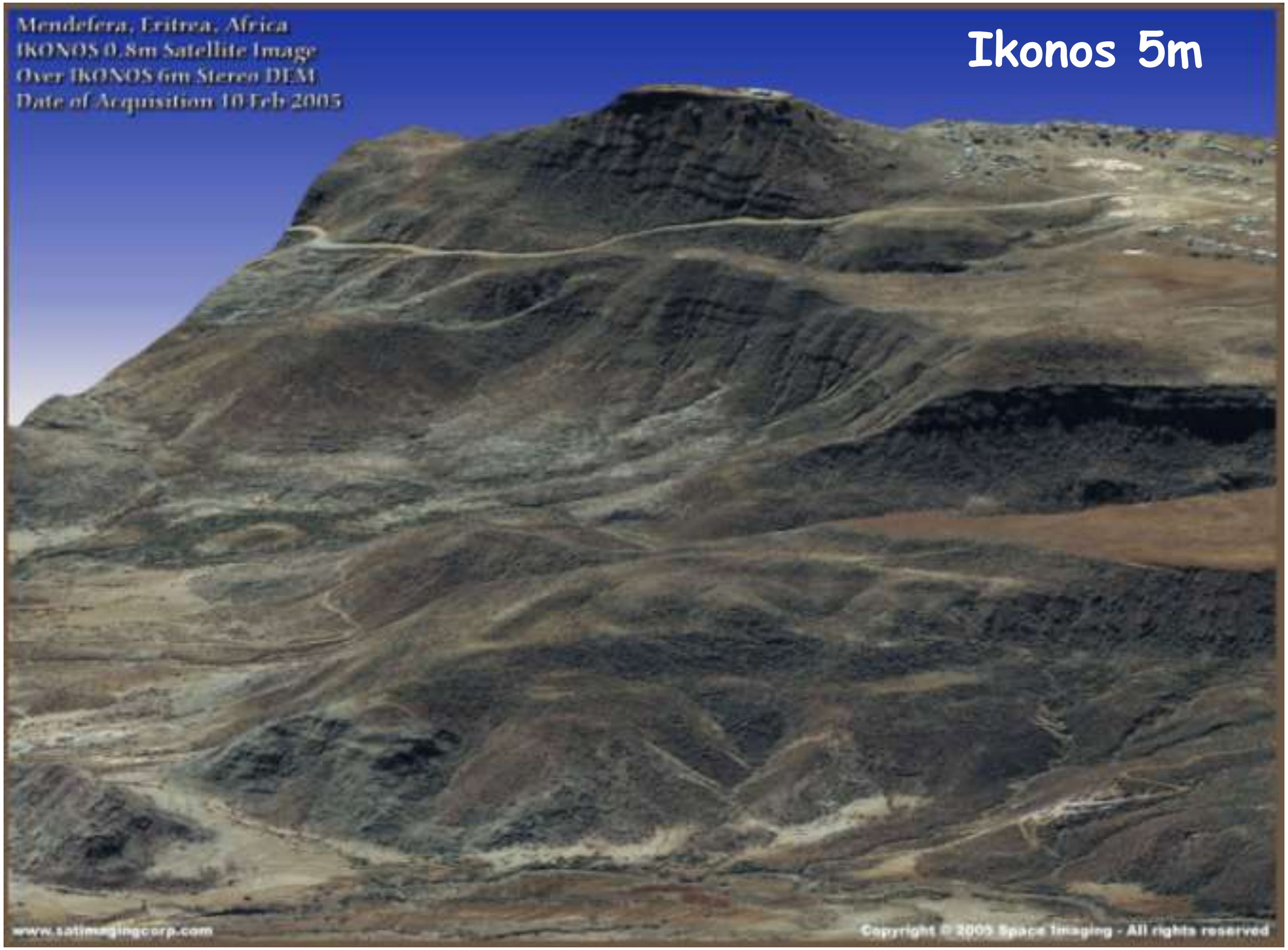
Satellite data receiving stations

ALOS DEM 2015-2019



https://www.eorc.jaxa.jp/ALOS/en/aw3d30/index.htm

DEM creation: **Direct image grid DEM** (> 2000)
From high resolution satellite raster imagery



Evolution of DEM creation

1950s Generation of contours from stereo photos

1980s Mass points from stereo photos

2000s Direct generation of grids from stereo-imagery
e.g. high-res sensors, ASTER, RADAR

2010s LiDAR / digital photography / UAVs
– cloud of millions of points -> high-res grid

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

LiDAR: sub-metre PG, Aleza, Ancient Forest etc..

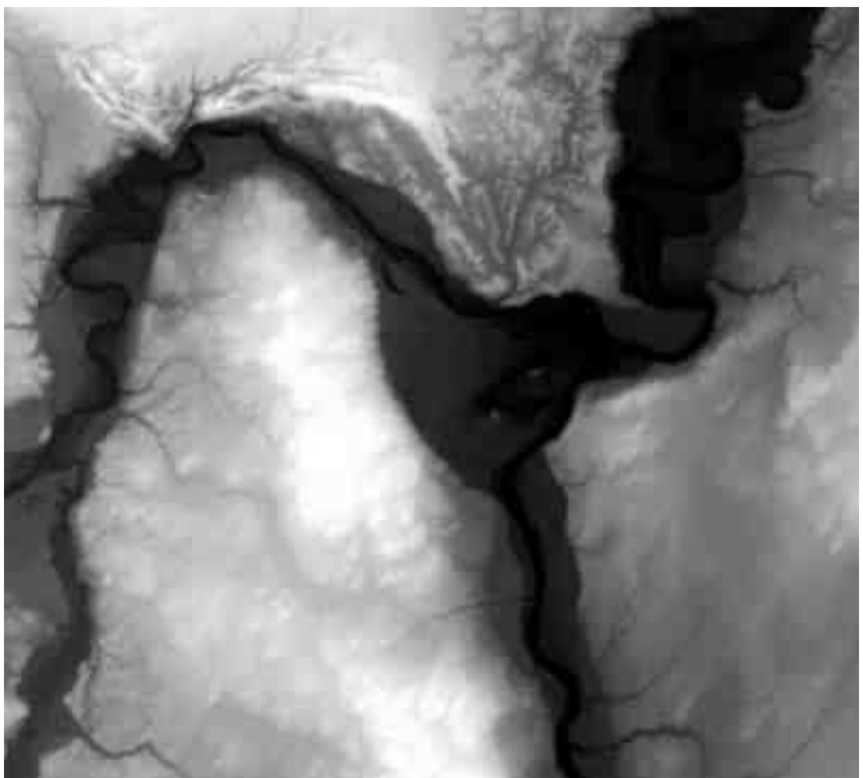
DEM error in Google Earth – Mt. Robson (AB/BC)
NTDB (Alberta) meets TRIM (BC) ... Oops!

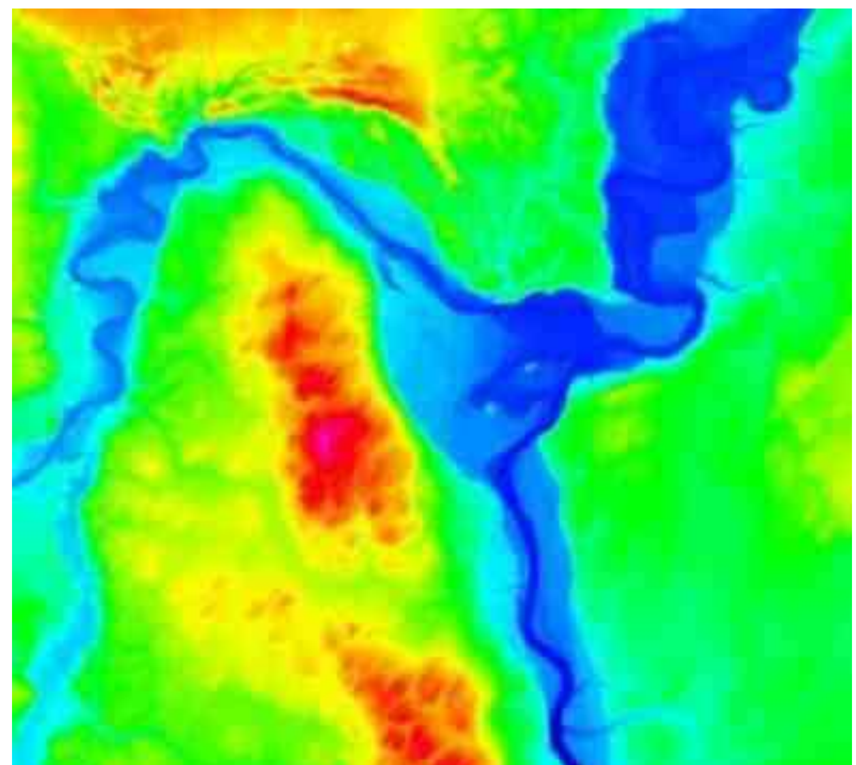
2. DEM - layers

A. Elevation ('DEM')

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

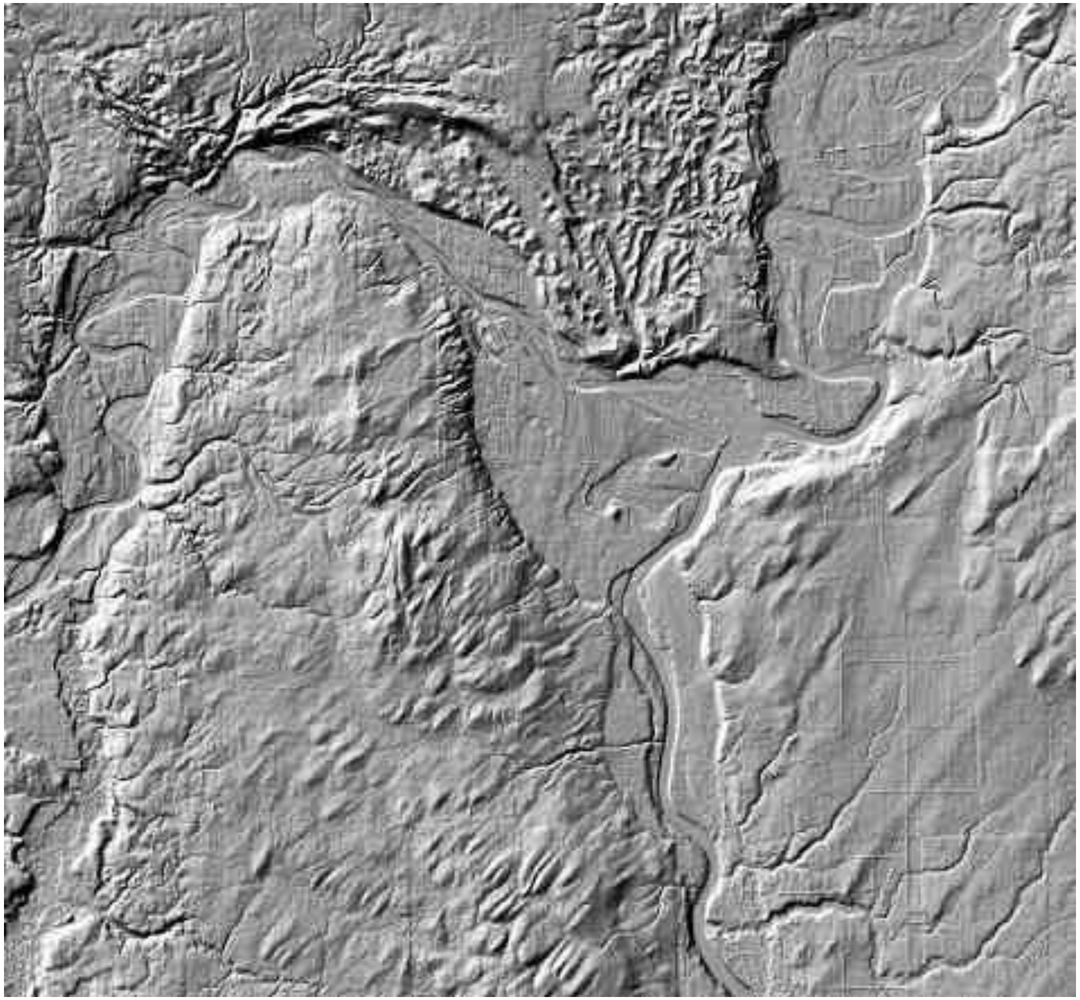
DEMs are stored as integers (metres) or 32 bit (after interpolation)
- 32 bit merited only for LiDAR, NOT BC TRIM
some (NTS) DEM tiles in Canada may be in feet .... conversion = .3048





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.

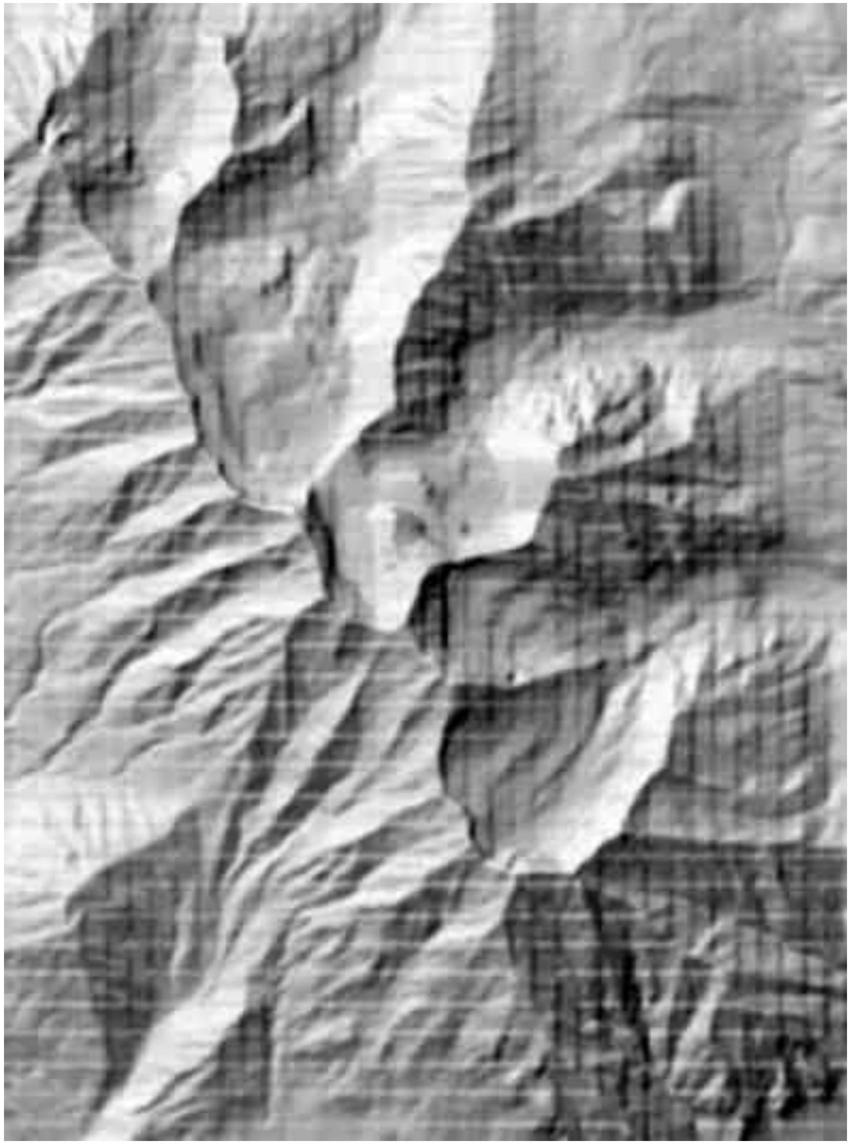


Select light source azimuth and angle
Default = 315, 45

useful / essential to detect errors / assess DEM quality

Use of shading to assess DEM

Nooooooooo !!



DEM data often stored in 'geographic' (lat/long) must be 'projected'

Reprojection can cause striping and artifacts

Avoid reprojecting rasters if possible

Stripes – often caused by WGS84 - NAD83 difference

examine hillshade for errors / quality (geog357 project)

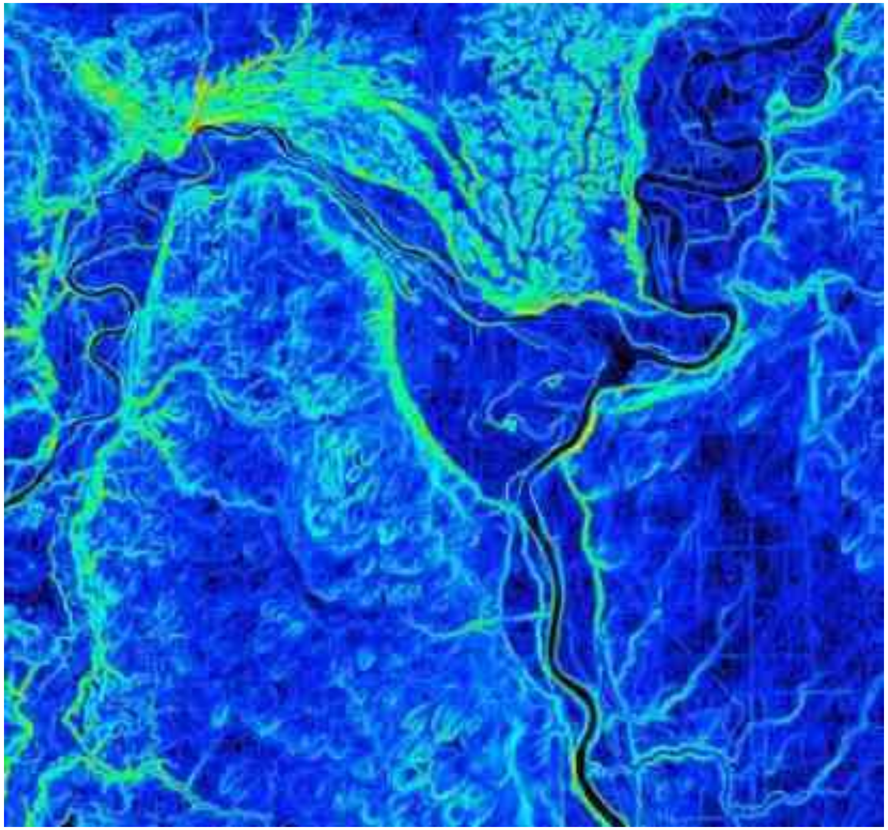
Holes: due to clouds

c. Slope (gradient)

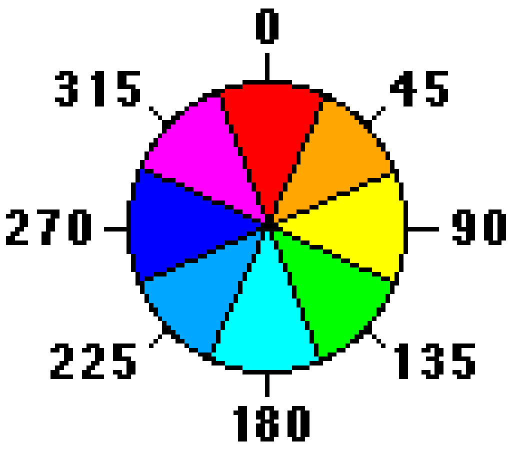
Calculated in degrees (0-90) or % (0 -> infinity)

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

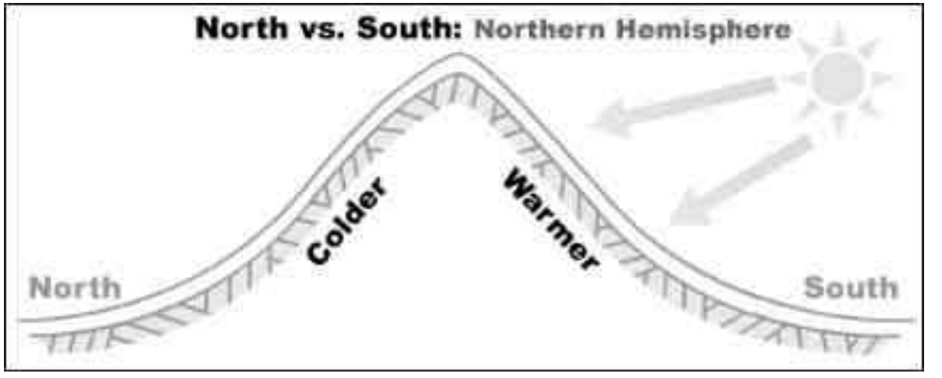
8 bit results (0-255) should be adequate for most purposes (GIS)



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)

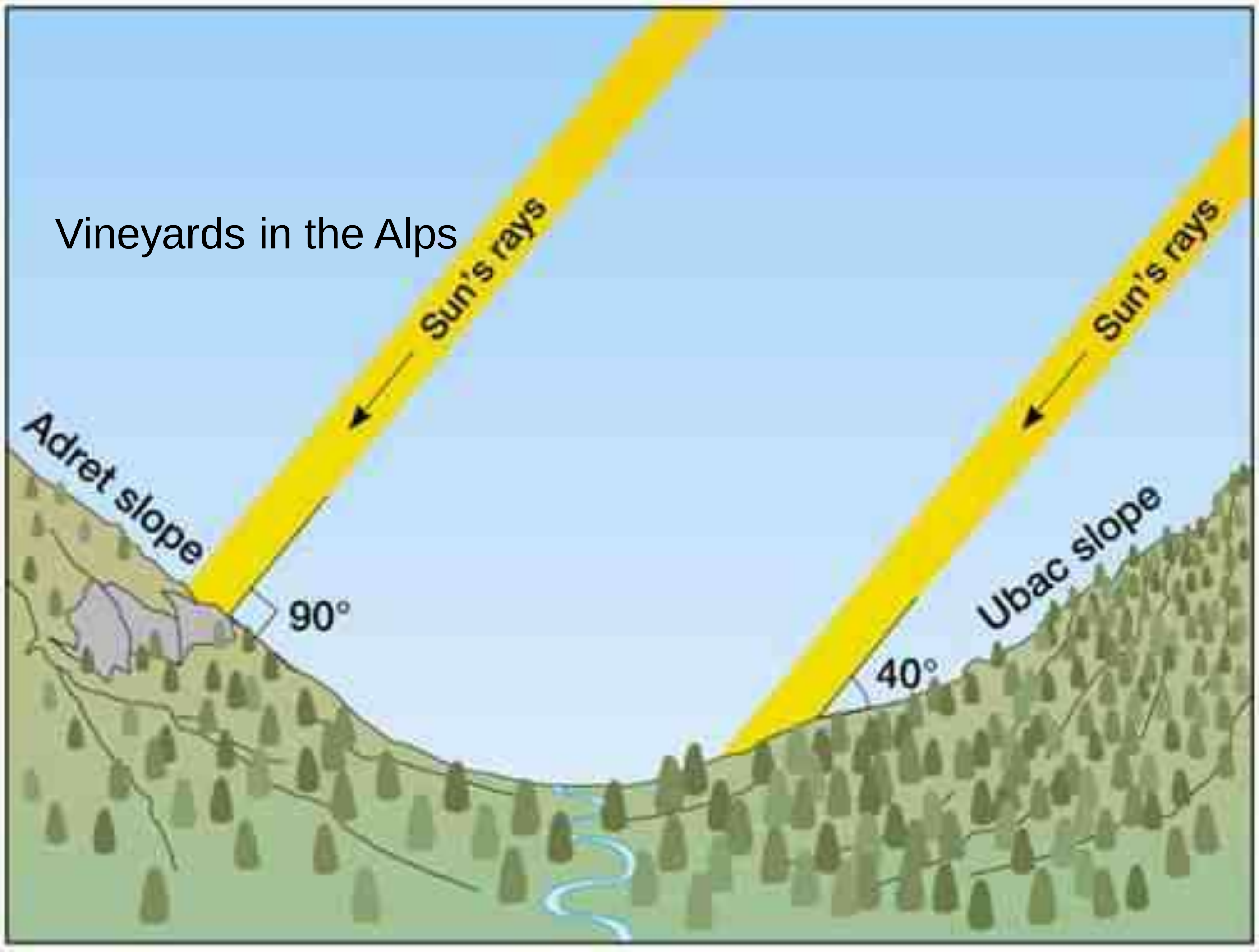
0-360 requires 16 bit data;

Aspect has an impact on land use/cover

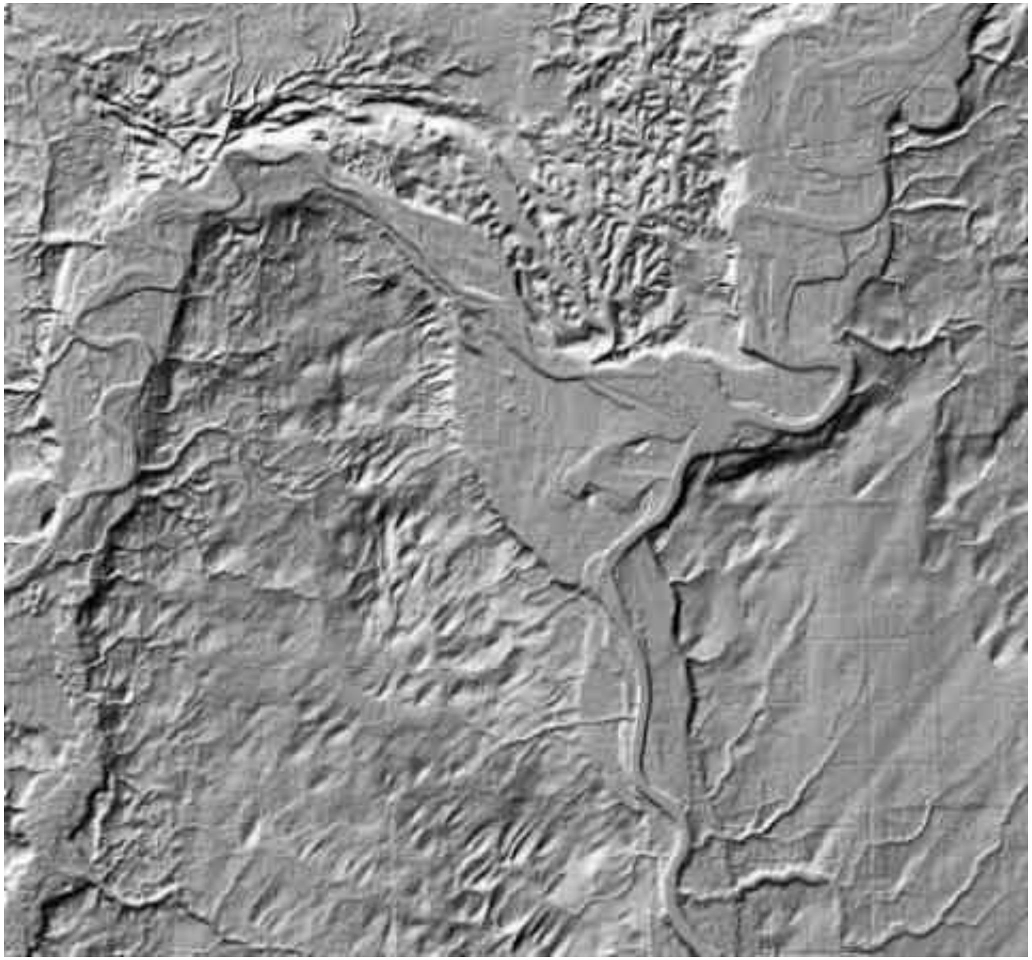
But we can’t use it as classification input - Not directly, instead we use:

e. Incidence

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



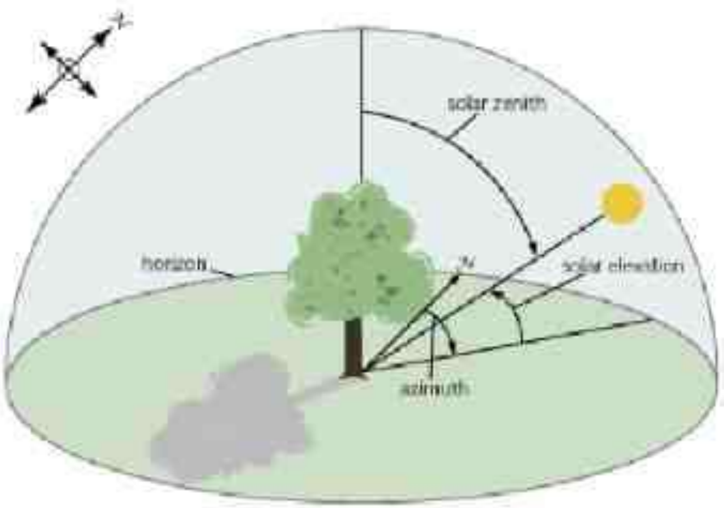
- **Incidence** looks similar (inverted!) to shaded relief, but DN 0-90
- the angle (degree) of light incidence, is based on the sun position
- Requires metadata for sun elevation and azimuth for the scene



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 PLUS

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

DEM Elevation
Slope (gradient)
Incidence (not aspect)

Other: e.g. Curvature (concavity/convexity), texture

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

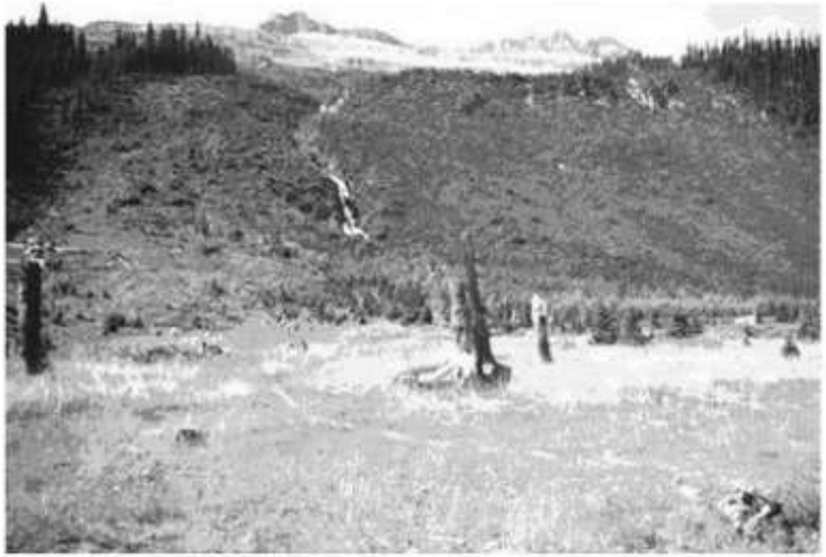


Fig. 1. Avalanche Slope at Takakkaw Falls, Yoho National Park. Looking west, slope is approximately 500 metres wide.

Avalanche slopes : 25-45°

Avalanche slopes : 25-45°

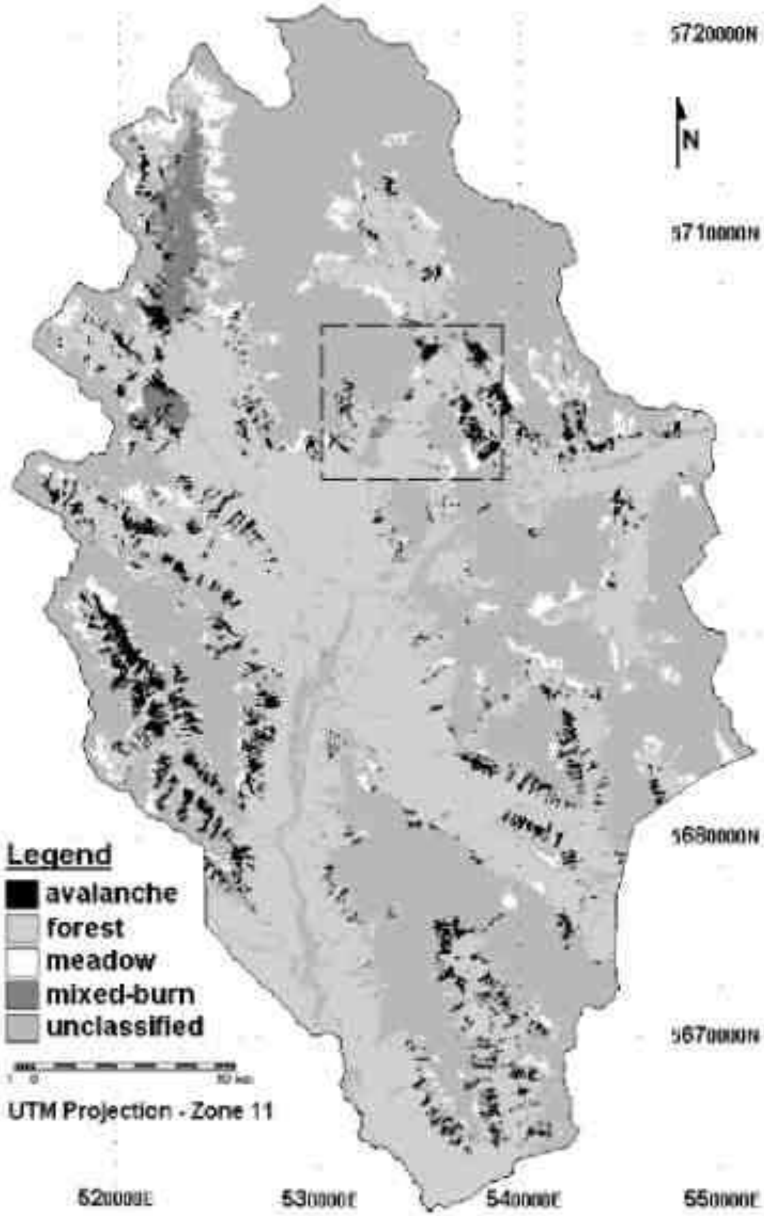


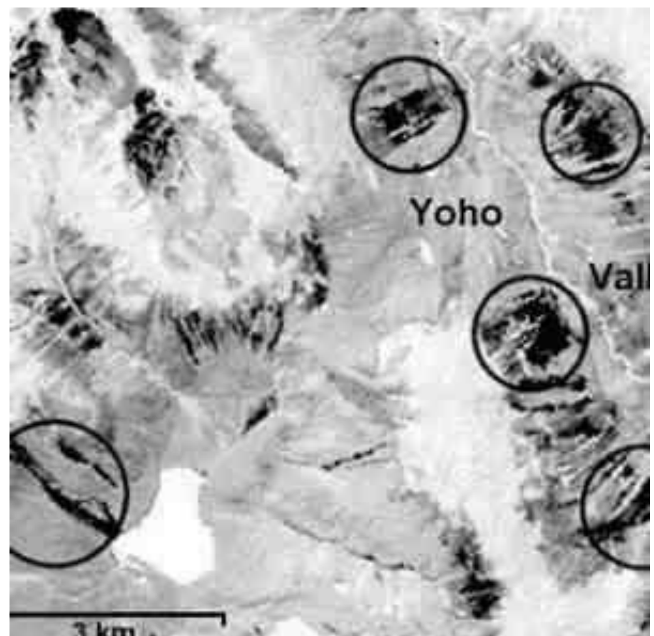
Fig. 6. Classification Results after the 3x3 filter. Dashed box indicates the area featured in Figs. 4 and 5)

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.

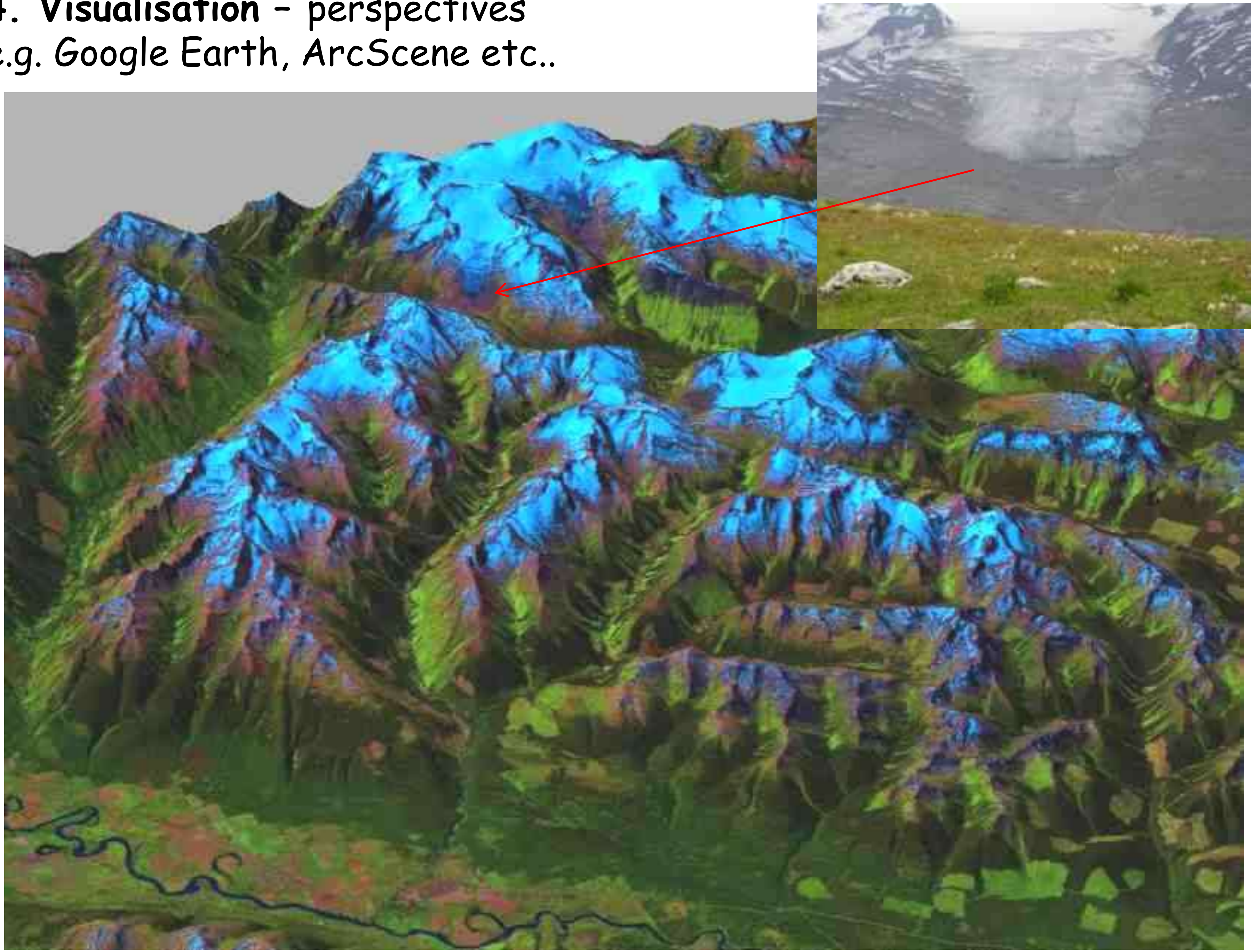
TABLE III
CLASSIFICATION ACCURACY RESULTS (PERCENT)

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..



DEM from Photogrammetry: Tatras, Slovakia 2m

Lloyd George Icefield

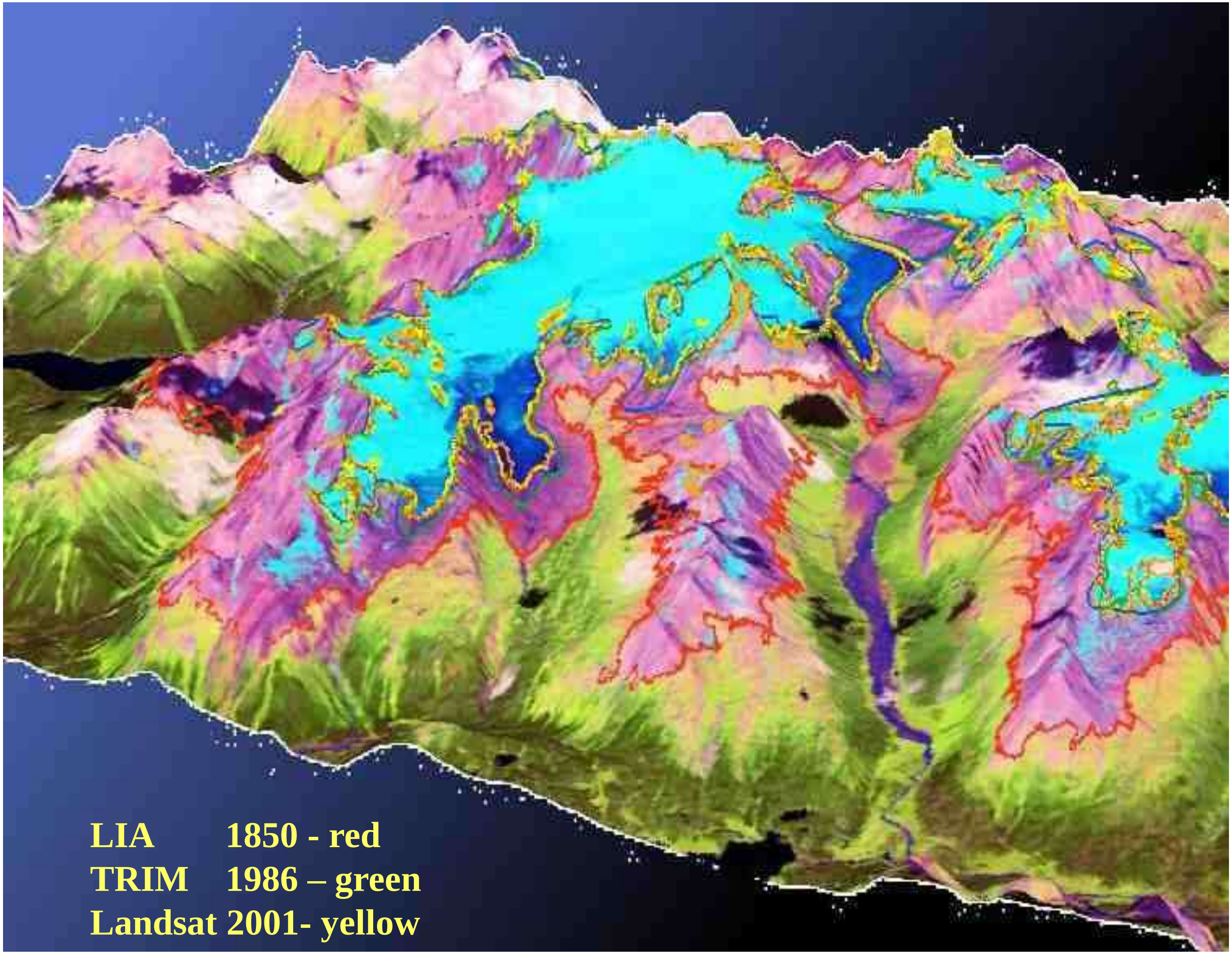
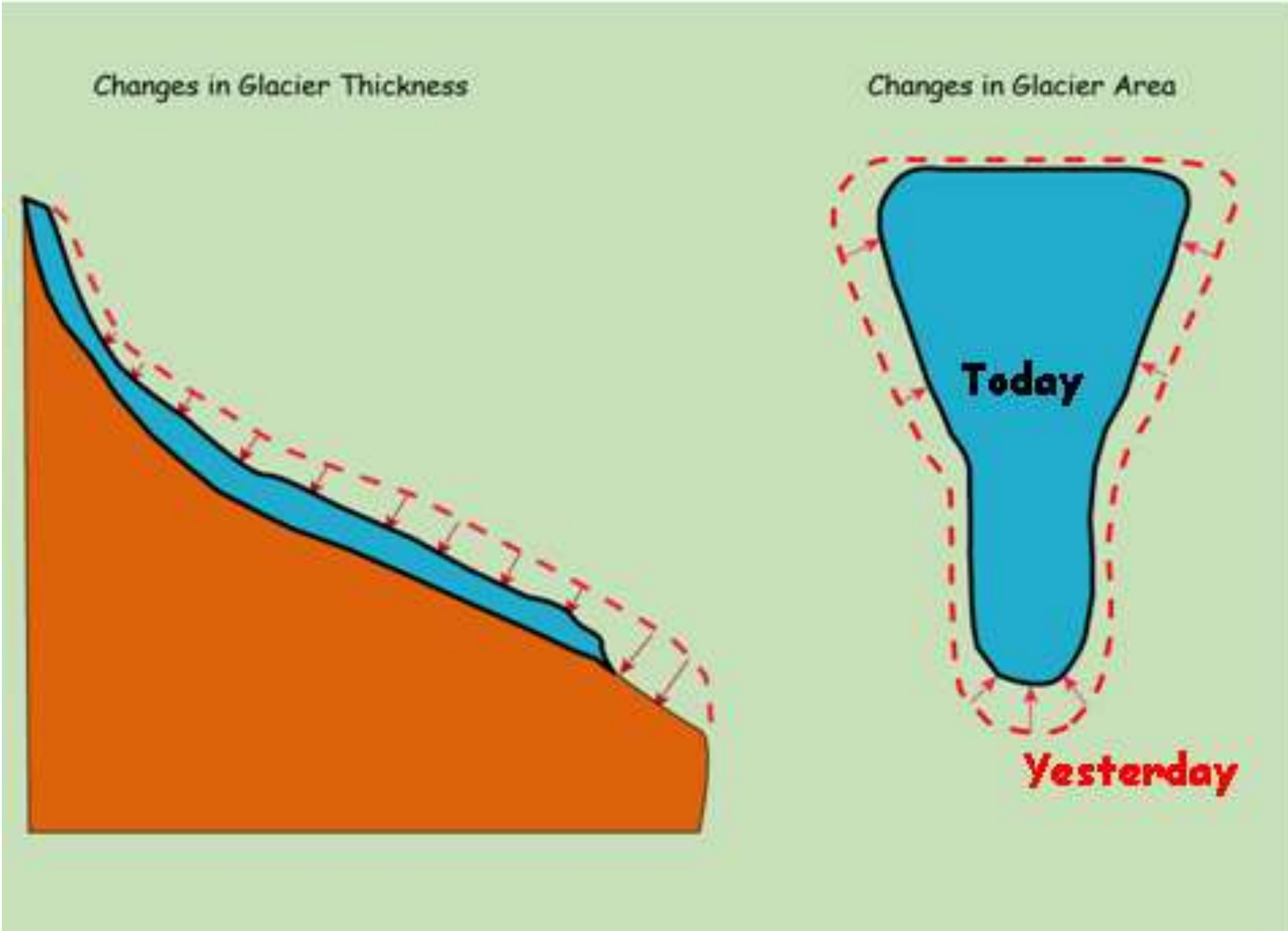


Image processing can be used to map and measure :

e. Elevation change / Volume loss from DEMs



Downwasting

Retreat

5. DEM differencing – to show glacier downwasting

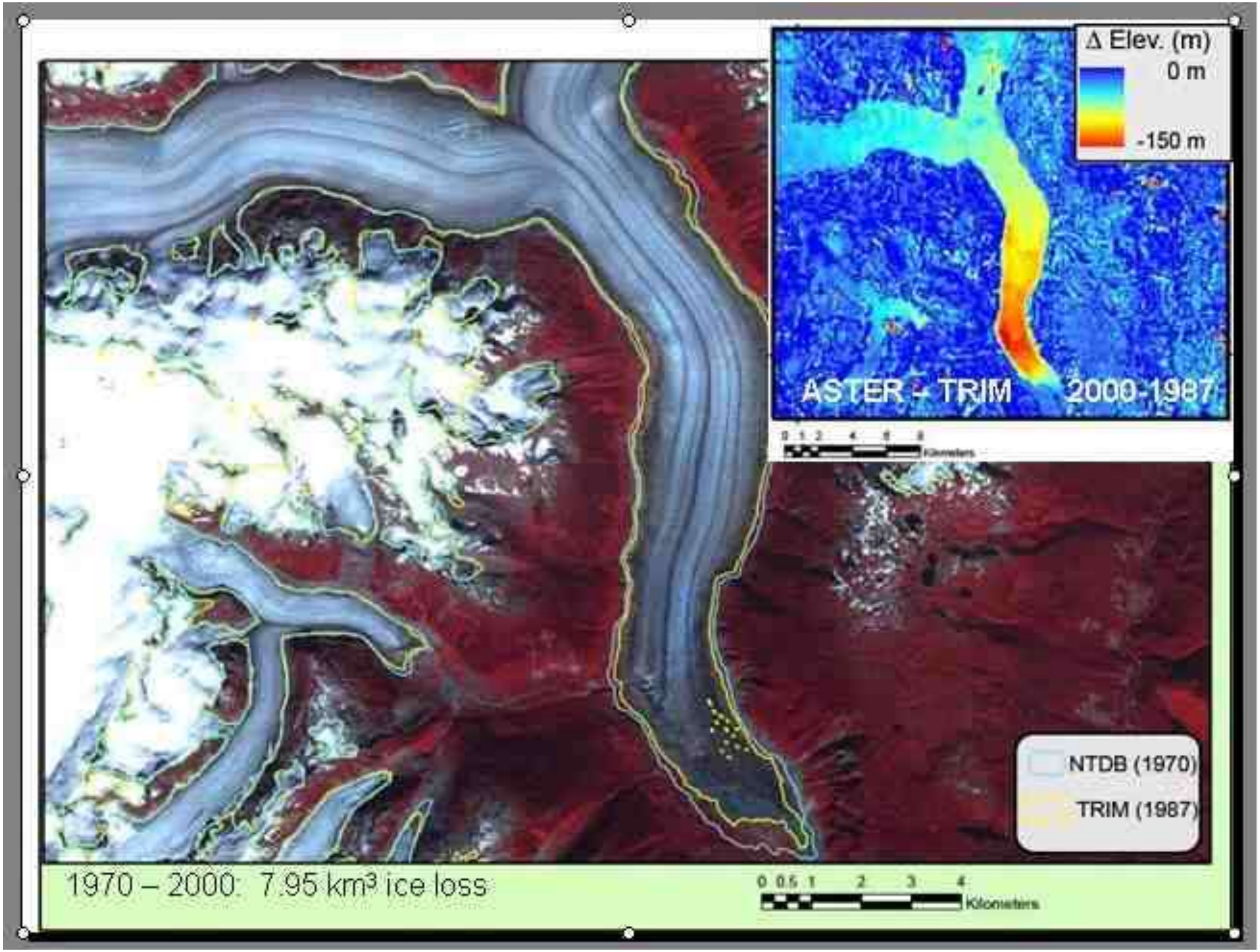
Athabasca Glacier
1919 - 2005

Animation series, implying elevation change: Klinaklini Glacier


2006

4. Thickness loss and volume estimates from DEMs

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



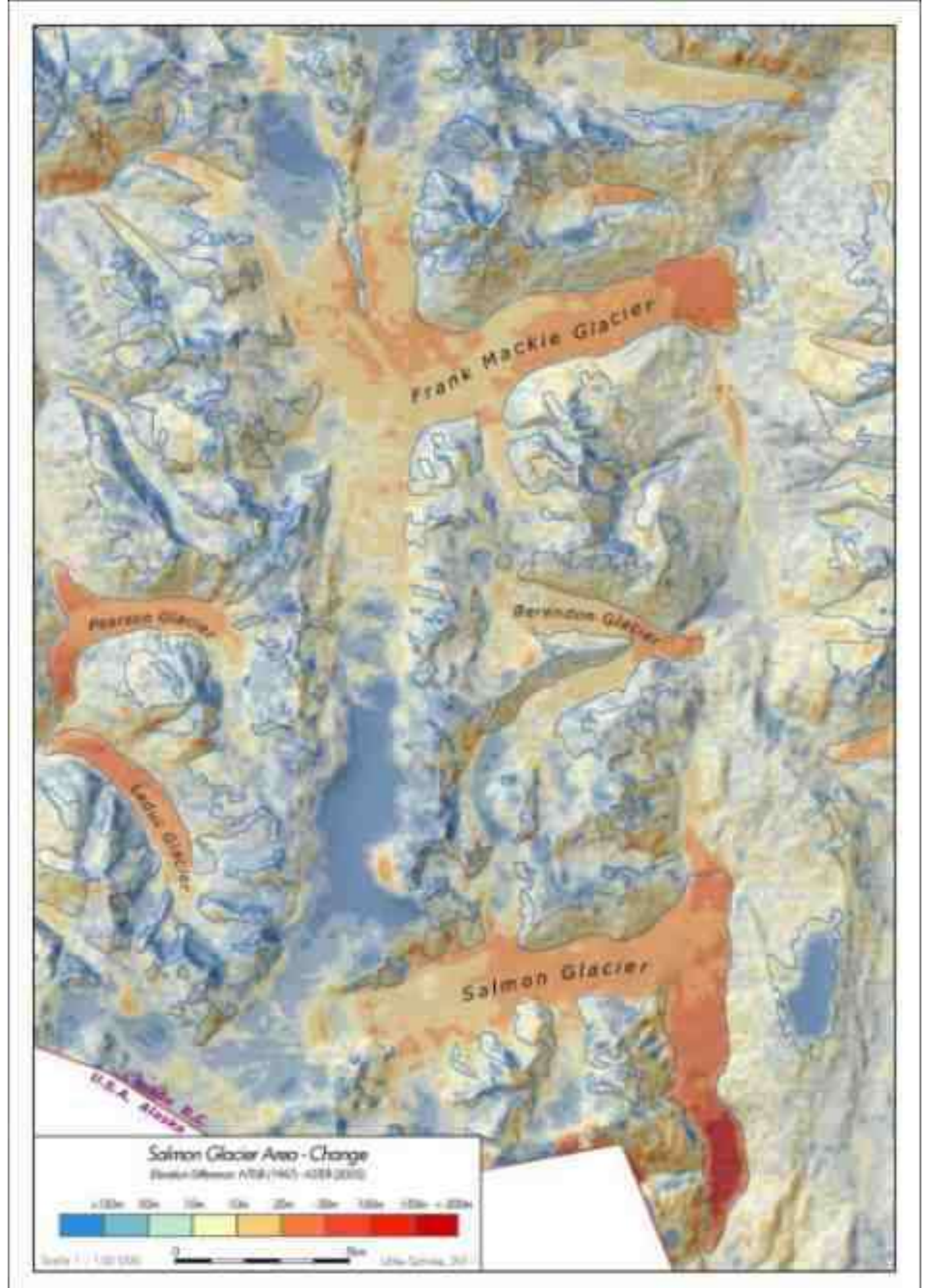
Salmon Glacier
North of Prince Rupert

Glacier downwasting

Subtraction of two DEMs:
2008 minus 1965

Red shades show
increased loss

Blue shades slight gain



True 3D: The holodeck

Hololens by Microsoft

https://www.youtube.com/watch?v=xCVuRNc6fWY