

# GEOG 357

## LECTURE 15

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### Digital Elevation Models (DEM) / DTM (terrain)

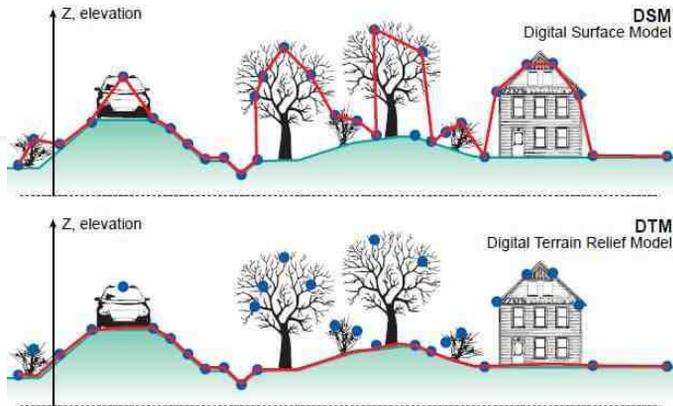
Raster DEMs are naturally suited to overlay / combine with raster imagery



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

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## DEM, DTM and DSM



### Digital Surface Models

Spaceborne / LiDAR

### Digital Terrain Models

Photogrammetric / LiDAR

= 'Bare Earth'

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

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**Almost all DEMs have been created from remote sensing:**

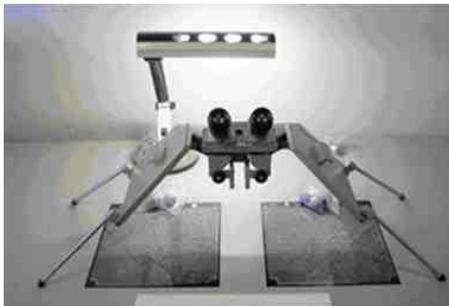
## 1. DEM sources

### 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



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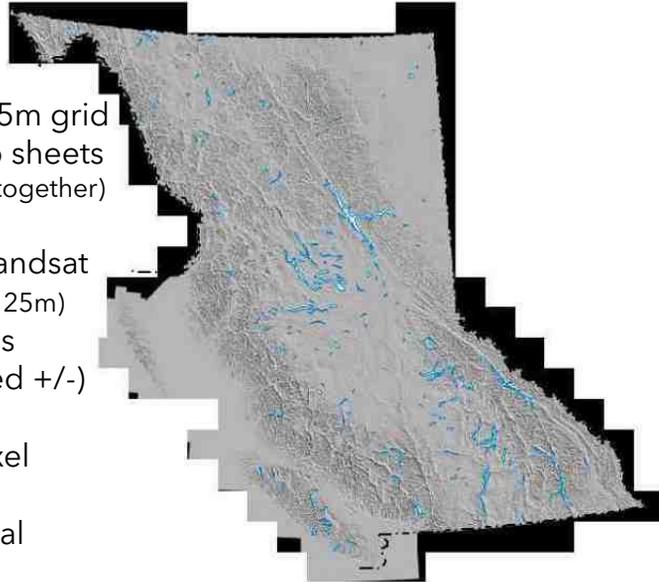
## BC provincial TRIM DEM - 25metre grid

**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 +/-)

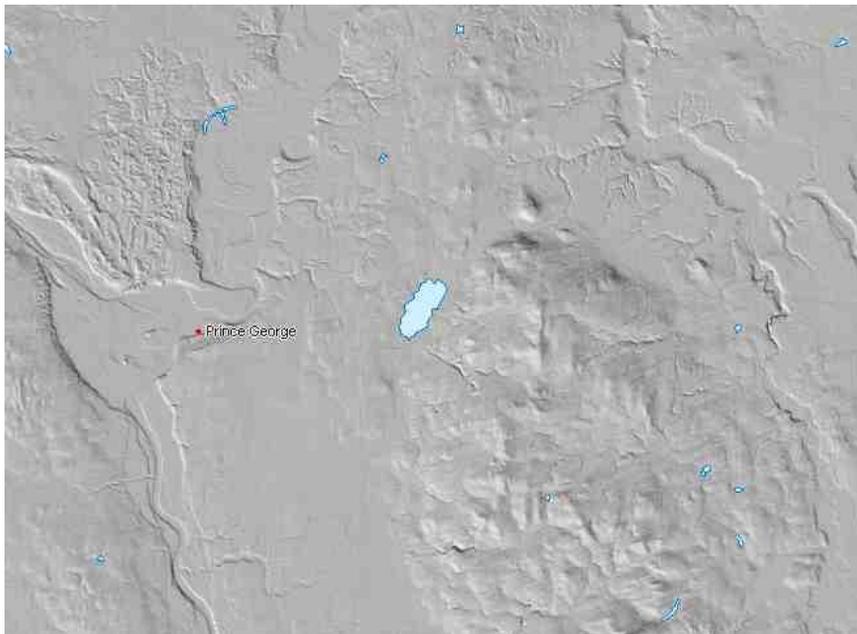
A DN for every pixel

created from digital  
stereo air photos



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



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Almost all DEMs have been created from remote sensing:

## DEM sources (continued)

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

Stereo Optical imagery and RADAR

### d. LiDAR terrestrial and airborne: 2005->

High resolution point cloud, sub-metre

Non- RS sources: ??



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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



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## DSM sources 2000+

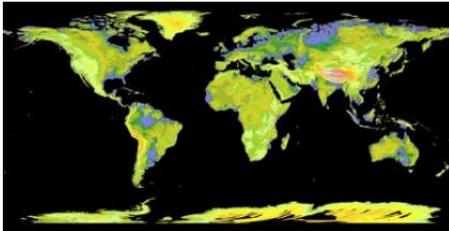
Shuttle Radar Topographic Mission (SRTM) Feb 2000  
 Data affected by steep slopes, Download by 5° x 5° area

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

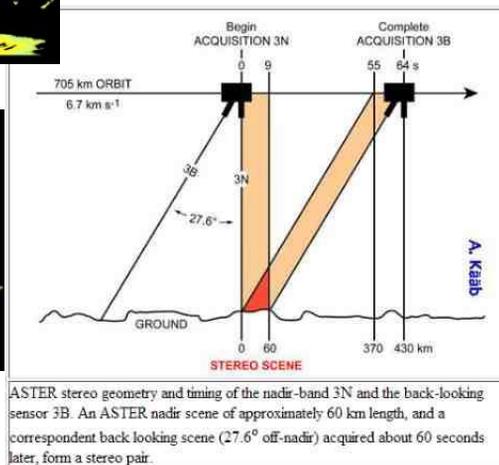
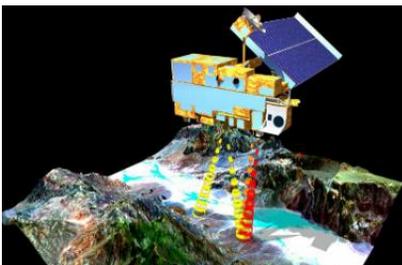
Used for most of Google Earth



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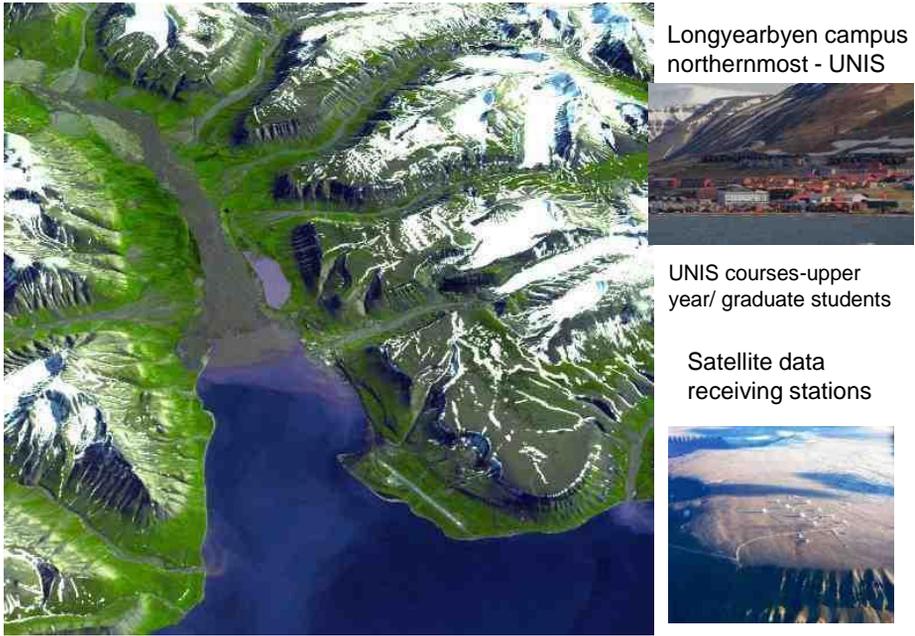
ASTER DEM  
 <- global DEM 30m pixels



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

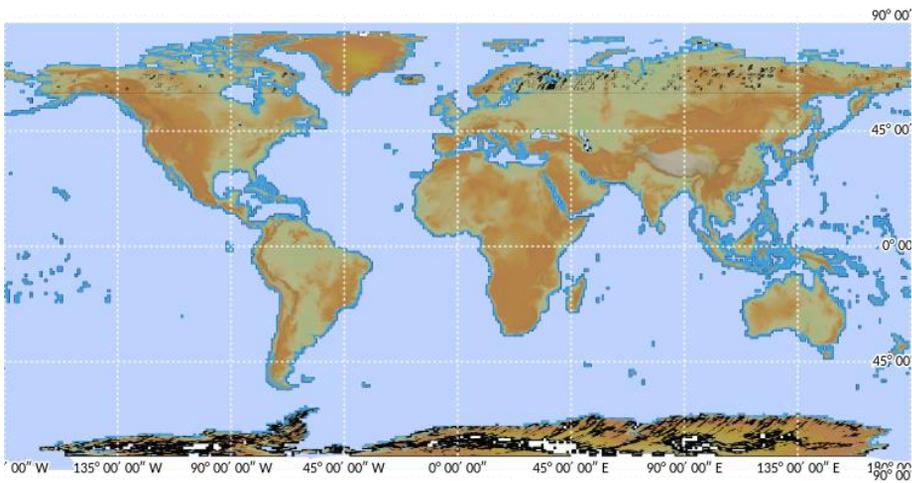
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ASTER image and DEM : Svalbard, Norway (80N) (15 metre resolution)



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## ALOS DEM 2015-2019



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

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



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## 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

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## 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

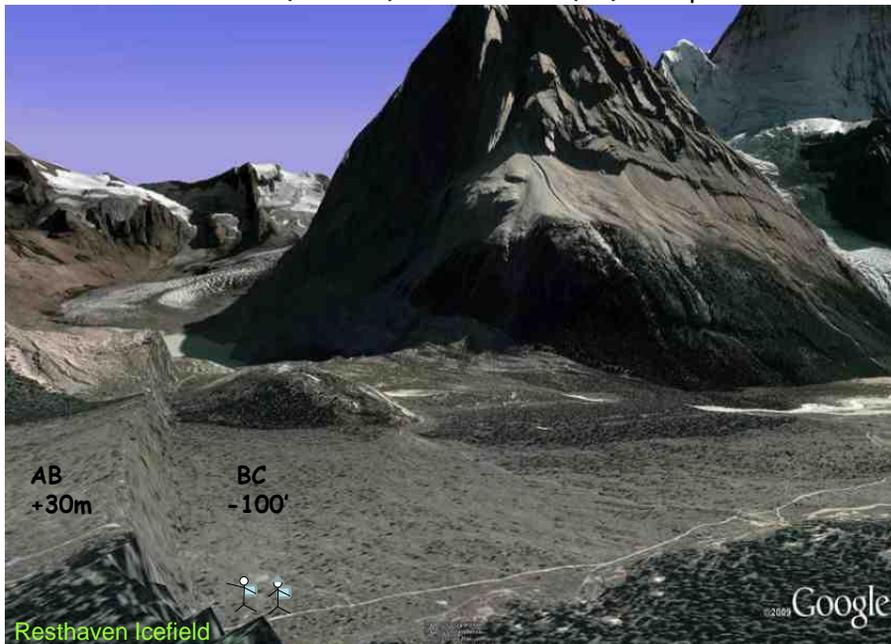
SRTM 90m (near global) 2000

ALOS 30m (global) 2015

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

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



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## 2. DEM - layers

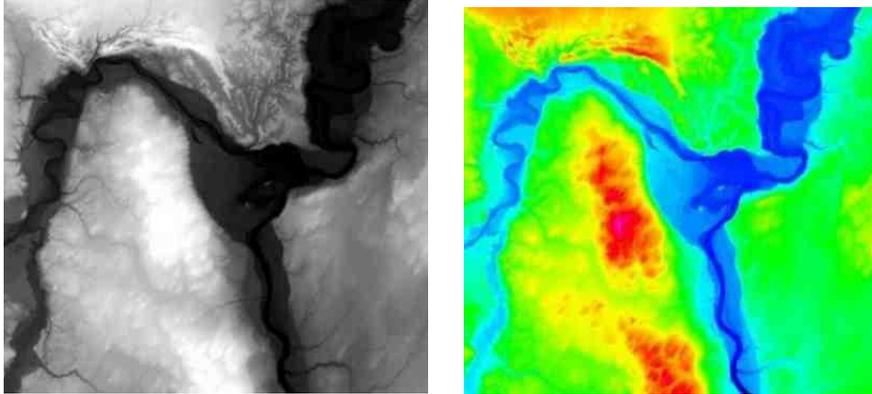
### A. Elevation ('DEM')

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

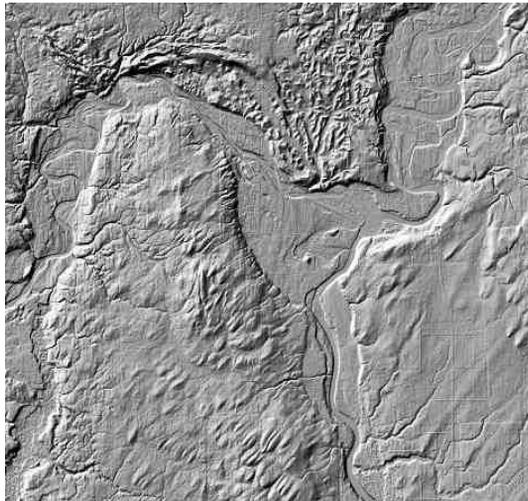


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### b. Shaded relief (hillshade)

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

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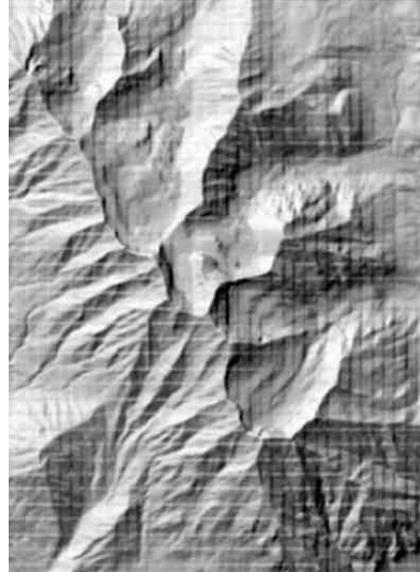
## Use of shading to assess DEM

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

**Reprojection can cause striping and artifacts**

**Avoid reprojecting rasters if possible**

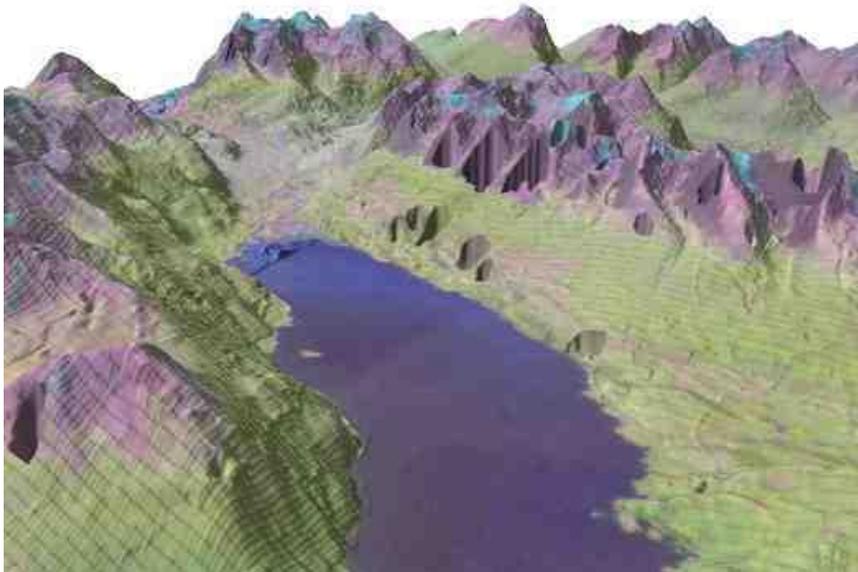
Stripes - often caused by  
WGS84 - NAD83 difference



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examine hillshade for errors / quality (geog357 project)

Holes: due to clouds



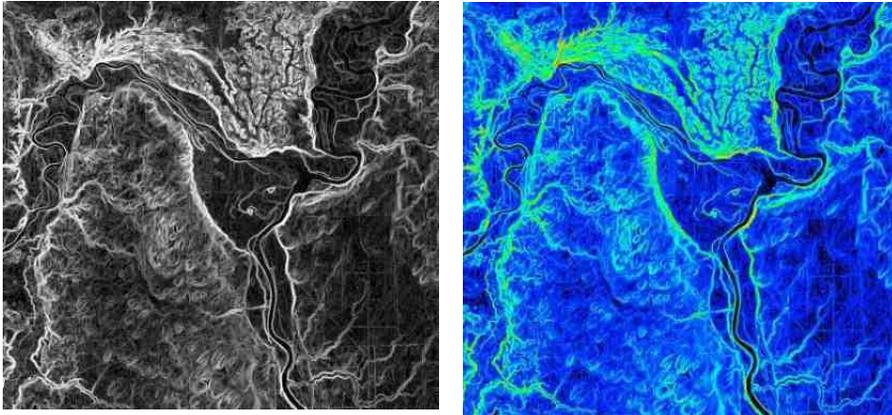
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### c. Slope (gradient)

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

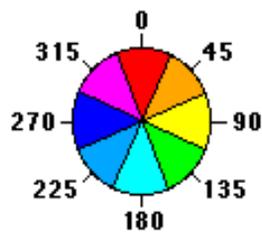
slope is  $\text{rise/run} = \text{vertical change over the horizontal distance}$

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

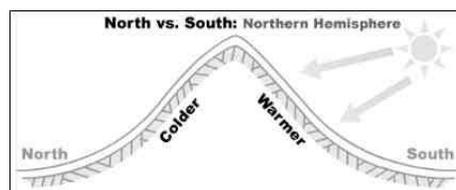


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d. Aspect: the compass direction a slope is facing



A circular scale: N = 0 and 360



#### **This raises three questions for analysis:**

north facing slope has both extreme values, 0 and 360 \*\*\*\*\*

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

0-360 requires 16 bit data;

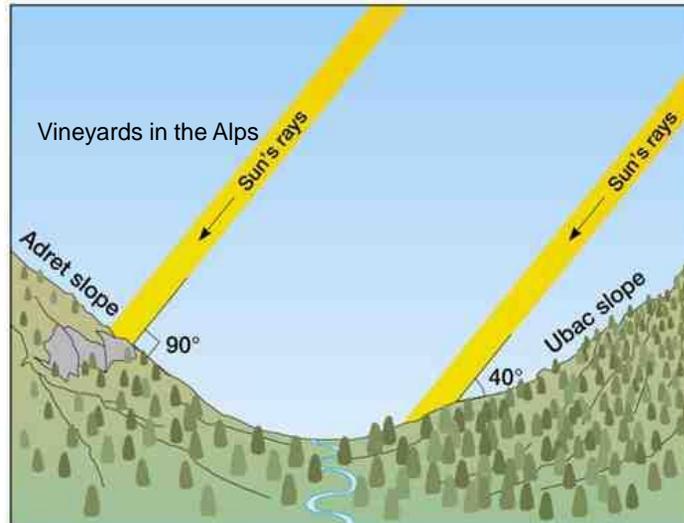
Aspect has an impact on land use/cover

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

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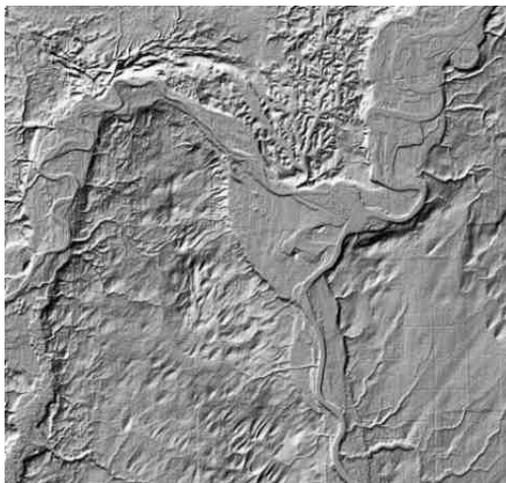
### e. Incidence

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



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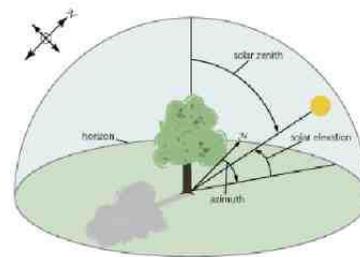
- **Incidence** looks similar (inverted!) to shaded relief, but DN 0-90
- the angle (degree) of light incidence, is based on the sun position
- Requires metadata for sun elevation and azimuth for the scene



Azimuth = sun's compass direction

Elevation = height of sun

Solar zenith =  $90 - \text{elevation}$



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### 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

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IEEE TRANSACTIONS ON GEOSCIENCE AND REMOTE SENSING, VOL. 41, NO. 11, NOVEMBER 2003

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### 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

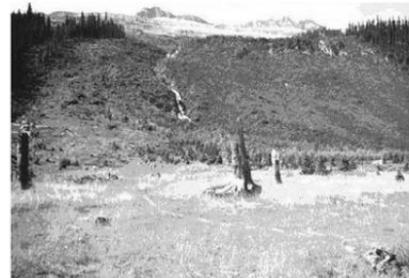


Fig. 1. Avalanche Slope at Takakkaw Falls, Yoho National Park. Looking west, slope is approximately 500 metres wide.

Avalanche slopes : 25-45°

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Avalanche slopes : 25-45°

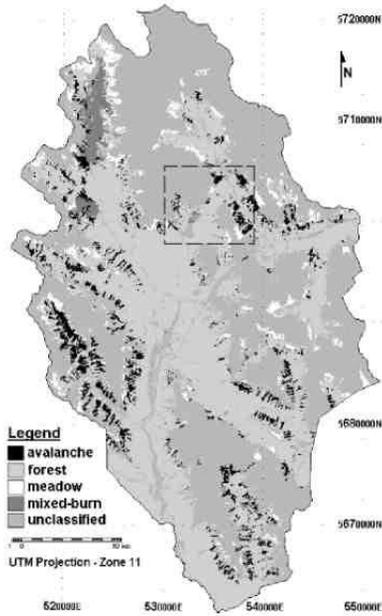


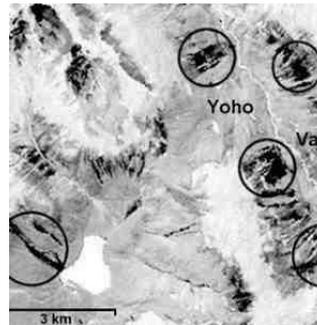
Fig. 6. Classification Results after the 3x3 filter. Dashed box indicates the area featured in Figs. 4 and 5)

### 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)

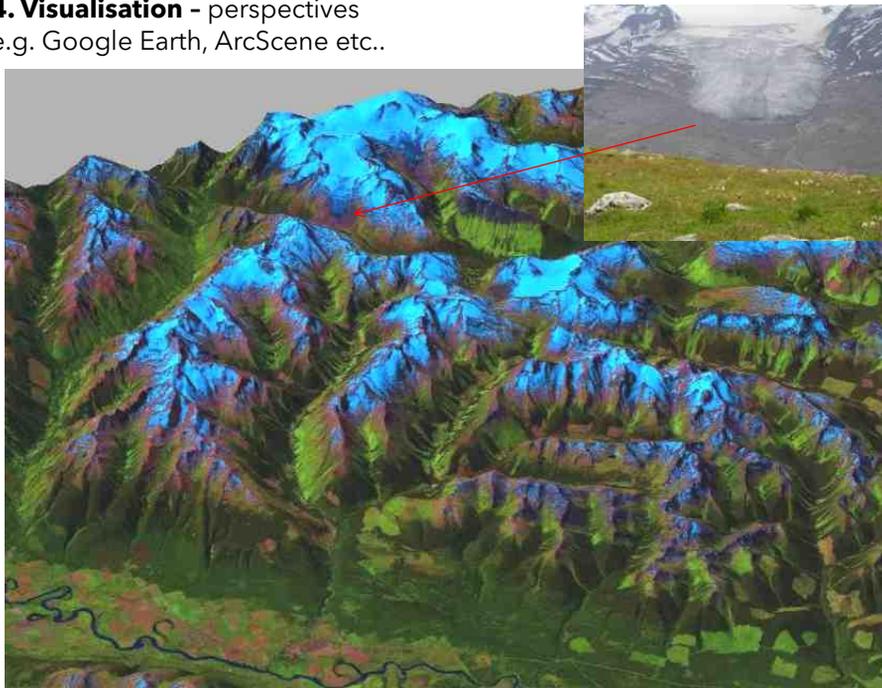
Classification	Avalanche	Forest	Meadow	Mixed	Overall
a. bands 3,4,5,7	79.0	99.0	69.8	78.0	79.75
b. a + elev	78.9	98.3	100.0	88.2	84.50
c. b + slope	76.8	99.0	99.5	94.1	91.75
d. c + incidence	80.6	100.0	99.4	88.2	92.25
e. d + NDVI, PC3	81.7	95.4	99.0	94.4	90.00



DEM:  
1:250,000  
100m pixels

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### 4. Visualisation - perspectives e.g. Google Earth, ArcScene etc..

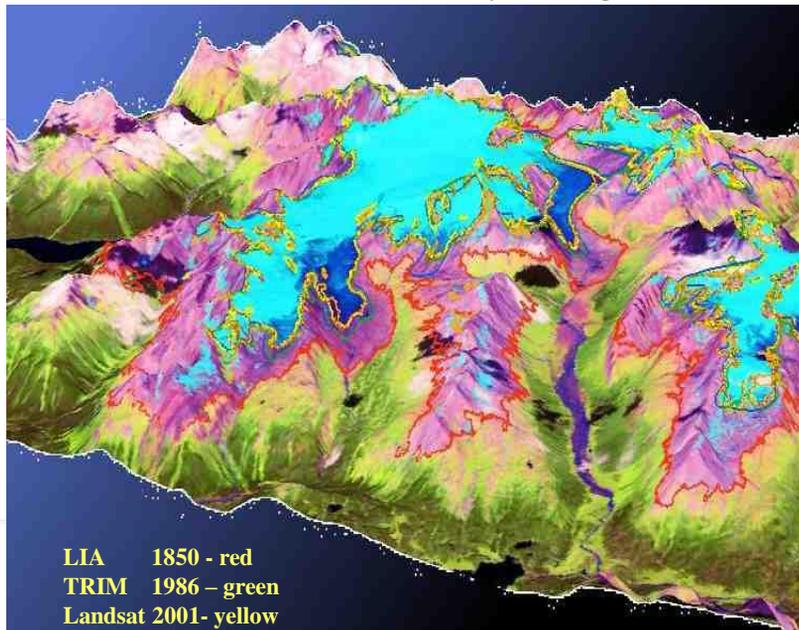


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DEM from Photogrammetry: Tatras, Slovakia 2m

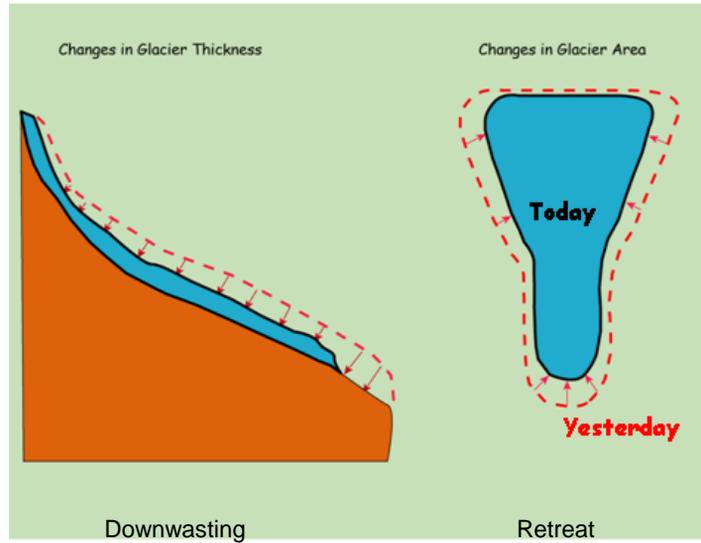


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**Lloyd George Icefield**

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Image processing can be used to map and measure :  
e. Elevation change / Volume loss from DEMs



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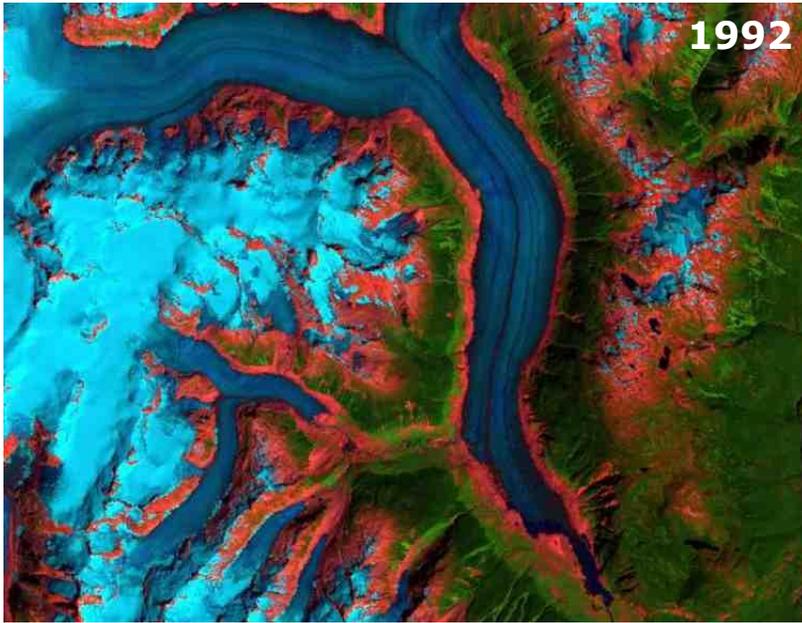
5. DEM  
differencing - to  
show glacier  
downwasting

Athabasca Glacier  
1919 - 2005

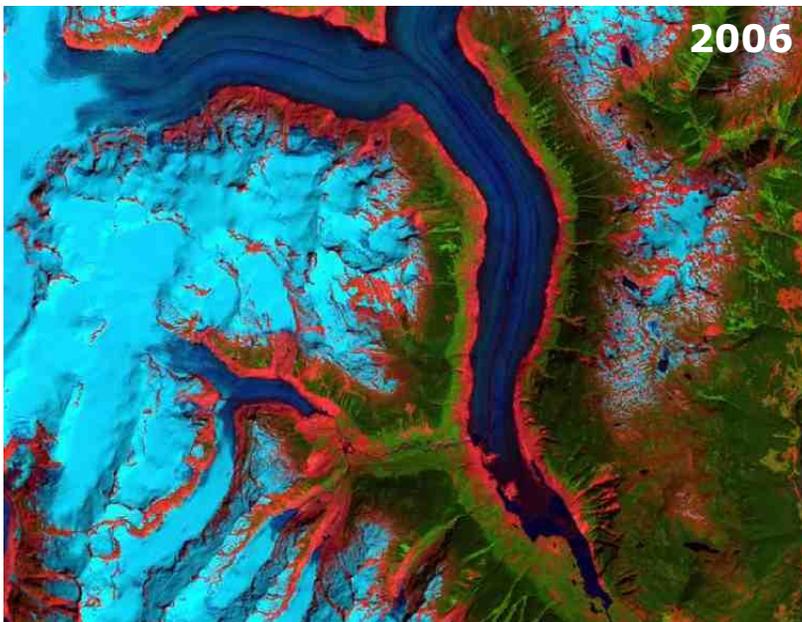


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**Animation series, implying elevation change: Klinaklini Glacier**



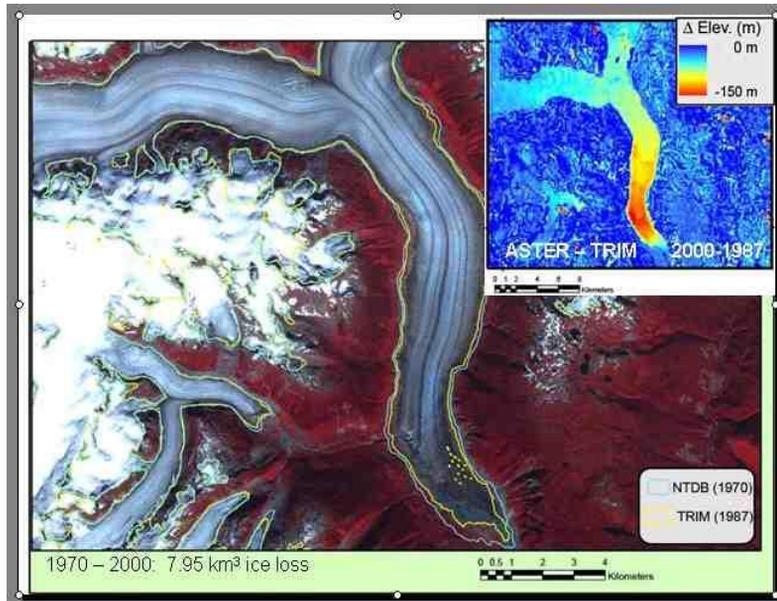
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#### 4. Thickness loss and volume estimates from DEMs

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



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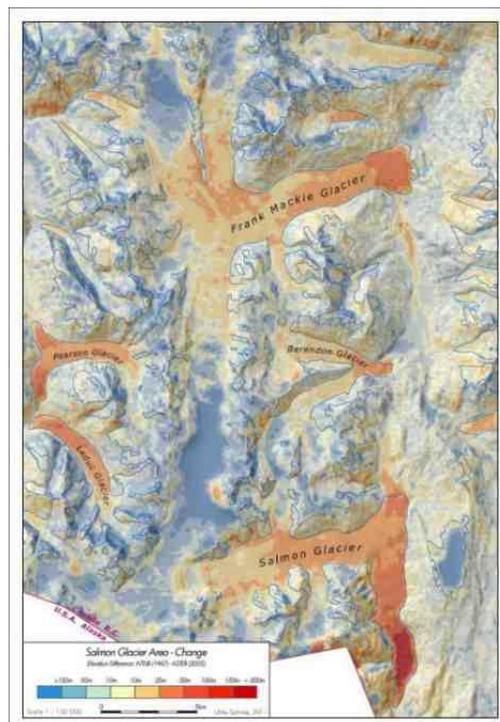
Salmon Glacier  
North of Prince Rupert

Glacier downwasting

Subtraction of two DEMs:  
2008 minus 1965

Red shades show  
increased loss

Blue shades slight gain



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True 3D: The holodeck

Hololens by Microsoft



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