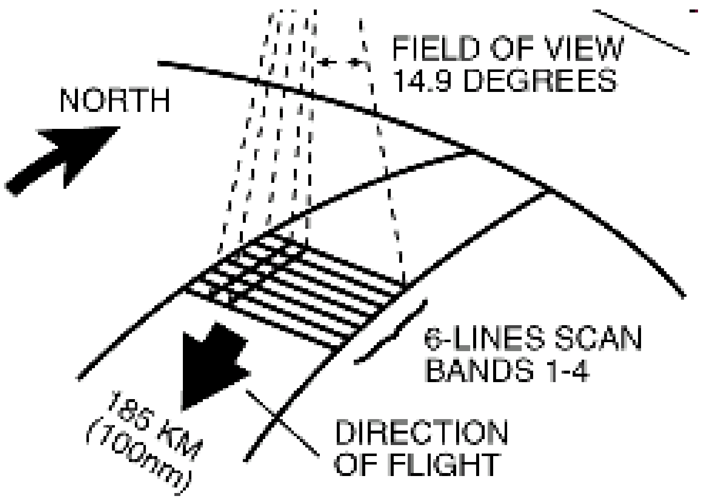
DIGITAL DATA and DISPLAY

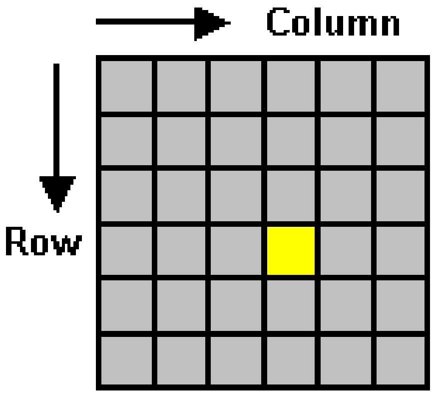
Satellite image data - capture

Landsat 1



Onboard scanners (not cameras!) capture energy reflected (or emitted) in bands by wavelength for each pixel (picture element) by row and column (captured row by row)

Data are recorded in a continuous swath and then cut into scenes several thousand pixels in x and y, e.g. 4000 x 4000



Satellites: orbit at ~81-82º angle to equator (9º off the meridians) so that image data are ~ the same local time each day (~10.30am)

Time of day = compromise between minimum shadow / developing clouds (9.30-11.00am)

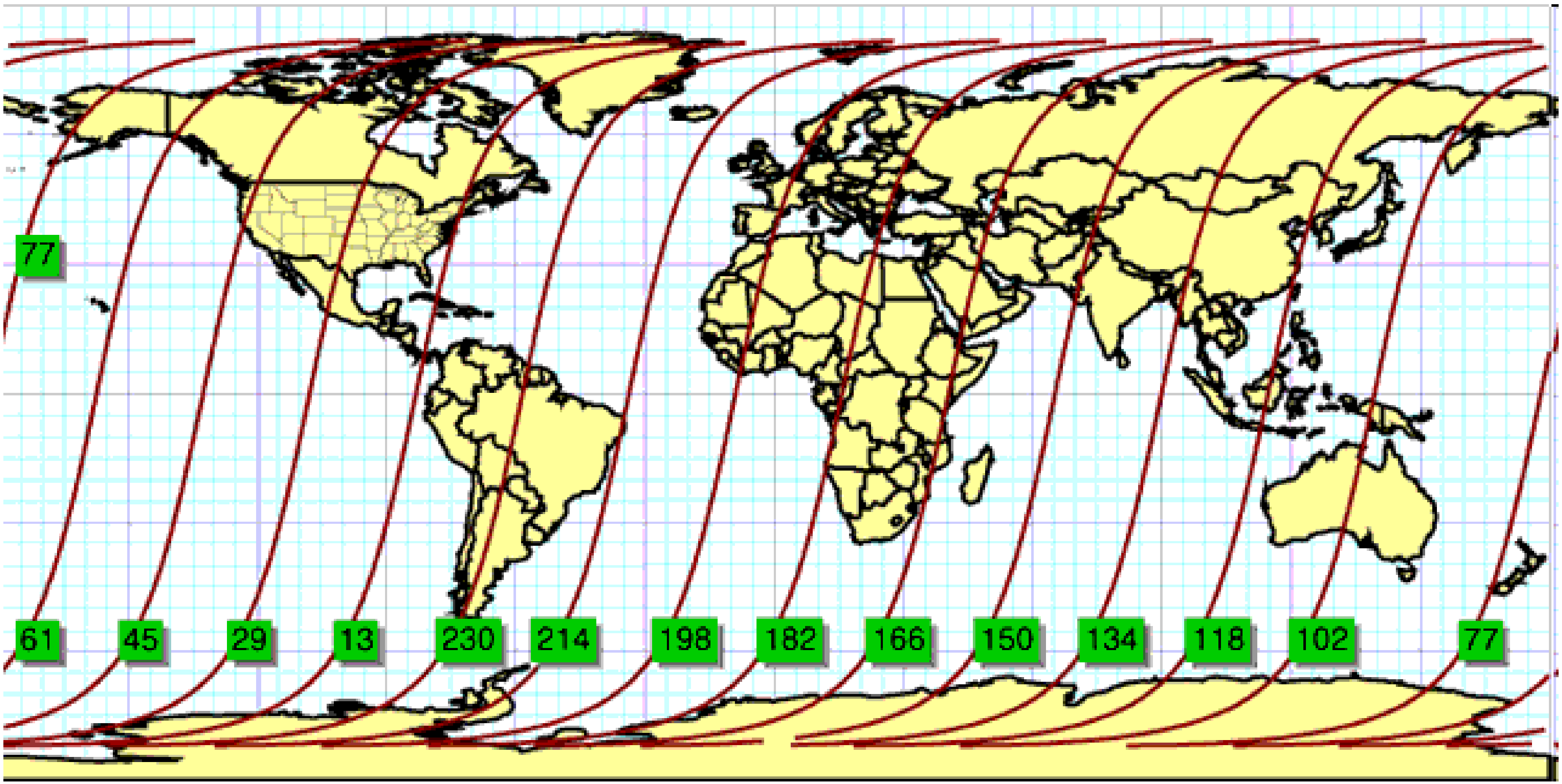
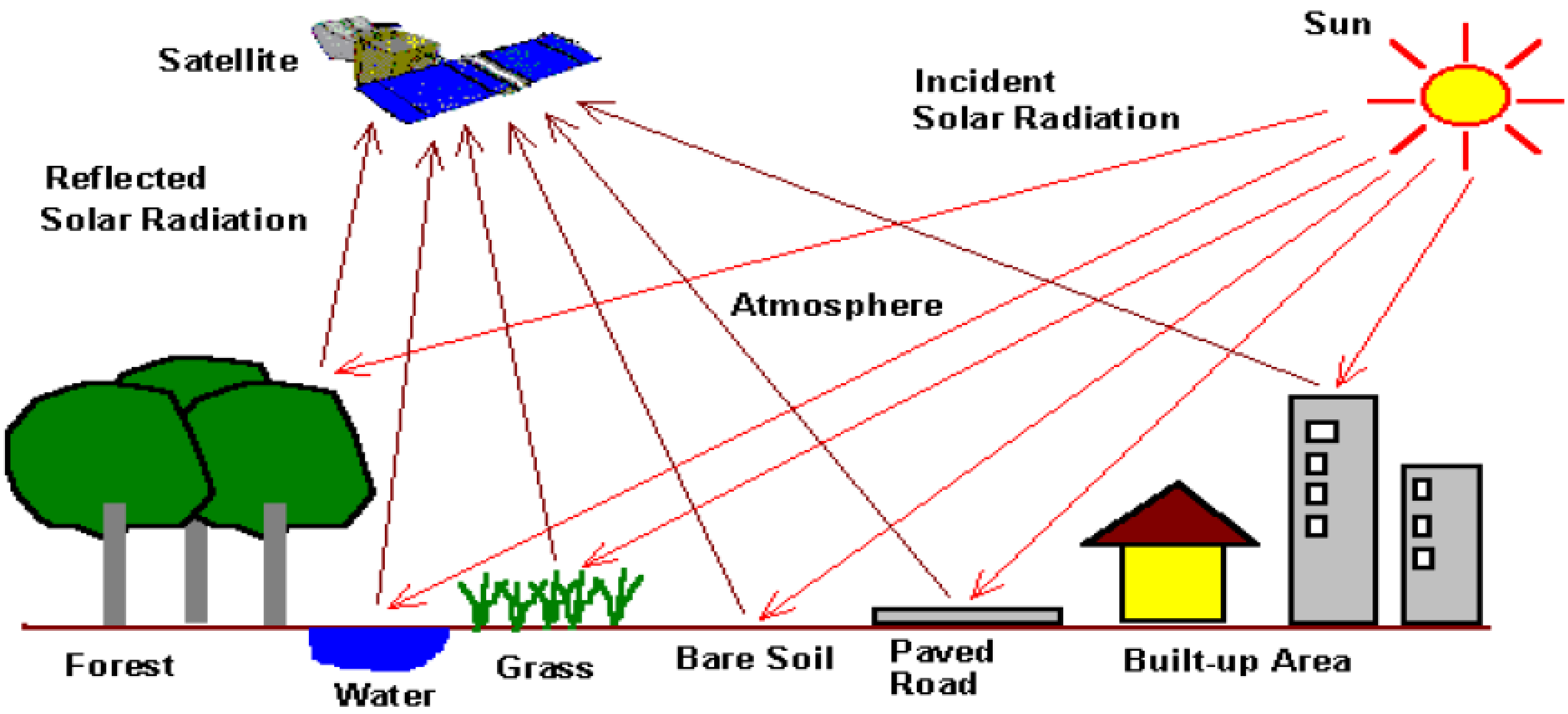


Image Scenes are catalogued by 'path' and 'row'

Landsat path

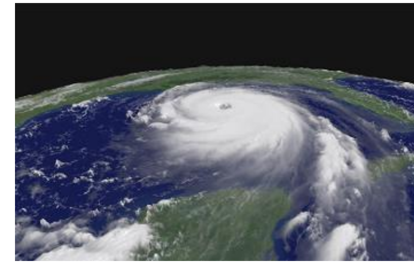
http://earthnow.usgs.gov

Data = digital measure of energy reflected/emitted from ground (or reflection recorded on film in the case of photographs)



Each pixel records a digital number (DN) giving the amount of reflection

Data characteristics: Spatial resolution (pixel size)



Spatial resolution is the size of the picture elements (pixels). This is determined by the sensor design, satellite altitude, and available energy.

Remote sensing data generally varies from <1 metre to 10km

Very high res: 25cm < 5m

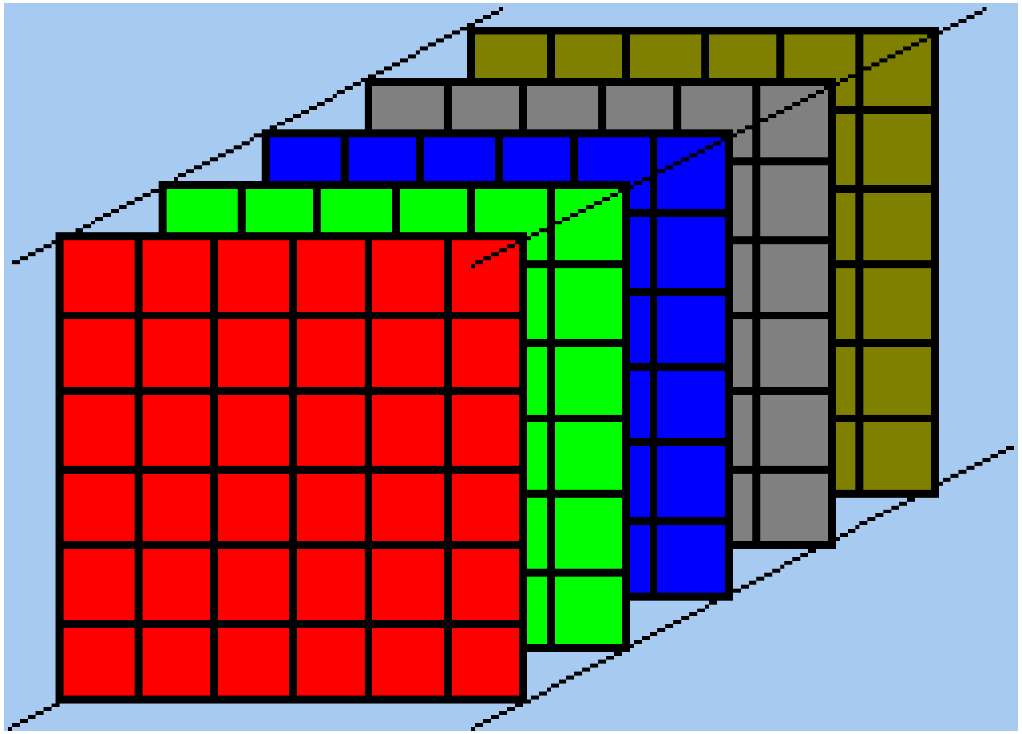
High resolution: 5-50metre

Medium res: 50-500m

Low res: > 500m (1km +)

Digital Numbers (DN)

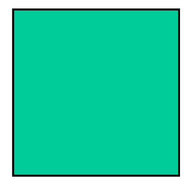
- Each aerial/satellite image has multiple layers (bands)
- The pixels line up perfectly between bands
- The 'attribute' = the brightness / reflection level
- e.g. dark = 0, bright = 255 (for '8-bit' data)



Radiometric resolution

Scanner input (amount of reflectance) is converted from a continuous radiance value (watts / sq metre) into a discrete value known as the digital number (DN).

These are integer numbers .. *e.g. 8-bit (256 values)* for easier handling and smaller overall file size:
one value per pixel per band.



- Each value can range from 0 (no reflection) to e.g. 255

- They can be converted back to (decimal) radiance in 'real' numbers if required (not often in GEOG 357)

Radiometric resolution

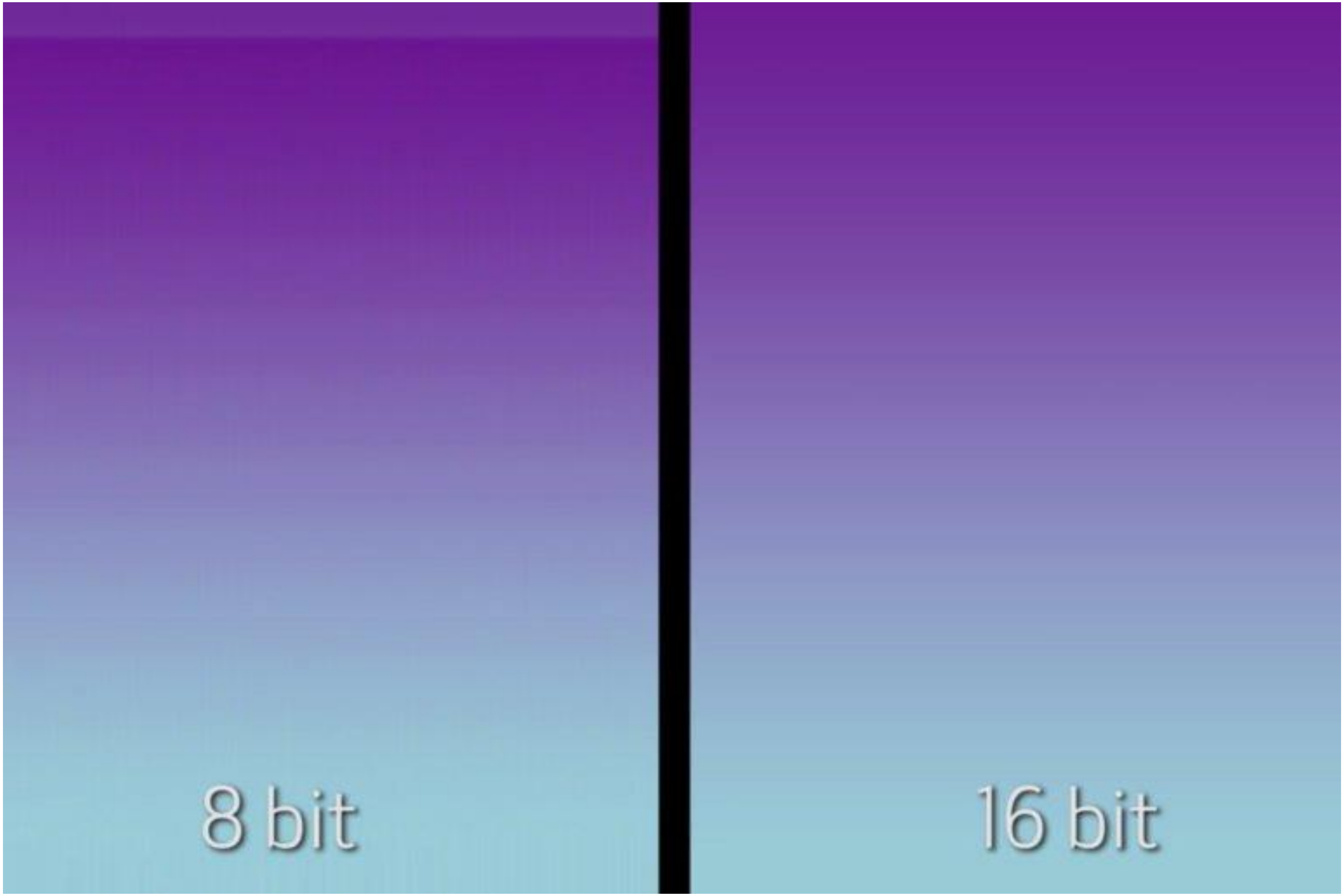
Powers of 2	Digital Value
2^0	1
2^1	2
2^2	4
2^3	8
2^4	16
2^5	32
2^6	64
2^7	128
2^8	256
2^9	512
2^{10}	1024
2^{12}	4096
2^{16}	65,536

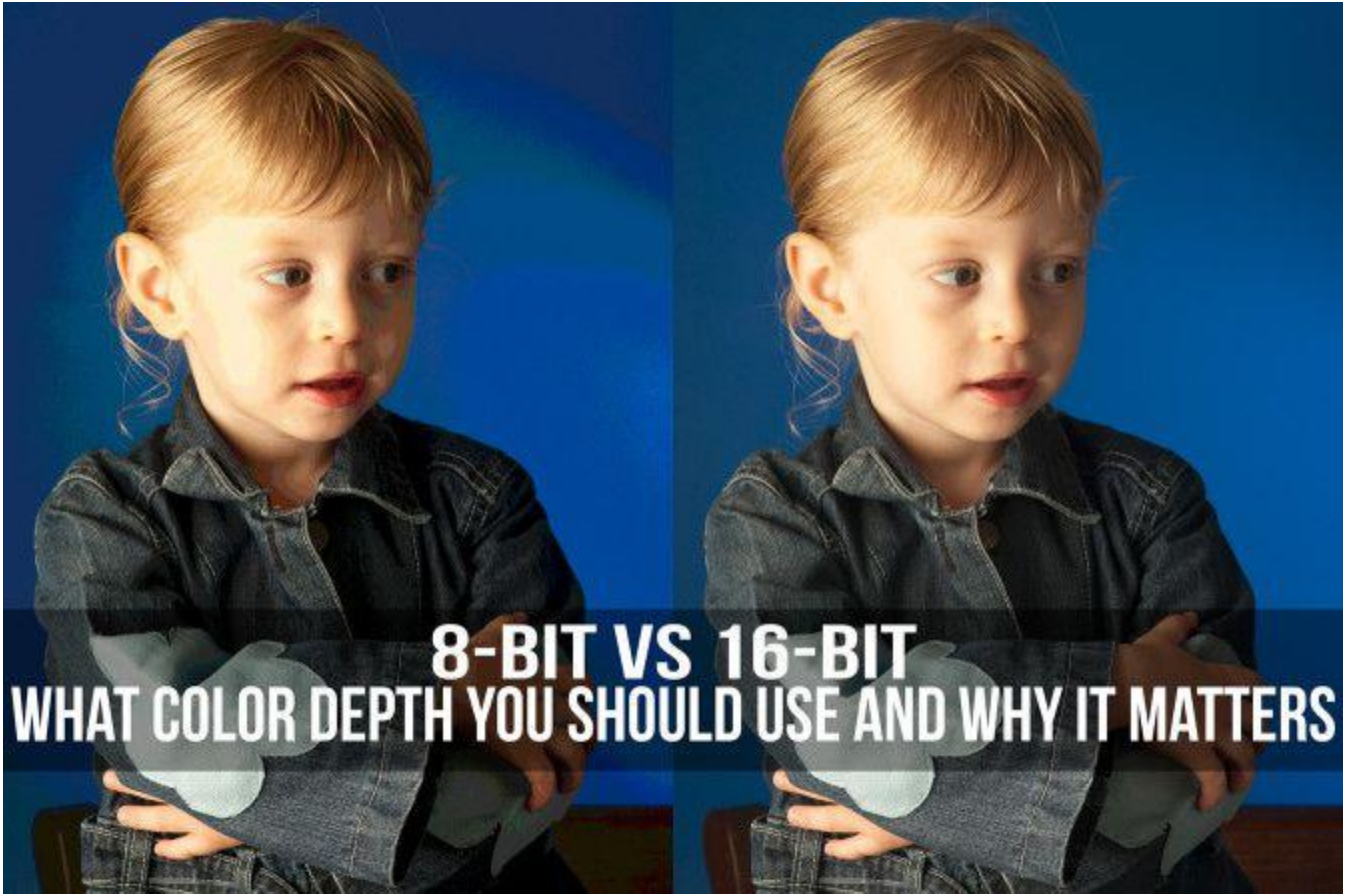
Bitmap layer = 0,1

Landsat 1-3 : 0-63

Landsat 4-7: 0-255

Landsat 8-9: 0-65,535

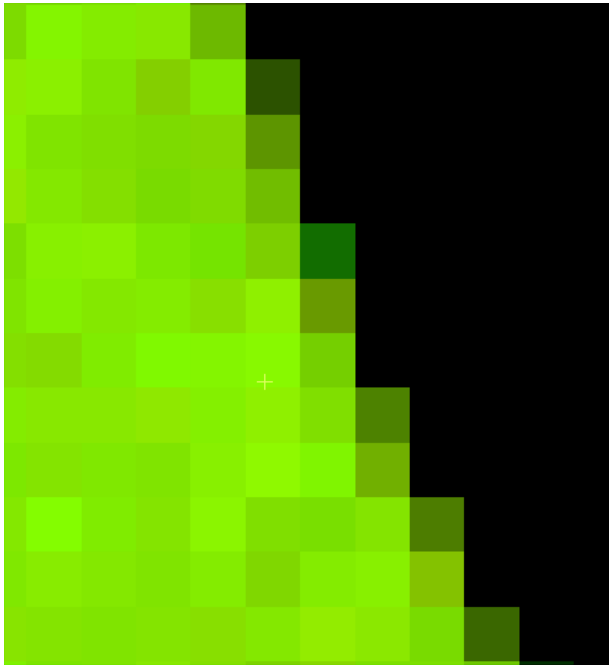

8 bit
16 bit


8-BIT VS 16-BIT
WHAT COLOR DEPTH YOU SHOULD USE AND WHY IT MATTERS

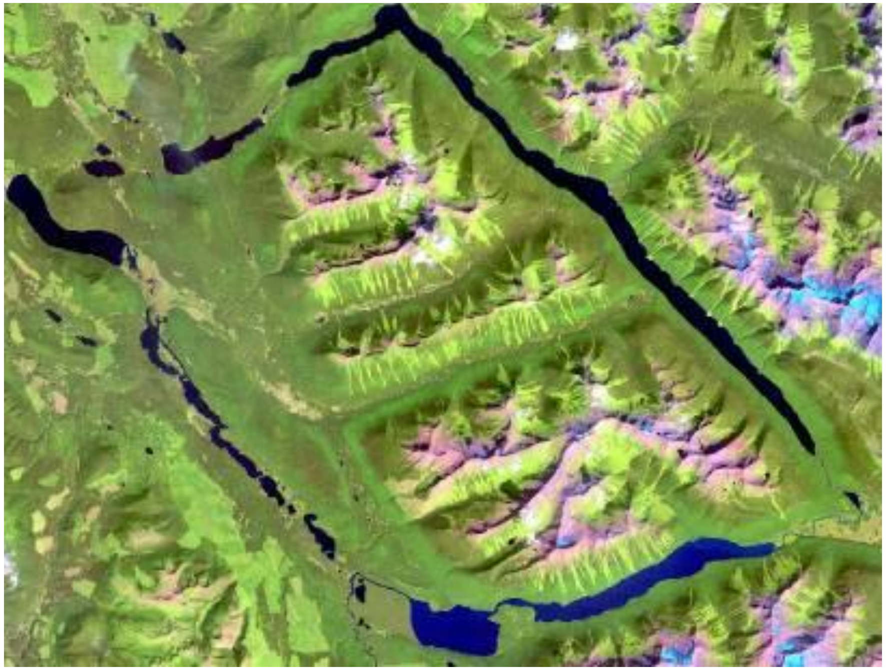
Side note on pixel size: Pure and Mixed Pixels

One pixel = one digital number value per layer

Remote sensing data and raster GIS data give the impression that a pixel has one uniform value across its width. This may be true for a small pixel or a homogenous cover, such as a large lake, or field, but often we need to know the nature of geographic data and understand that what we are seeing is an average value for a variable forest or a mixture of different surface covers. Landsat example: Bowron Lakes



1 pixel = 30 x 30m



Digital number summary

1984-2011: mostly 8-bit 0-255
2013-> mostly 16-bit 0-63,536

= higher radiometric resolution
but greater complexity

1984-2011 Landsat 5 DNs: typically 0-120 (plus snow)

2013-present: Landsat 8/9 DNs: typically 5000-20000

Landsat bands 1982-2023 (mostly 30m pixels)

2013->

Landsat 8 Operational Land Imager (OLI) and Thermal Infrared Sensor (TIRS)

Reference

Barsi, J.A.; Lee, K.; Kvaran, G.; Markham, B.L.; Pedelty, J.A. The Spectral Response of the Landsat-8 Operational Land Imager. *Remote Sens.* **2014**, *6*, 10232-10251
doi:10.3390/rs61010232

Band	Wavelength	Useful for mapping
Band 1 – Coastal Aerosol	0.435 - 0.451	Coastal and aerosol studies
Band 2 – Blue	0.452 - 0.512	Bathymetric mapping, distinguishing soil from vegetation, and deciduous from coniferous vegetation
Band 3 - Green	0.533 - 0.590	Emphasizes peak vegetation, which is useful for assessing plant vigor
Band 4 - Red	0.636 - 0.673	Discriminates vegetation slopes
Band 5 - Near Infrared (NIR)	0.851 - 0.879	Emphasizes biomass content and shorelines
Band 6 - Short-wave Infrared (SWIR) 1	1.566 - 1.651	Discriminates moisture content of soil and vegetation; penetrates thin clouds
Band 7 - Short-wave Infrared (SWIR) 2	2.107 - 2.294	Improved moisture content of soil and vegetation and thin cloud penetration
Band 8 - Panchromatic	0.503 - 0.676	15 meter resolution, sharper image definition
Band 9 – Cirrus	1.363 - 1.384	Improved detection of cirrus cloud contamination
Band 10 – TIRS 1	10.60 – 11.19	100 meter resolution, thermal mapping and estimated soil moisture
Band 11 – TIRS 2	11.50 - 12.51	100 meter resolution, Improved thermal mapping and estimated soil moisture

Landsat 4-5 Thematic Mapper (TM) and Landsat 7 Enhanced Thematic Mapper Plus (ETM+)

Band	Wavelength	Useful for mapping
Band 1 - Blue	0.45 - 0.52	Bathymetric mapping, distinguishing soil from vegetation, and deciduous from coniferous vegetation
Band 2 - Green	0.52 - 0.60	Emphasizes peak vegetation, which is useful for assessing plant vigor
Band 3 - Red	0.63 - 0.69	Discriminates vegetation slopes
Band 4 - Near Infrared	0.77 - 0.90	Emphasizes biomass content and shorelines
Band 5 - Short-wave Infrared	1.55 - 1.75	Discriminates moisture content of soil and vegetation; penetrates thin clouds
Band 6 - Thermal Infrared	10.40 - 12.50	Thermal mapping and estimated soil moisture
Band 7 - Short-wave Infrared	2.09 - 2.35	Hydrothermally altered rocks associated with mineral deposits
Band 8 - Panchromatic (Landsat 7 only)	0.52 - 0.90	15 meter resolution, sharper image definition

= Spectral Resolution

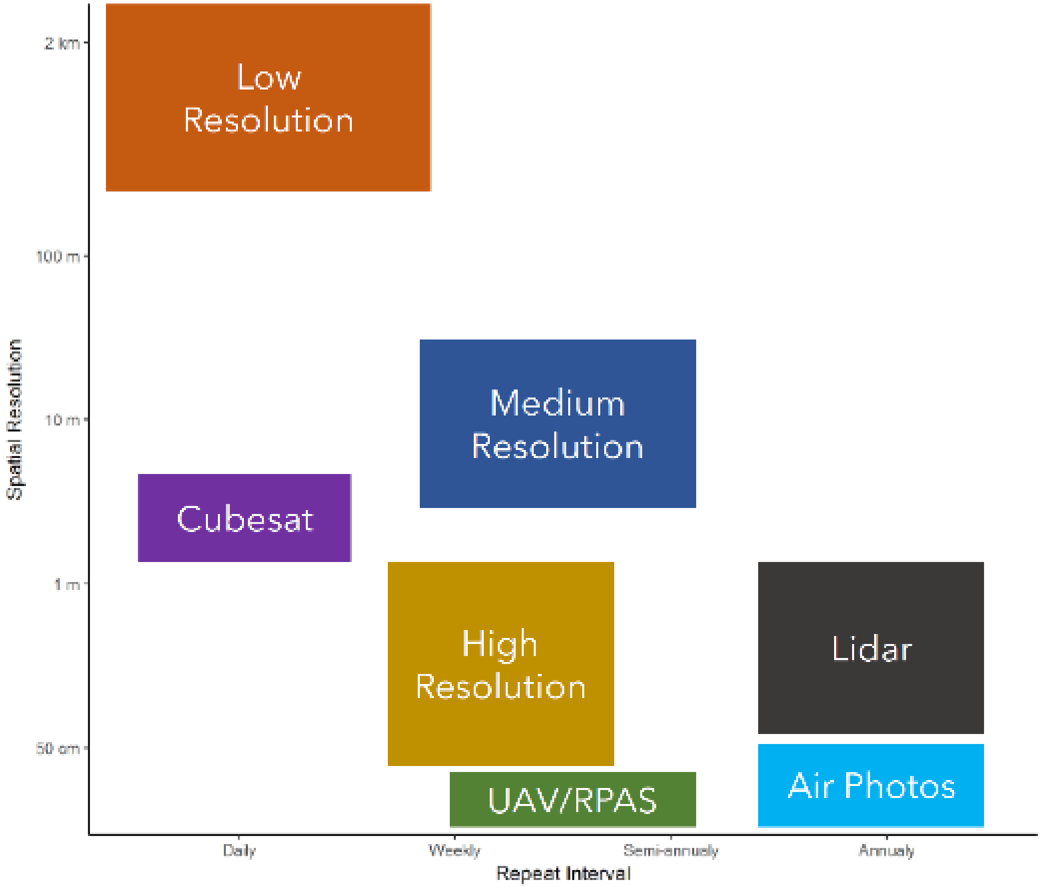
1982-2011

Four types of resolutions

Spatial – pixel size
Radiometric – data precision
Spectral – width (narrowness) of band in wavelengths
Temporal – repeat time for same area scene

temporal (x) resolution vs
Spatial (y) – pixel size

Generally:
higher spatial (smaller pixels)
= lower temporal
(longer repeat time)



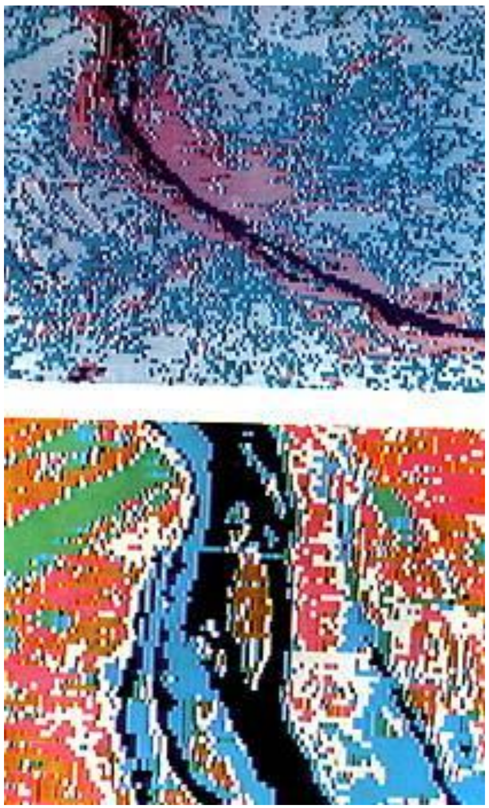
Data display

Modern computer screens display 24 bit colour - 8 bits each (256 shades) in red, green and blue (RGB) for a realistic image (right)

early PCs had fewer e.g. 2 bit = 4 colours (1982) and 8 bit = 256 colours (1990)

24 bit colour = 16 million colours; 10 bit = 1.07 billion (the new monitors)

RGB display (guns) Colour wheel: https://colorspire.com/rgb-color-wheel



Data: Bands and Channels

Bands scanned by the sensor (limited by the data captured)

e.g. 1-7 for Landsat 5 TM, 1-11 for Landsat 8 OLI

Channels data layers (including bands) stored in a database

new layers not bands e.g. DEMs, classifications

PCI Catalyst: .pix (no limit on number of channels)

Esri (spatial analyst): .img [.grd] many ?

Other: .tif (geotiff) – usually 3

Bands are usually stored in the same sequence in the database

e.g. Band 1 in channel 1, band 2 in channel 2 etc…

Guns are only RGB – you cannot display more than 3 bands / channels

Display Modes
A: Colour composites

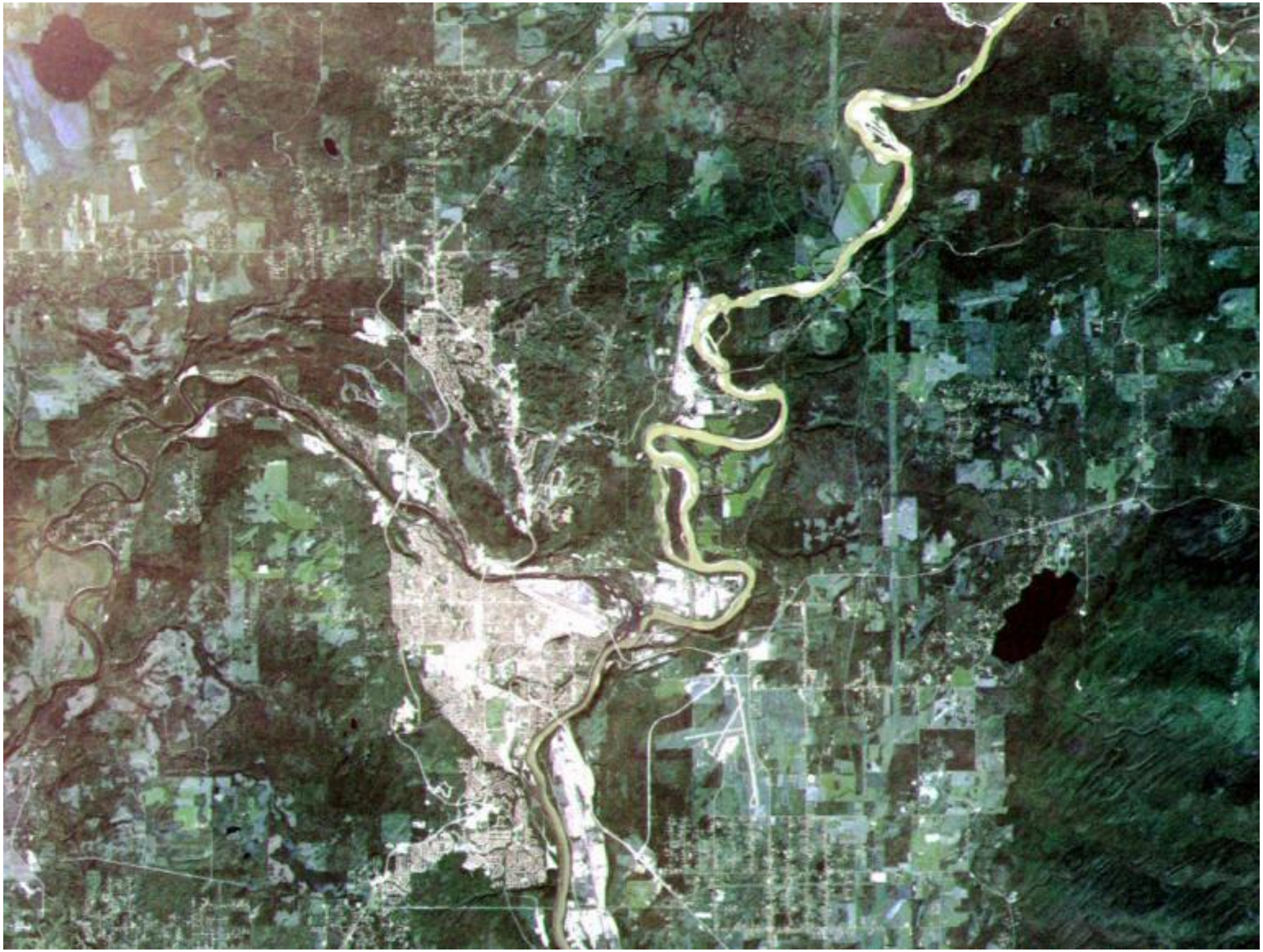
•Three different channels compose a **RGB colour composite**: any three channels can be selected. TM band 1 in Blue, 2 in Green and 3 in Red displays a 'natural colour' composite.

•But software may automatically load these in reverse as the display is 'RGB' … and you need to flip them (3-2-1 instead of 1-2-3)

• A TM 5-4-3 composition gives a higher contrast image as it incorporates 3 bands from different portions of the EM spectrum - or any combo with visible-Near-IR, mid-IR e.g. TM 742 or 541

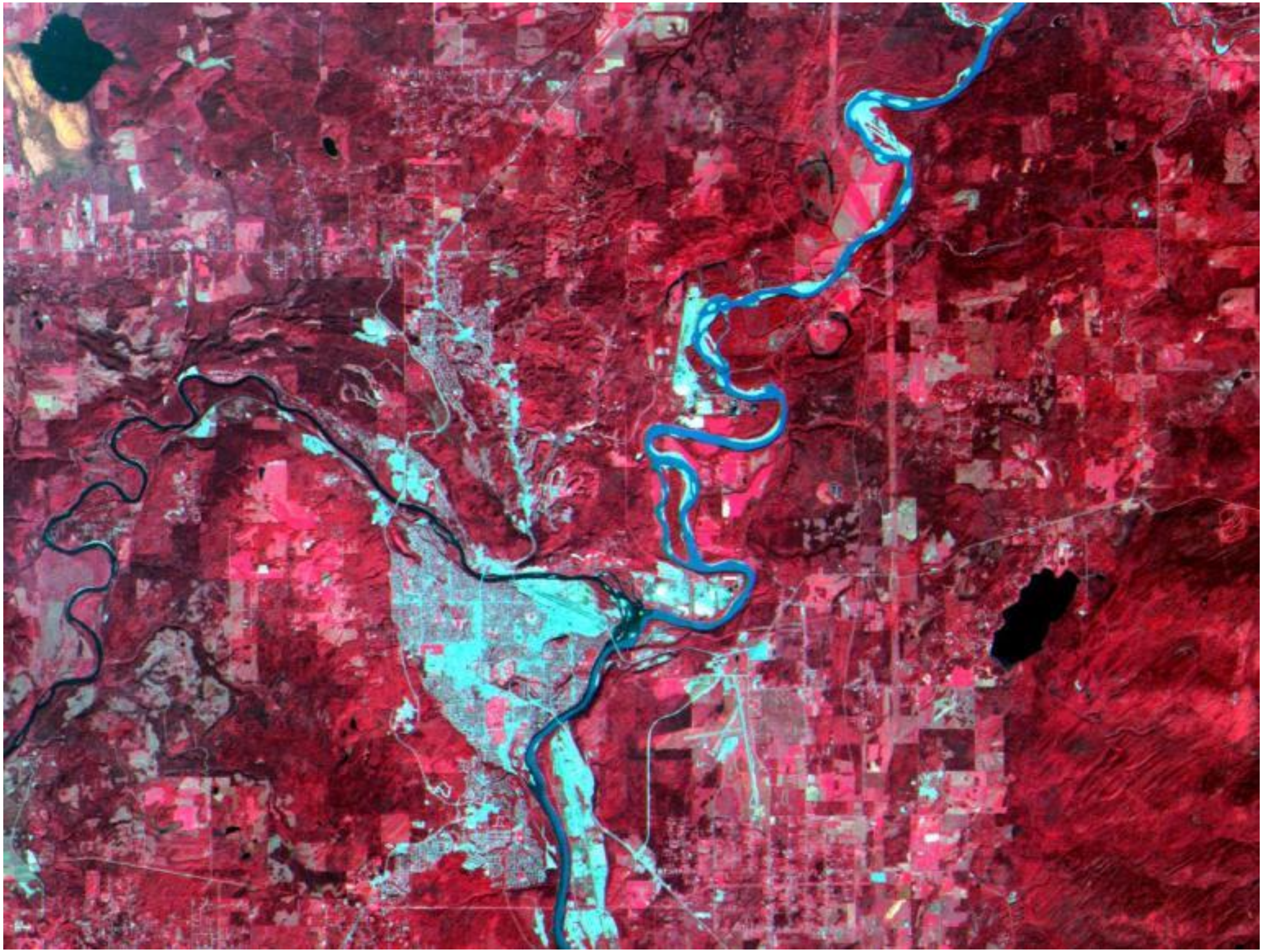
http://www.geo.mtu.edu/rs/keweenaw/

Blue-Green-Red (1-2-3)

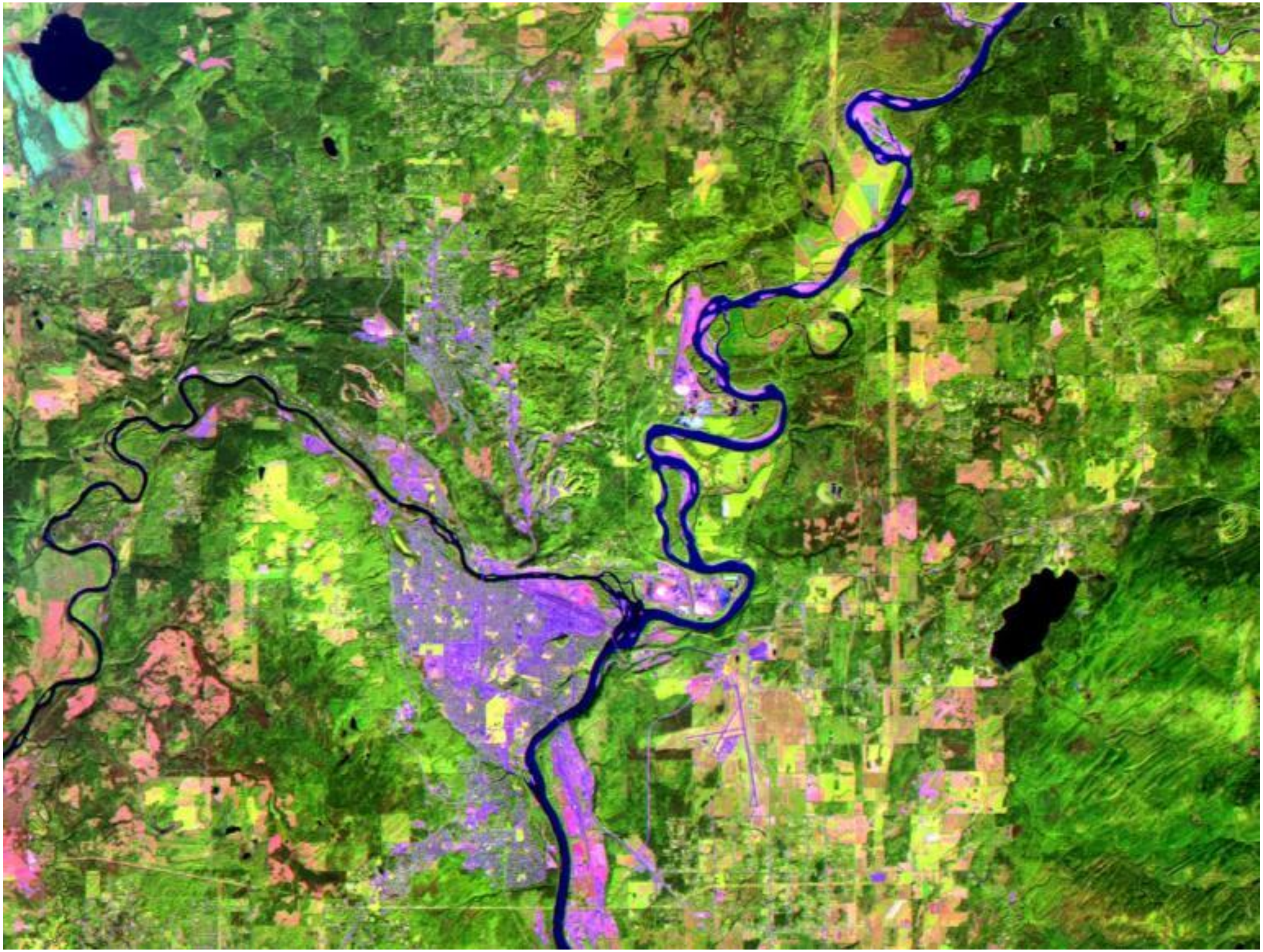


Red-Green-Blue (3-2-1) – natural colour, no IR

‘False’ colour (4-3-2) NIR, but no SWIR



TM 543 stretched – Vis-NIR-SWIR



What’s that funny blue-green area in the NW corner (next to Swamp Lake)?
Blue = high-medium visible reflectance
Green = high vegetation vigour
Low red = medium low dryness = medium high moisture

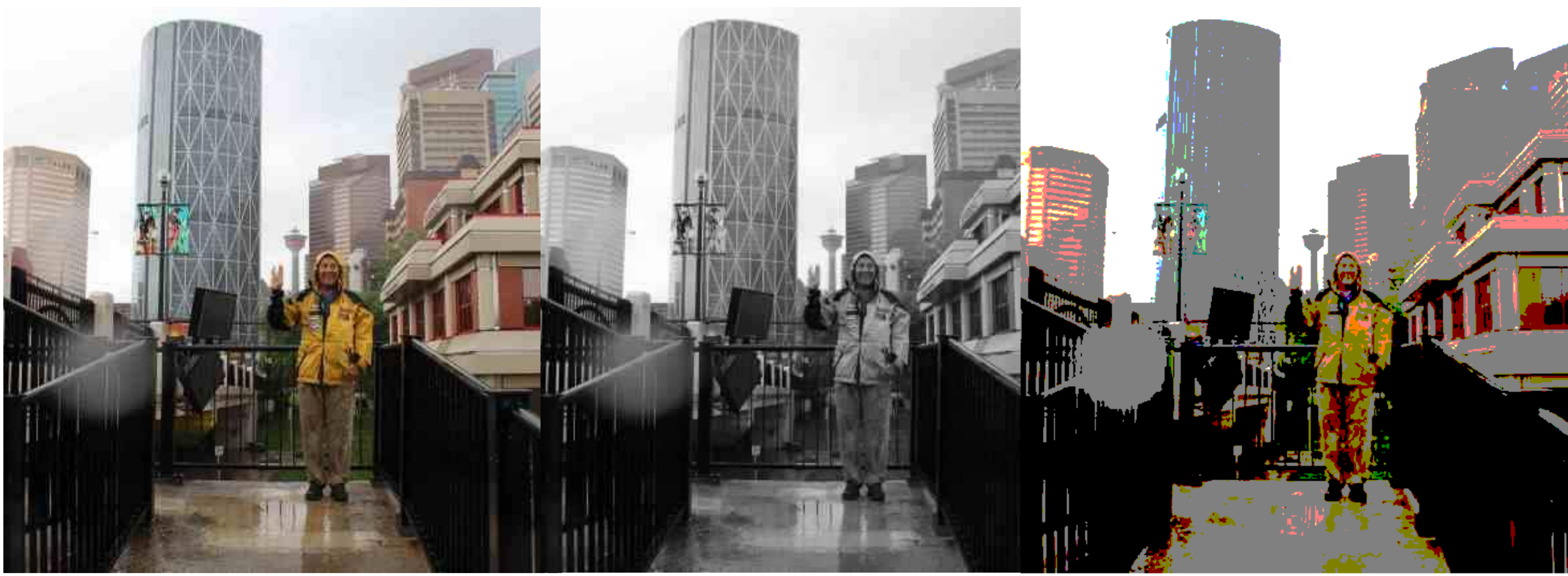
Other display modes: Single band displays

B. Grayscale C: Pseudocolour

B. The same one band or channel in all three guns creates a **grayscale image**:

C. One band or channel can also be displayed in **pseudocolour (PC)**: less useful for single bands, but used for thermal bands and thematic layers and DEMs

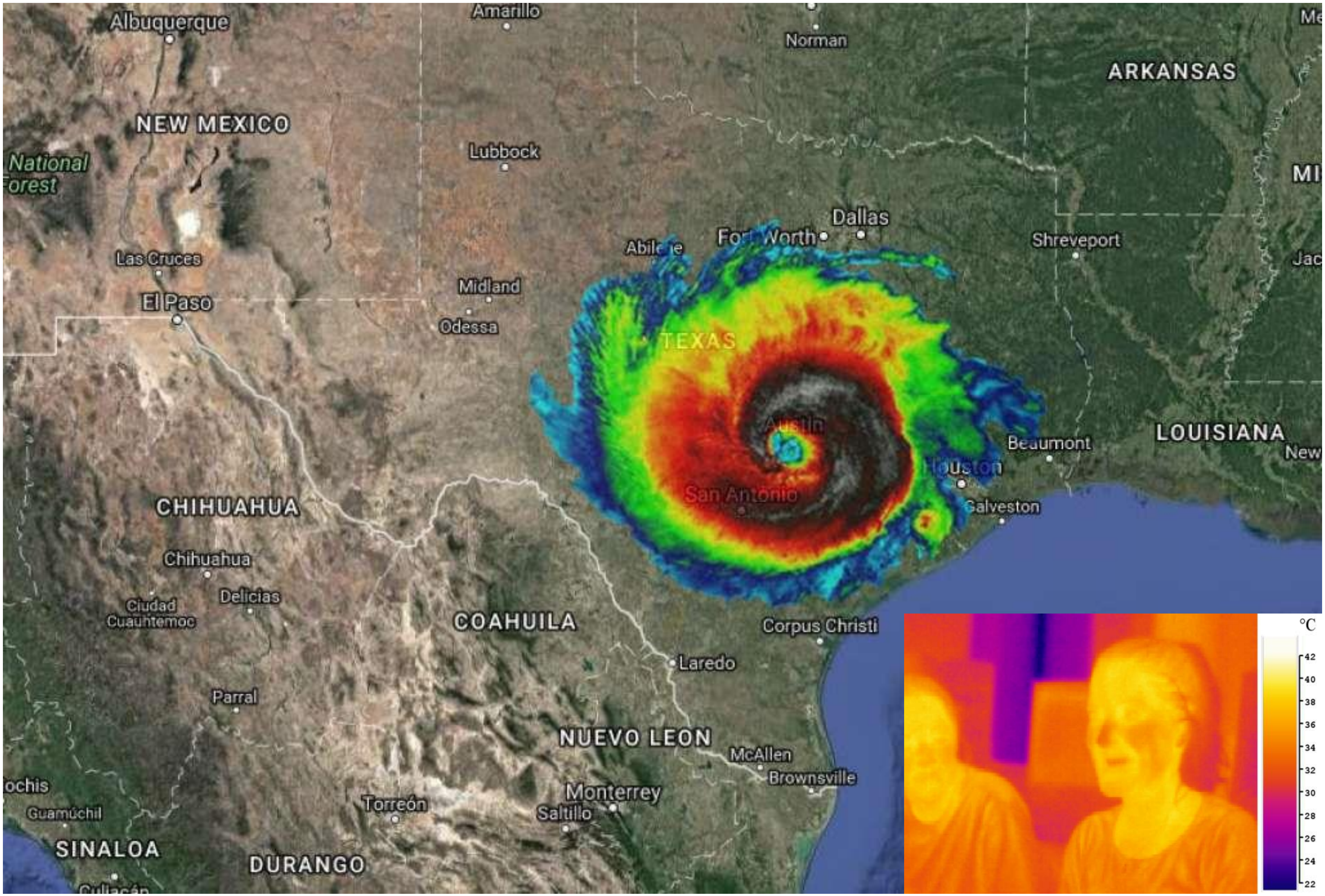
a. Colour composite b. Grayscale c. Pseudocolour



Calgary June 2013

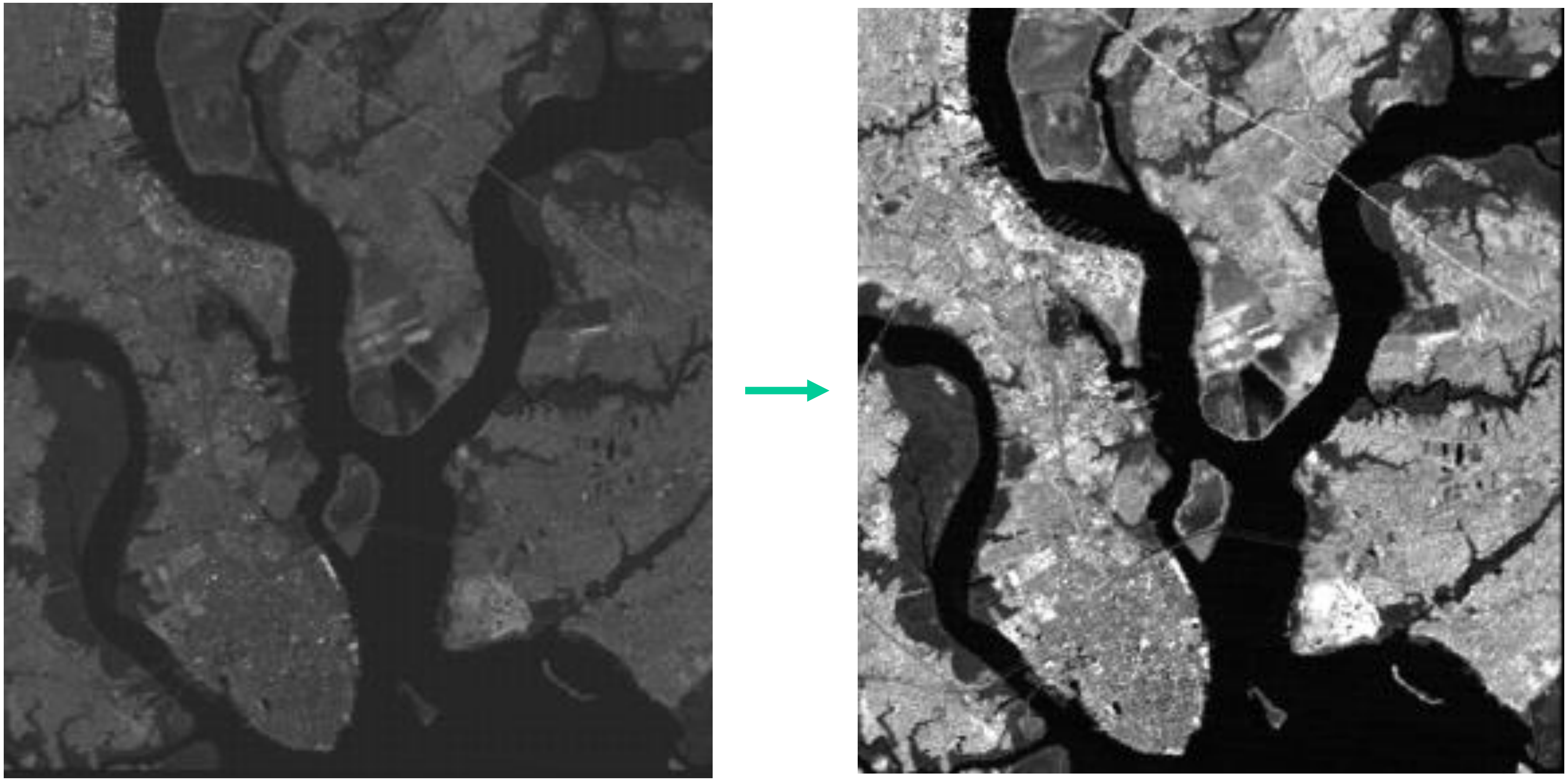
Pseudocolour display – Hurricane Harvey; colours represent temperature

Poor colour ramp choice ! – red to blue = increasing temperature



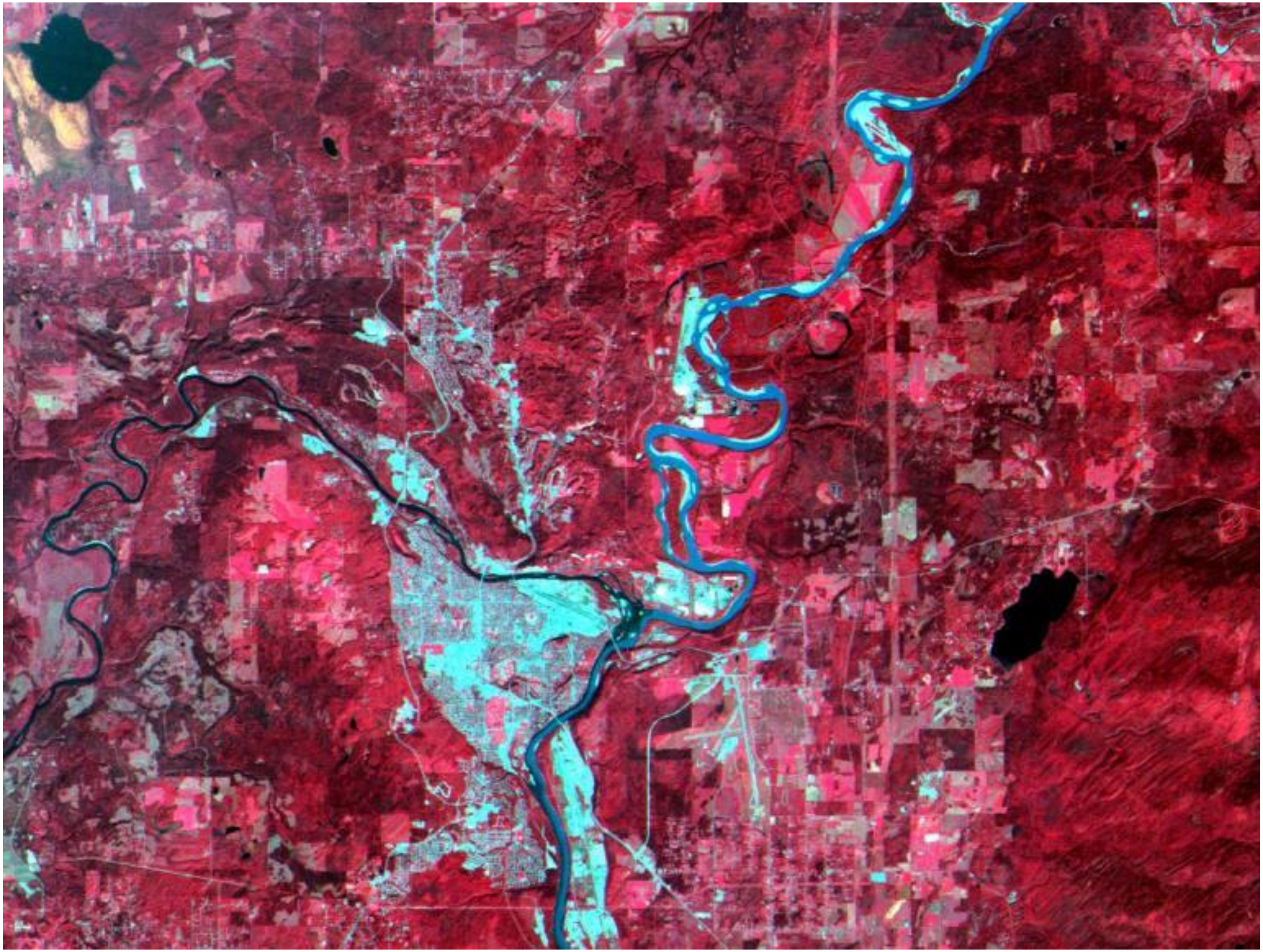
Enhancement / Histogram Stretching

The data rarely fill the maximum display range, so the screen image lacks contrast at first, and needs stretching



False colour Unstretched

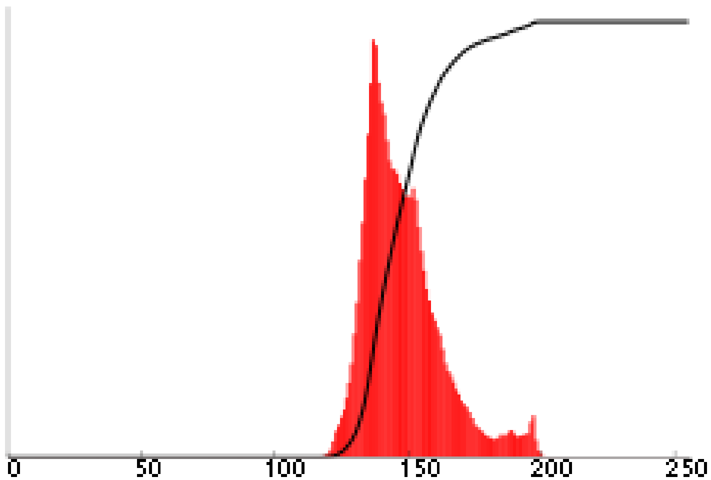
‘False’ colour (4-3-2) enhanced / stretched

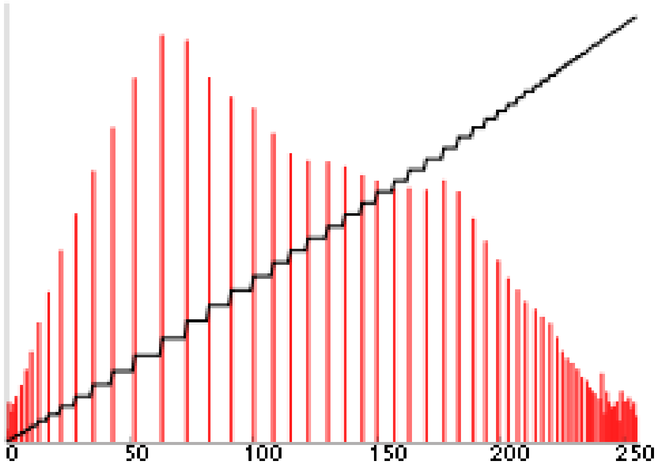


Histogram equalization / contrast stretching / image enhancement

A histogram plots the Digital Numbers (DN) on the x-axis against the frequency of values with those DNs.

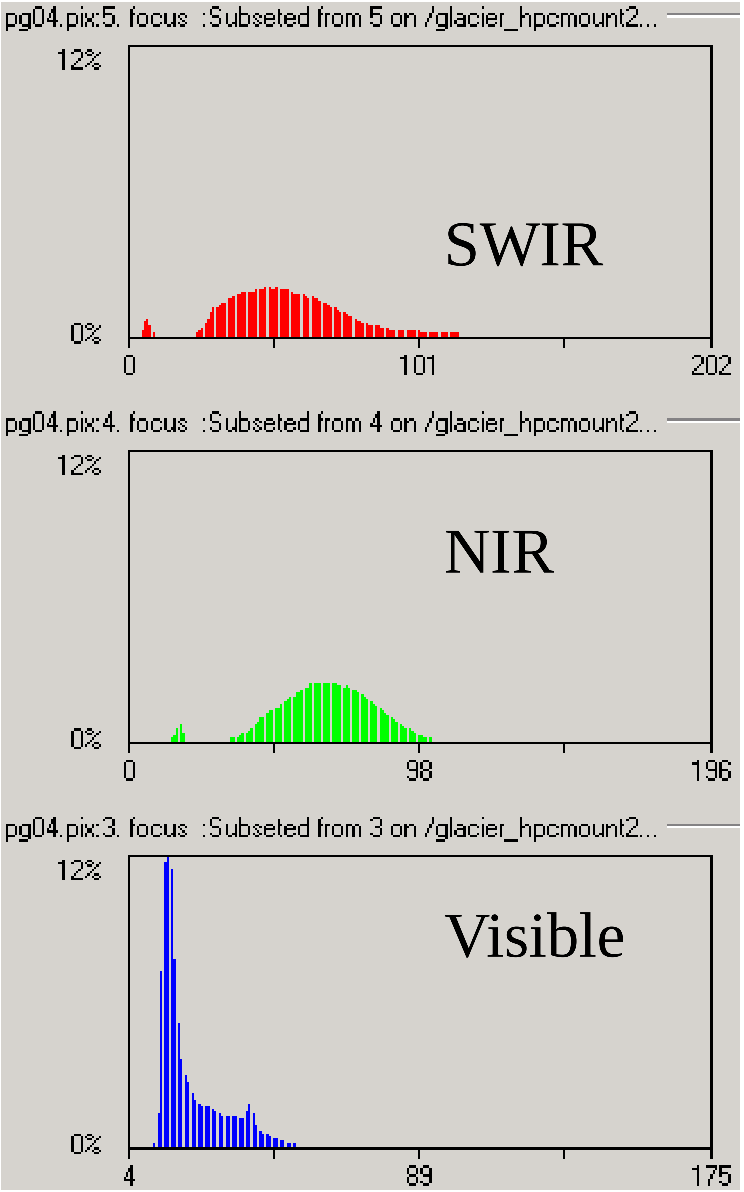
From Wikipedia



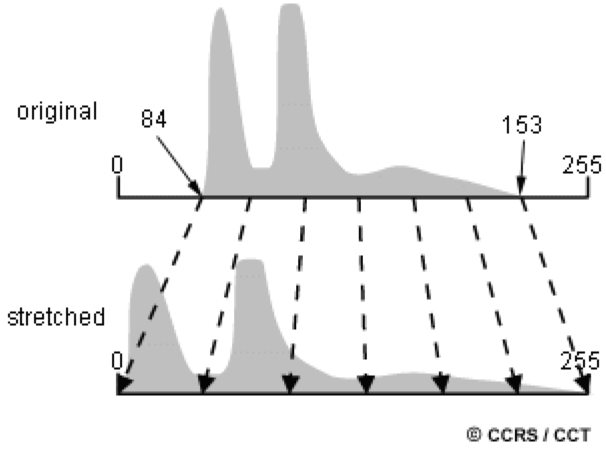


http://www.nrcan.gc.ca/earth-sciences/geography-boundary/remote-sensing/fundamentals/2187

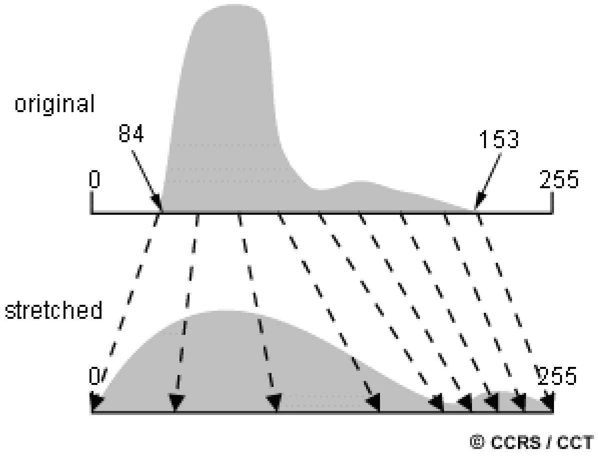
Contrast stretch / enhancement as DNs do not fill the display range



Linear stretch



Root stretch



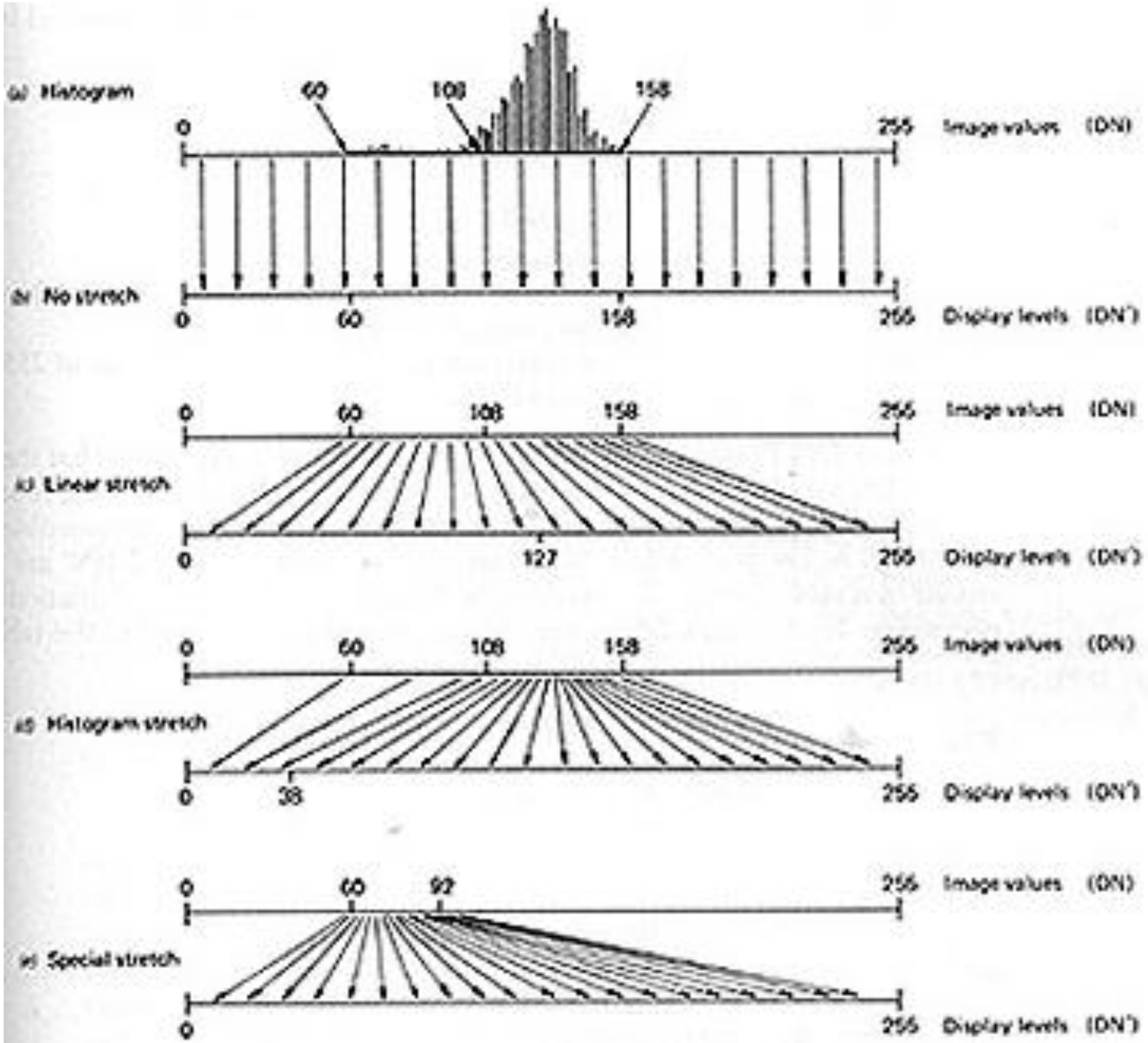
A histogram plots the Digital Numbers (DN) e.g. 0-255, on the x-axis against the frequency of values with those DNs.

None

Linear

Root

Special



Stretching is the manipulation of display colours to fit the DN ranges:

Final note on Stretches:

Enhancement is based on screen display

Based on whole scene

Based on zoom into UNBC campus

Screen enhancement does NOT affect digital numbers