No Lab on Monday 19 Sept

quick note on SWIR v MIR

Thermal IR

Division name	Abbreviation	Wavelength	Frequency
Near-infrared	NIR, IR-A *DIN*	0.75–1.4 μm	214–400 THz
Short-wavelength infrared	SWIR, IR-B *DIN*	1.4–3 μm	100–214 THz
Mid-wavelength infrared	MWIR, IR-C *DIN*; MidIR.[19] Also called intermediate infrared (IIR)	3–8 μm	37–100 THz
Long-wavelength infrared	LWIR, IR-C *DIN*	8–15 μm	20–37 THz
Far infrared	FIR	15–1,000 μm	0.3–20 THz

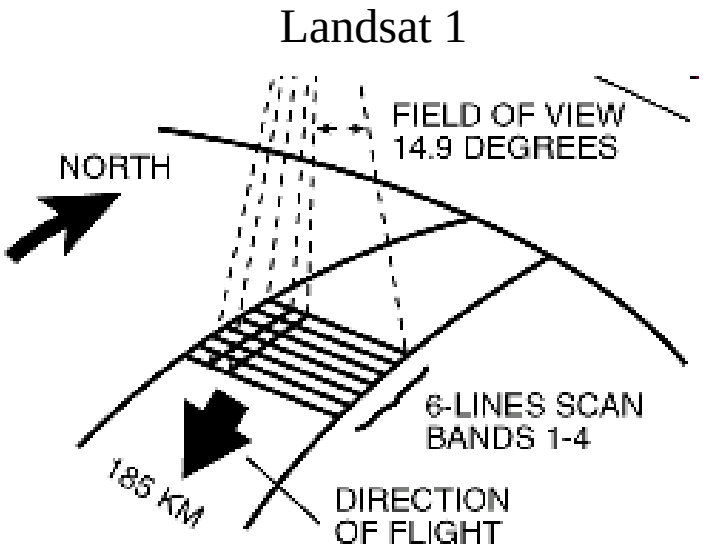
"**Shortwave radiation** (SW) describes wavelengths in the Visible, UV, and NIR spectra." !?

https://en.wikipedia.org/wiki/Infrared

DIGITAL DATA and DISPLAY

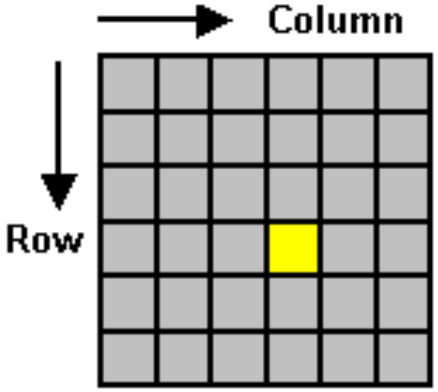
Satellite image data - capture

Onboard scanners capture the energy reflected by band (wavelength) for each pixel (picture element) by row and column

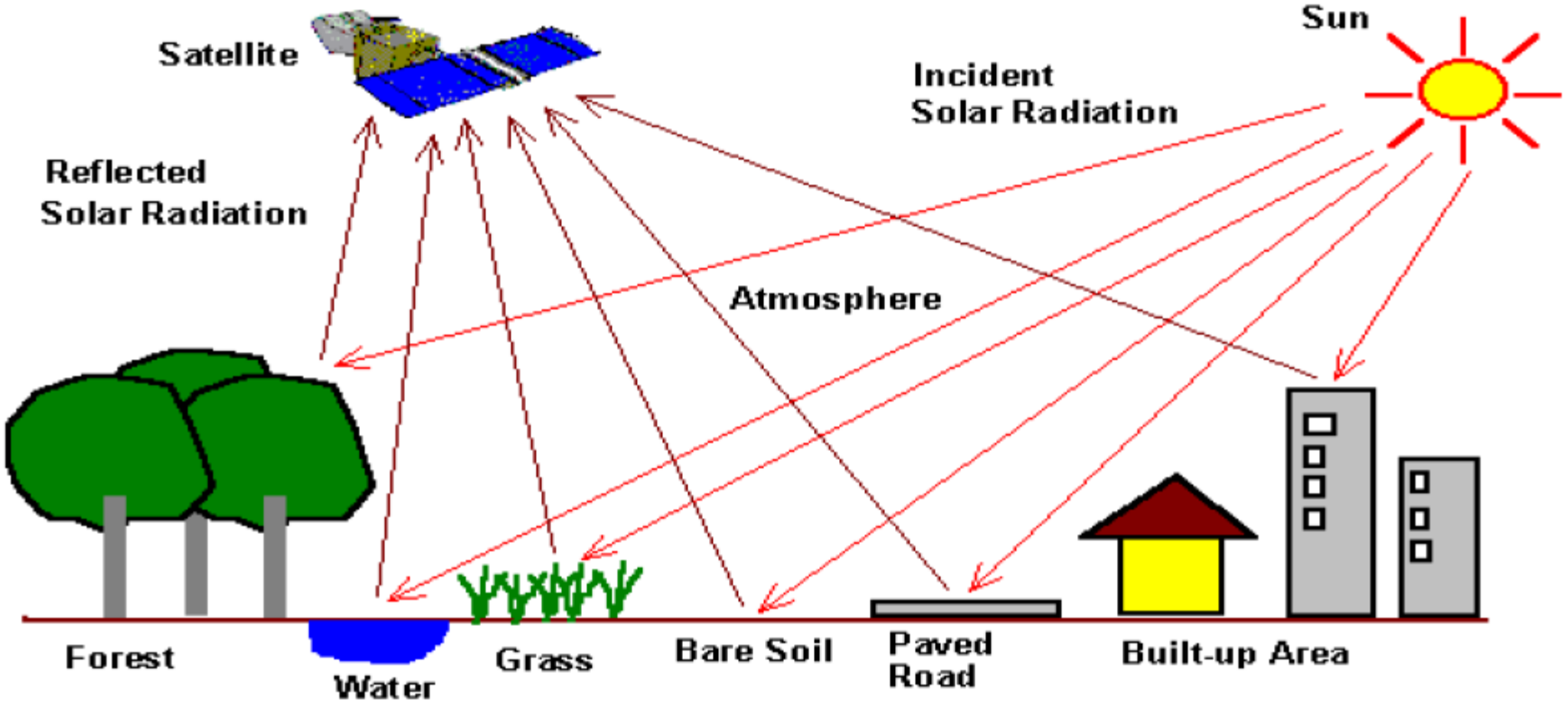


http://earthnow.usgs.gov

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



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

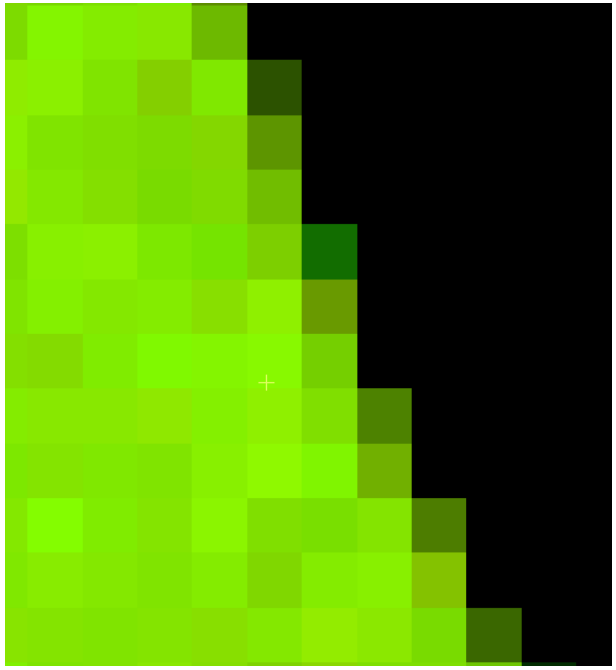


Each pixel records a digital number (DN) giving the amount of reflection

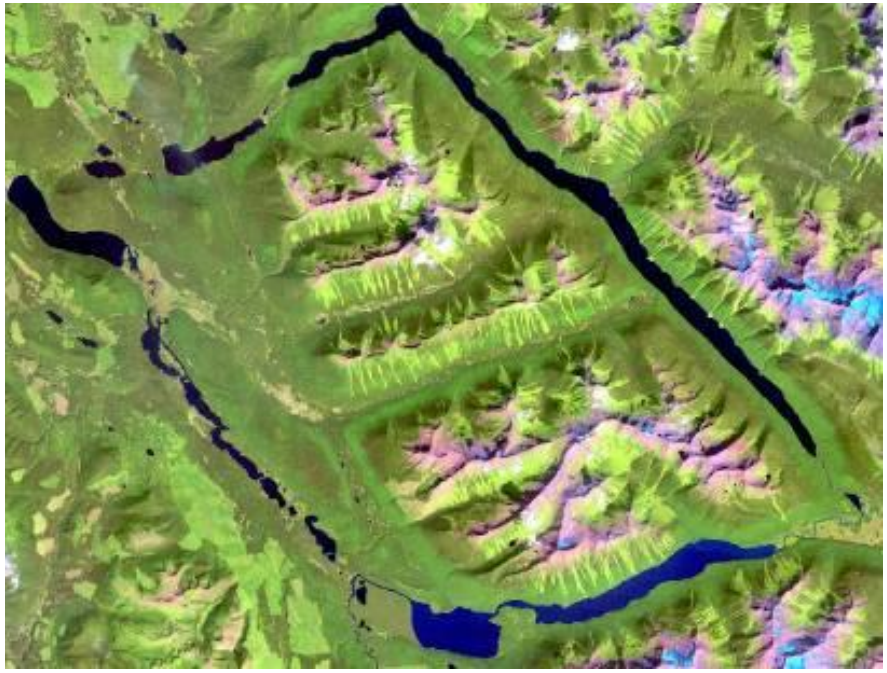
Side note: Pure and Mixed Pixels

One pixel = one digital value per layer (often 0-255)

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



Data characteristics: Spatial resolution (pixel size)

Hurricane Katrina (2004)

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

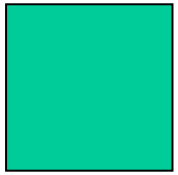
Medium res: 50-500m

Low res: > 500m (1km +)

Radiometric resolution

Scanner input (amount of reflectance) is converted from a continuous (decimal) 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.

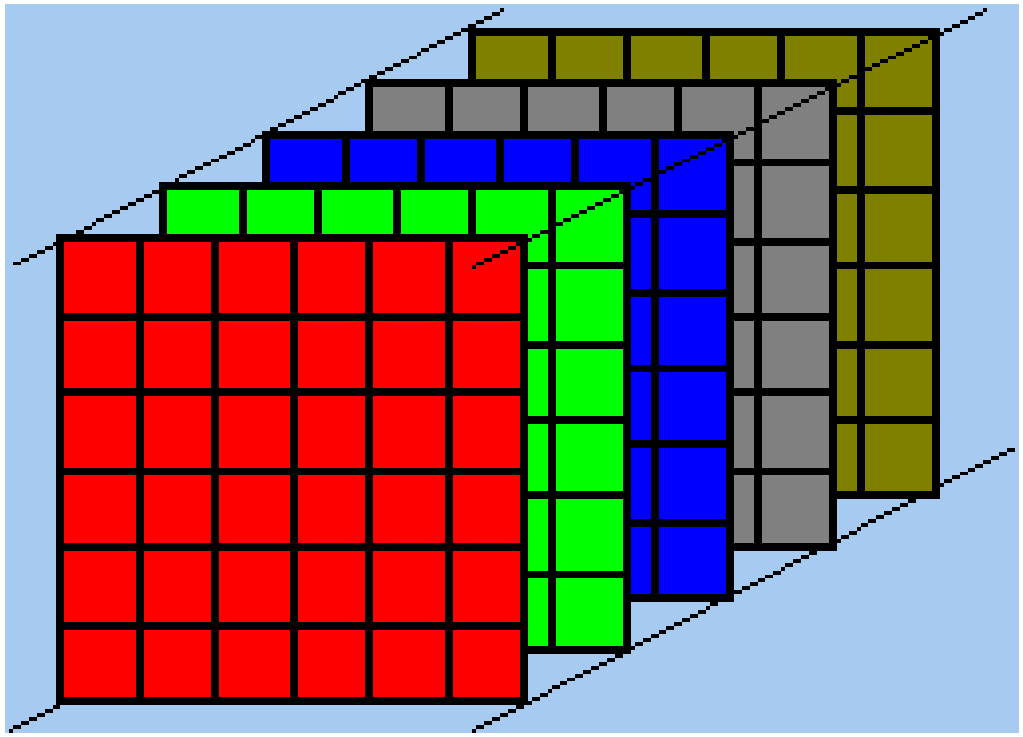


- Each value can range e.g. from 0 (no reflection) to 255

- They can be converted back to (decimal) radiance in 'real' numbers if required. Not often done in Intro RS !

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

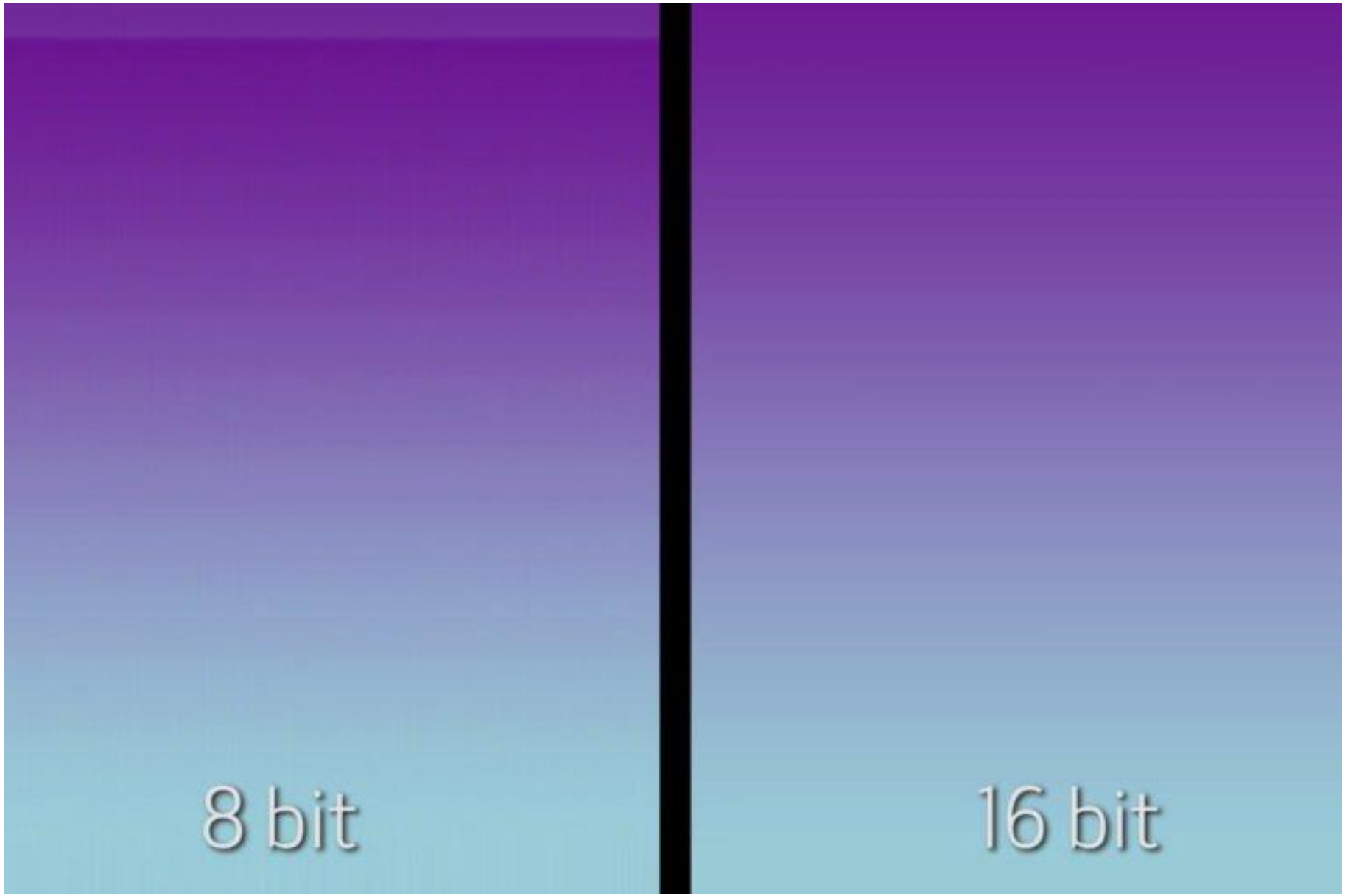
Powers of 2	*Digital Value*
2^0	1
2^1	2
2^2	4
2^3	8
2^4	16
2^5	32
2^6	64
2^7	128
2^8	256
2^9	512
2^{10}	1024
2^{12}	4096
2^{16}	65,536

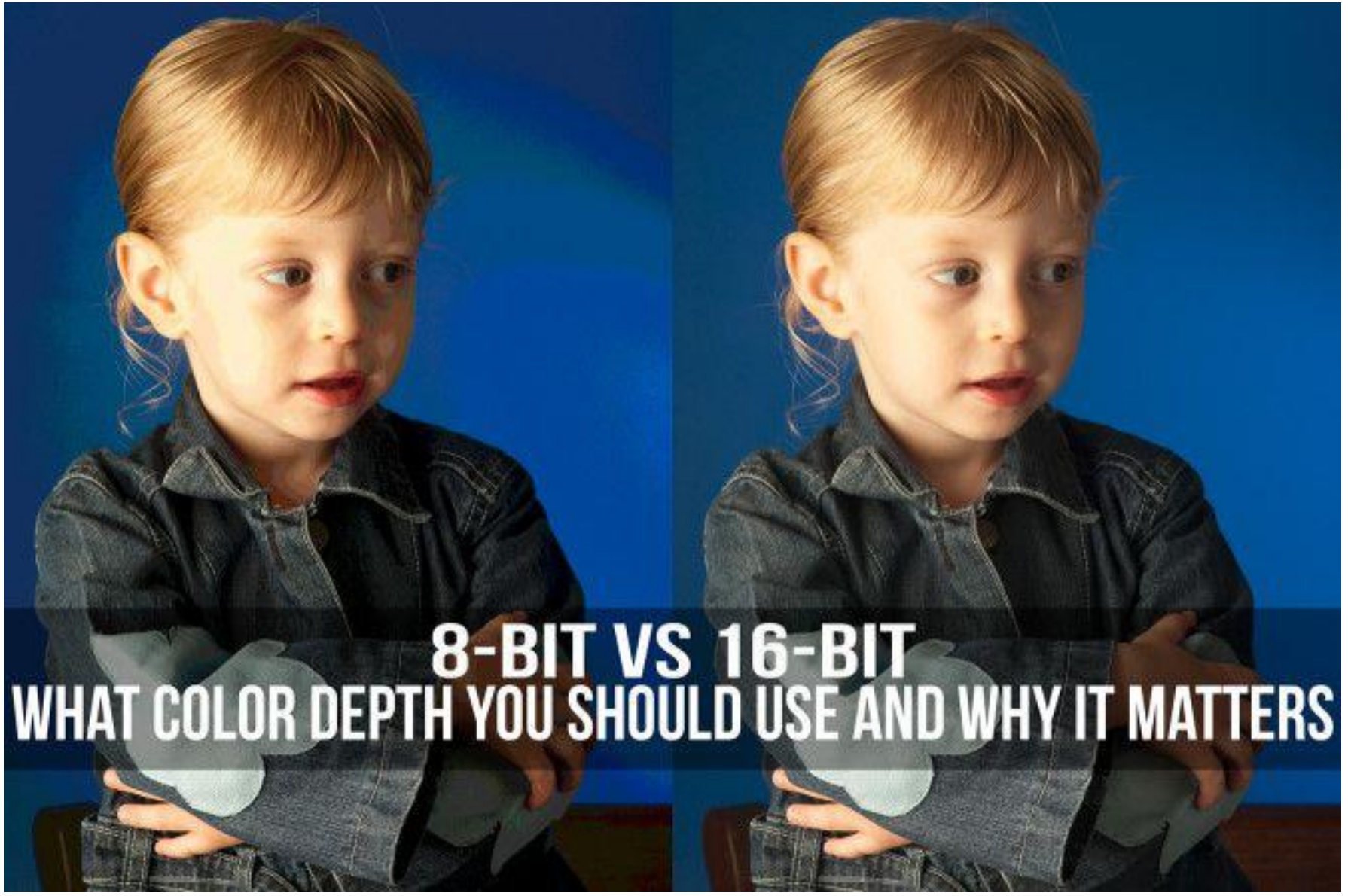
Bitmap layer = 0,1

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

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

16 bit data 2013->

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

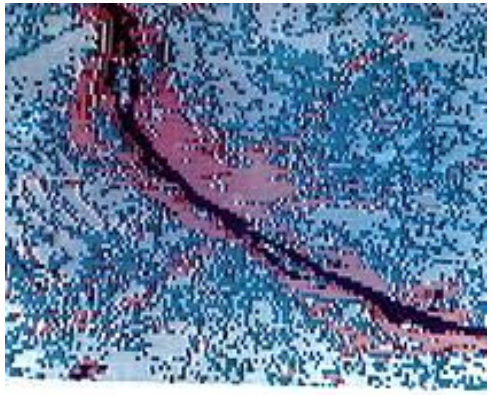
Landsat 4-5 Thematic Mapper (TM) and Landsat 7 Enhanced Thematic Mapper Plus (ETM+)

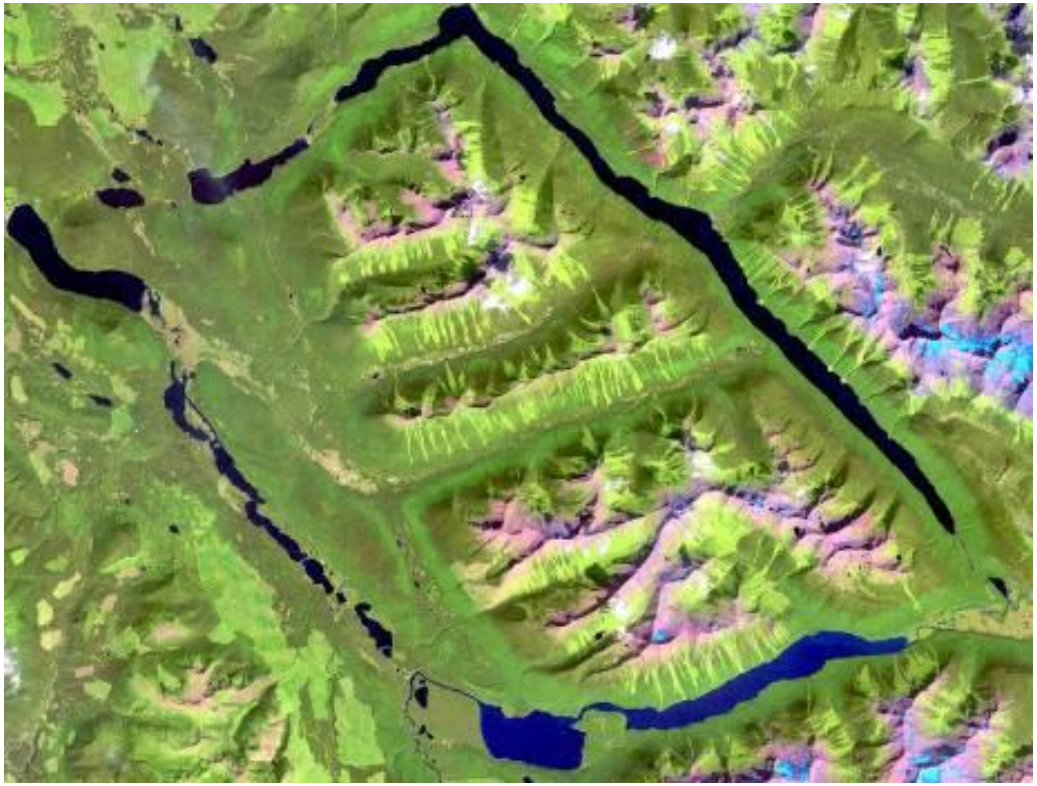
Band	Wavelength	Useful for mapping
Band 1 - Blue	0.45 - 0.52	Bathymetric mapping, distinguishing soil from vegetation, and deciduous from coniferous vegetation
Band 2 - Green	0.52 - 0.60	Emphasizes peak vegetation, which is useful for assessing plant vigor
Band 3 - Red	0.63 - 0.69	Discriminates vegetation 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

8 bit data 1982-2011

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)
(= potential 256 x 256 x 256 different colours ~16 million – but never this many)
early PCs had fewer e.g. 2 bit = 4 colours (1982) and 8 bit = 256 colours (1990)





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 are not 'bands' e.g. DEMs, classifications

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

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

Other: .tif (geotiff) – usually 3

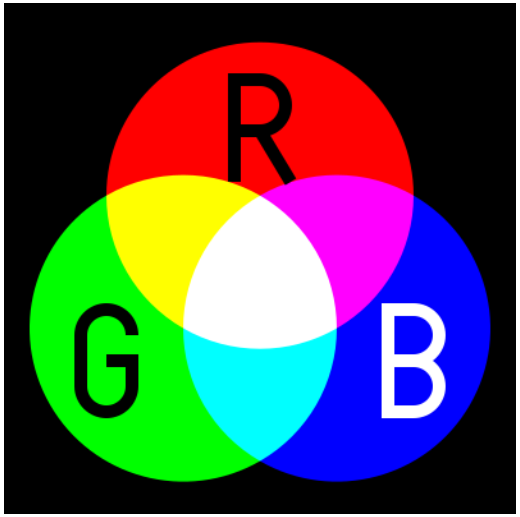
Bands are usually stored in the same sequence in the database

e.g. Band 1 in channel 1, band 2 in channel 2 etc... (unless you enjoy strife :)

Display: RGB Guns

RGB the three colour display guns (Red, Green, Blue)

A monitor has 3 guns (RGB), only 3 bands can be displayed at one time



http://www.colorspire.com/rgb-color-wheel

Display Modes
A: Colour composites

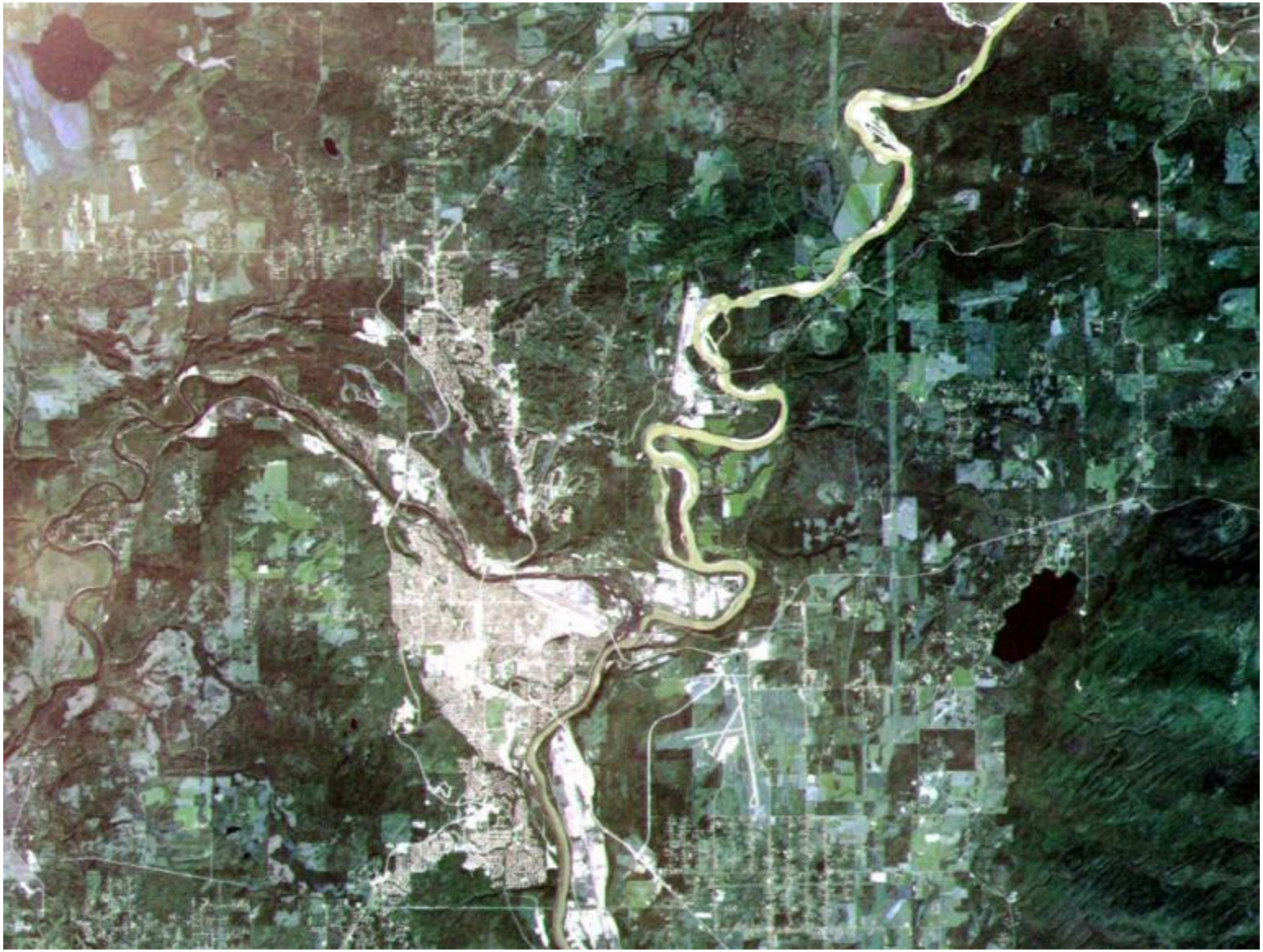
•Three different channels compose a **RGB colour composite**: any three channels can be selected. Selecting TM band 1 in Blue, 2 in Green and 3 in Red displays a 'normal colour' composite.

•But software automatically loads these in reverse as the display is 'RGB' … so 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. 742 or 541

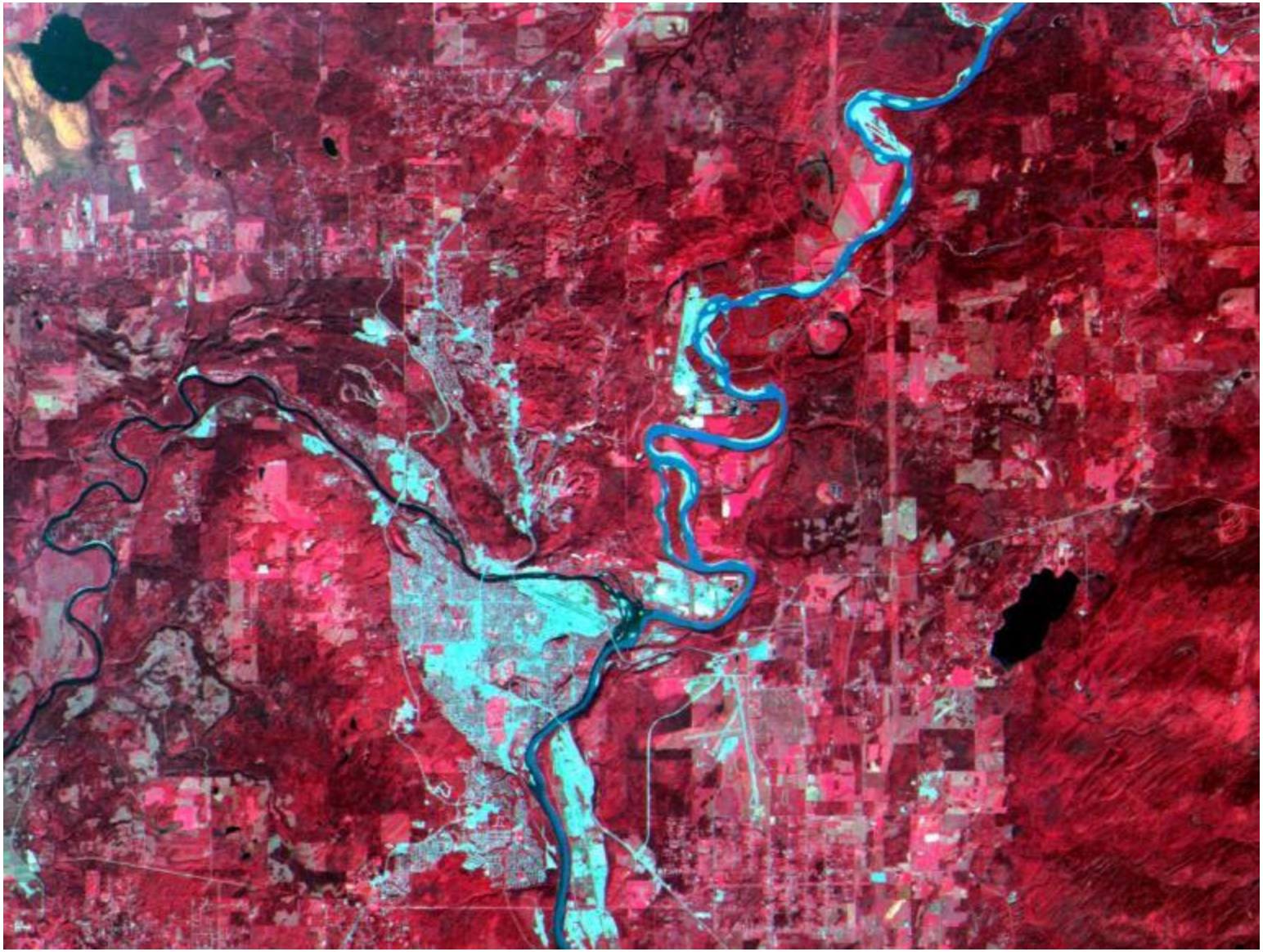
http://www.geo.mtu.edu/rs/keweenaw/

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

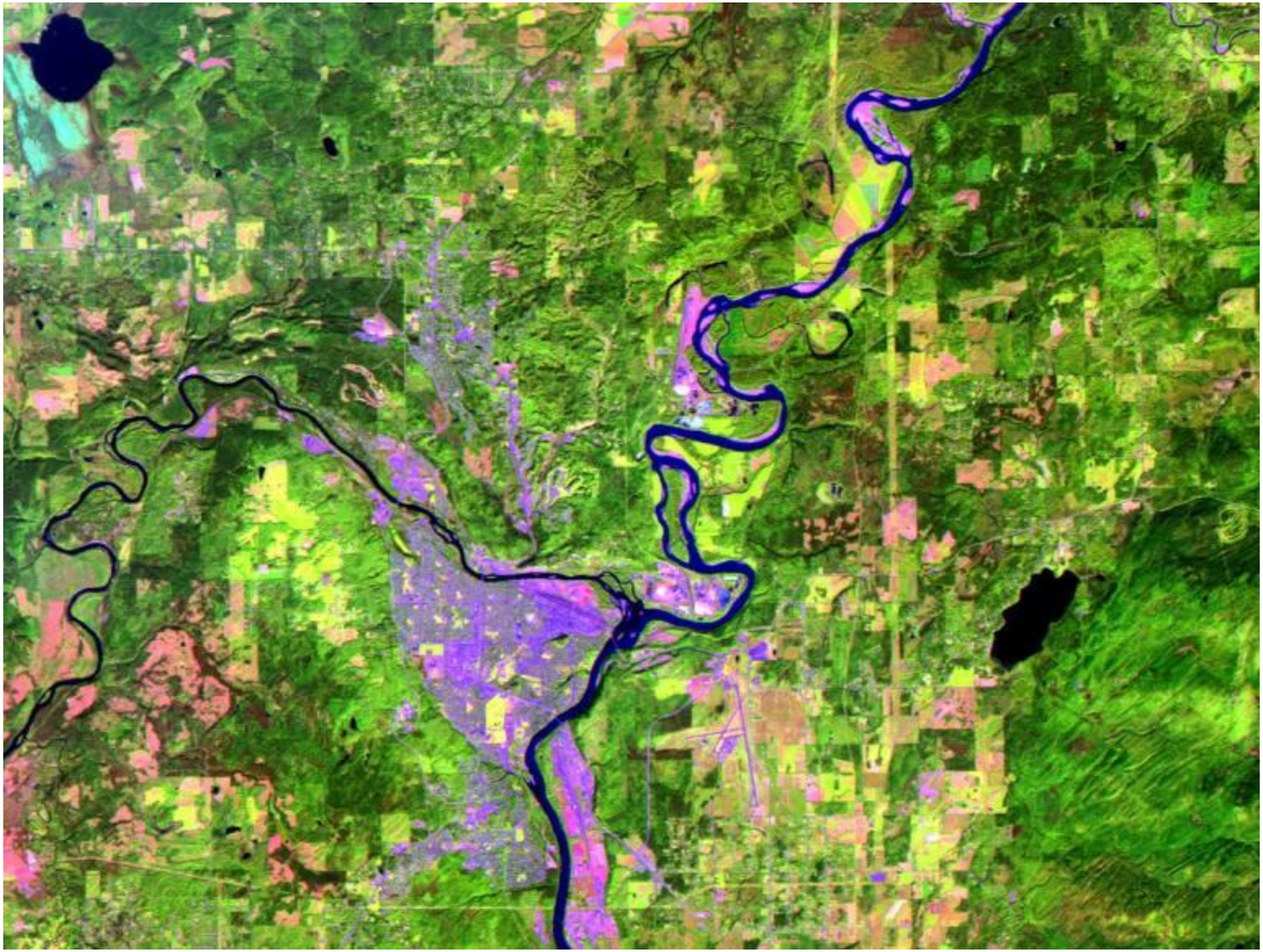


Red-Green-Blue (3-2-1)

‘False’ colour (4-3-2)



TM 543 stretched



Other display modes: Single band displays

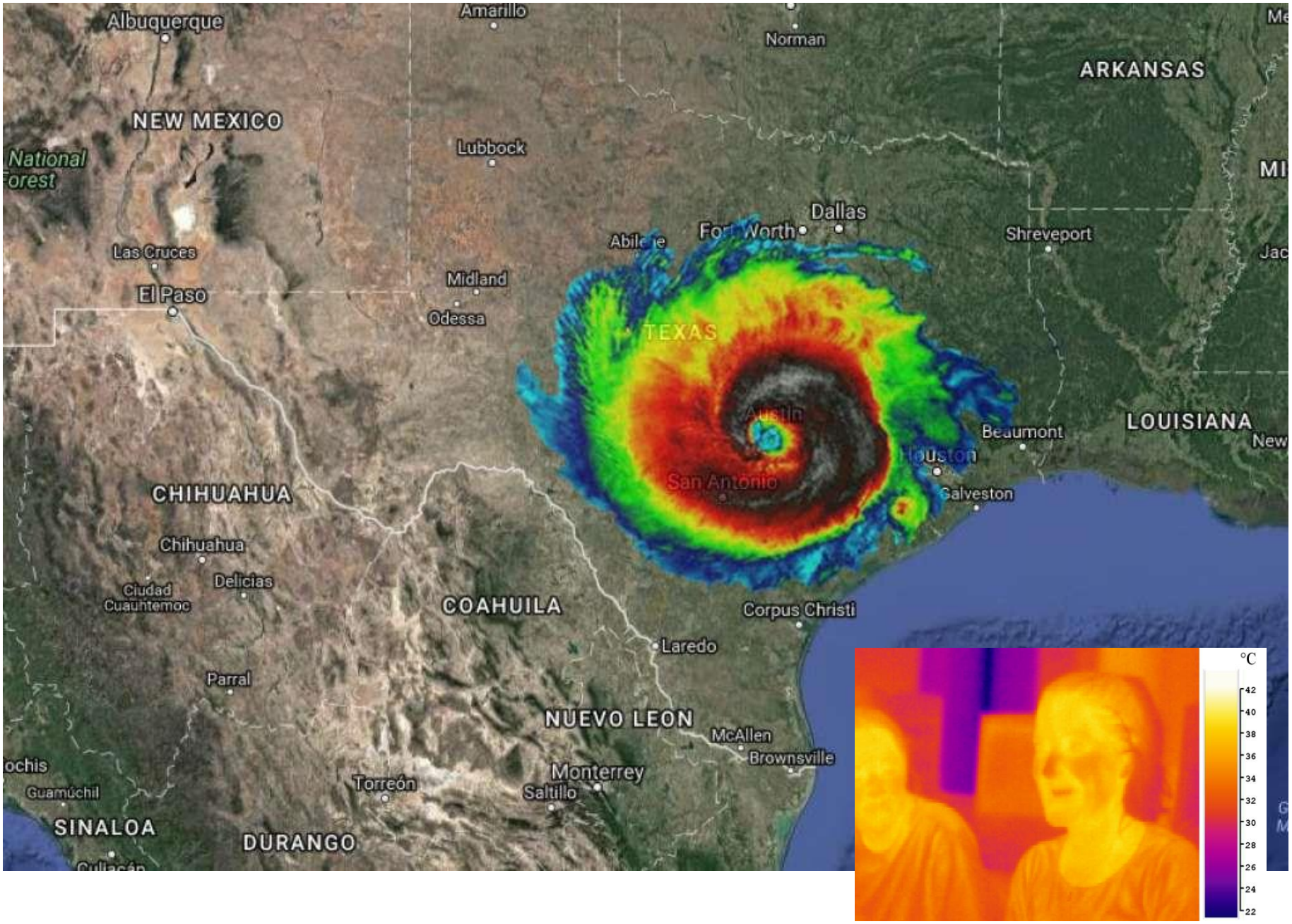
B. Grayscale C: Pseudocolour

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 thematic layers, Also thermal bands

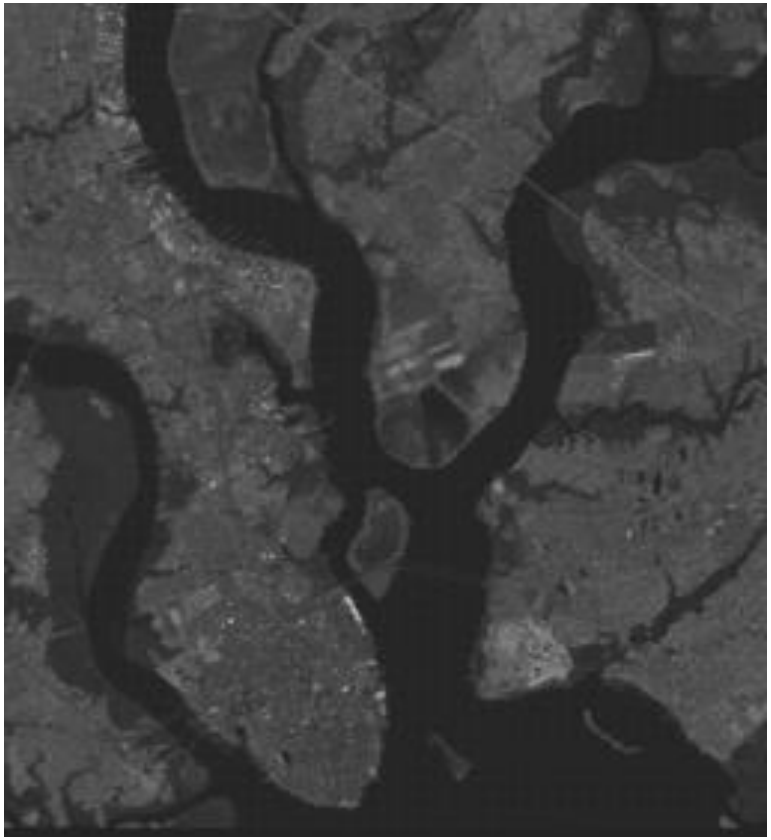
a. Colour composite b.Grayscale c.Pseudocolour

Pseudocolour display – Hurricane Harvey (2017)- colours represent temperature



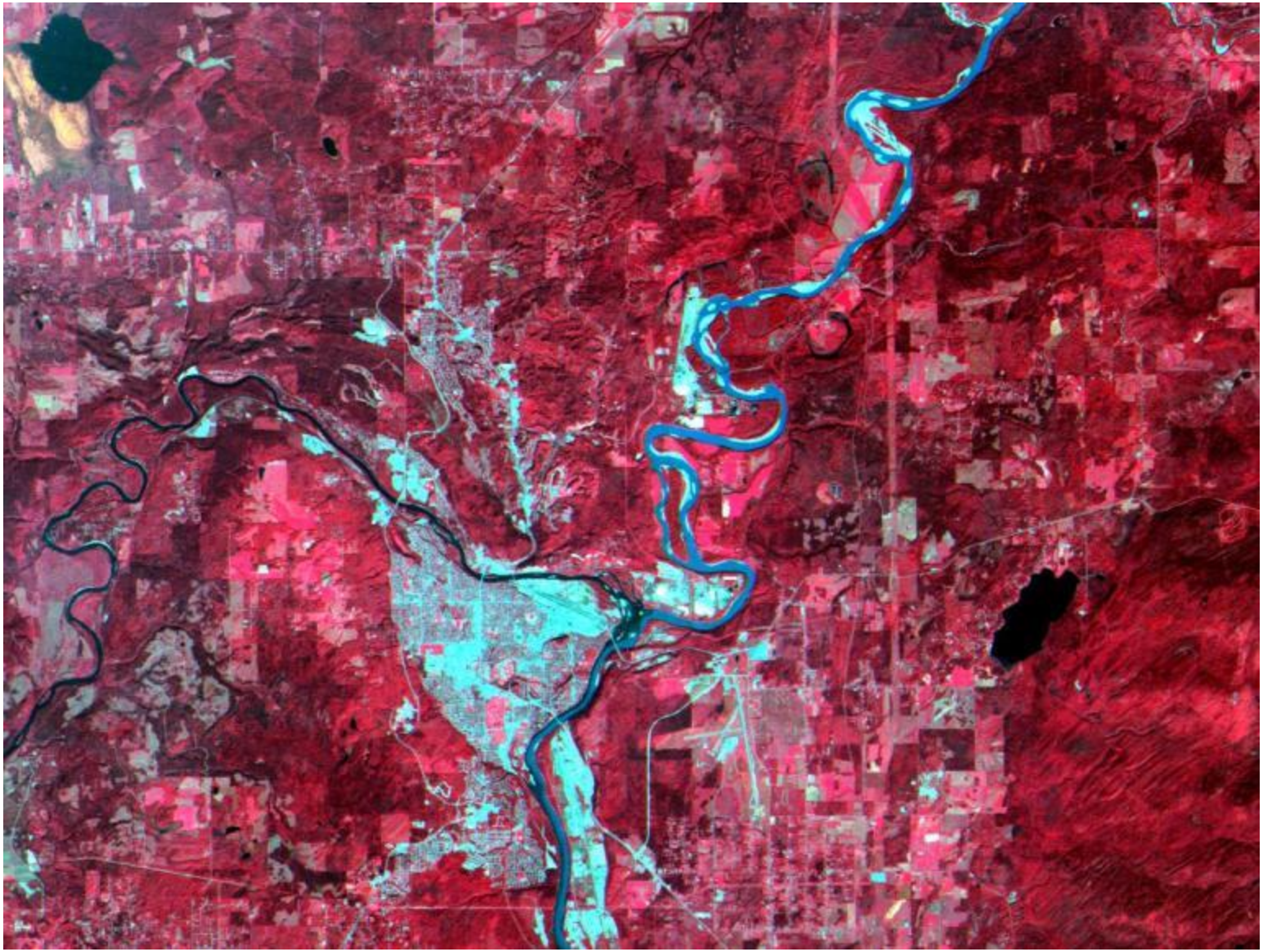
Enhancement / Histogram Stretching

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



False colour Unstretched

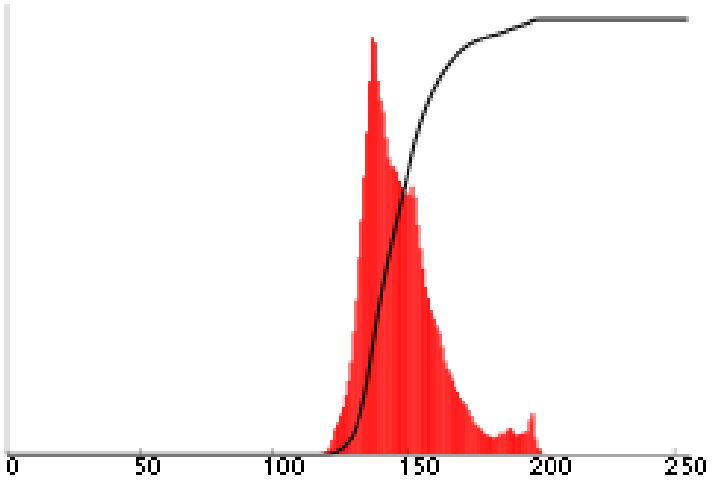
‘False’ colour (4-3-2) enhanced

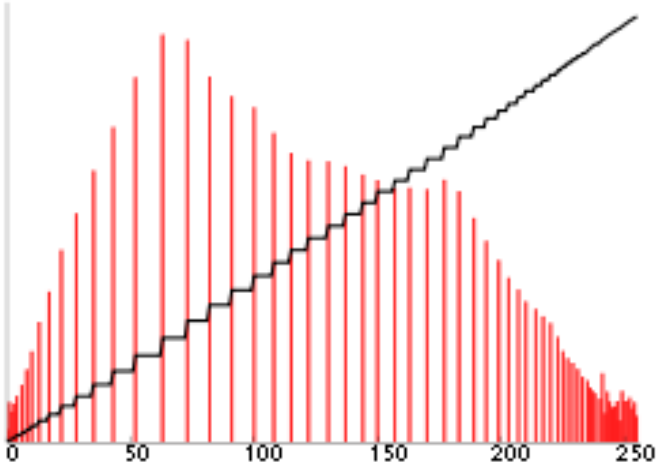


Histogram equalization / contrast stretching / image enhancement

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

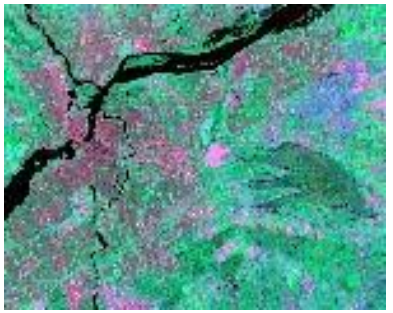
From Wikipedia

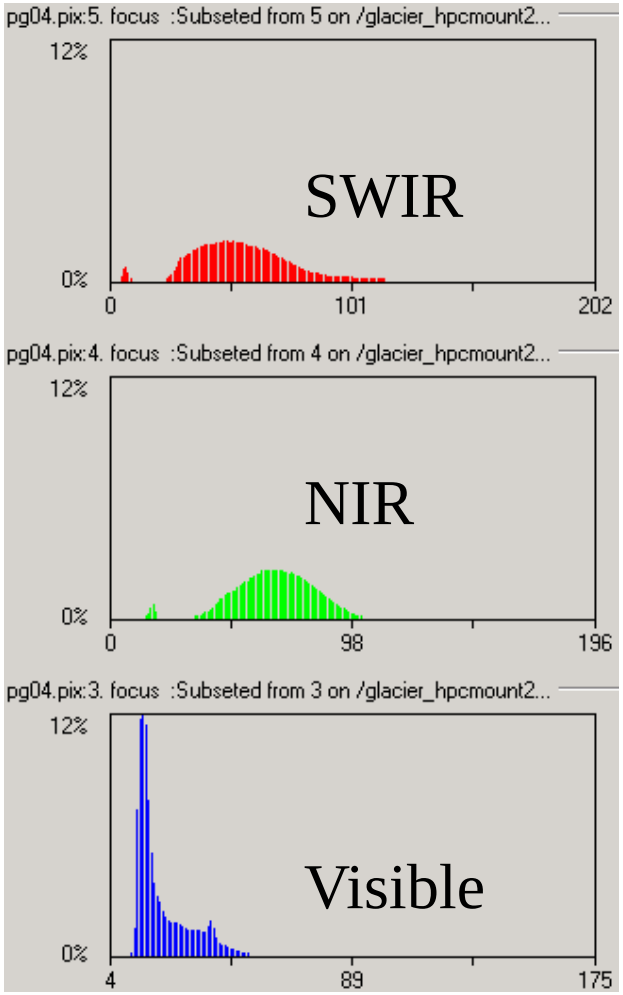


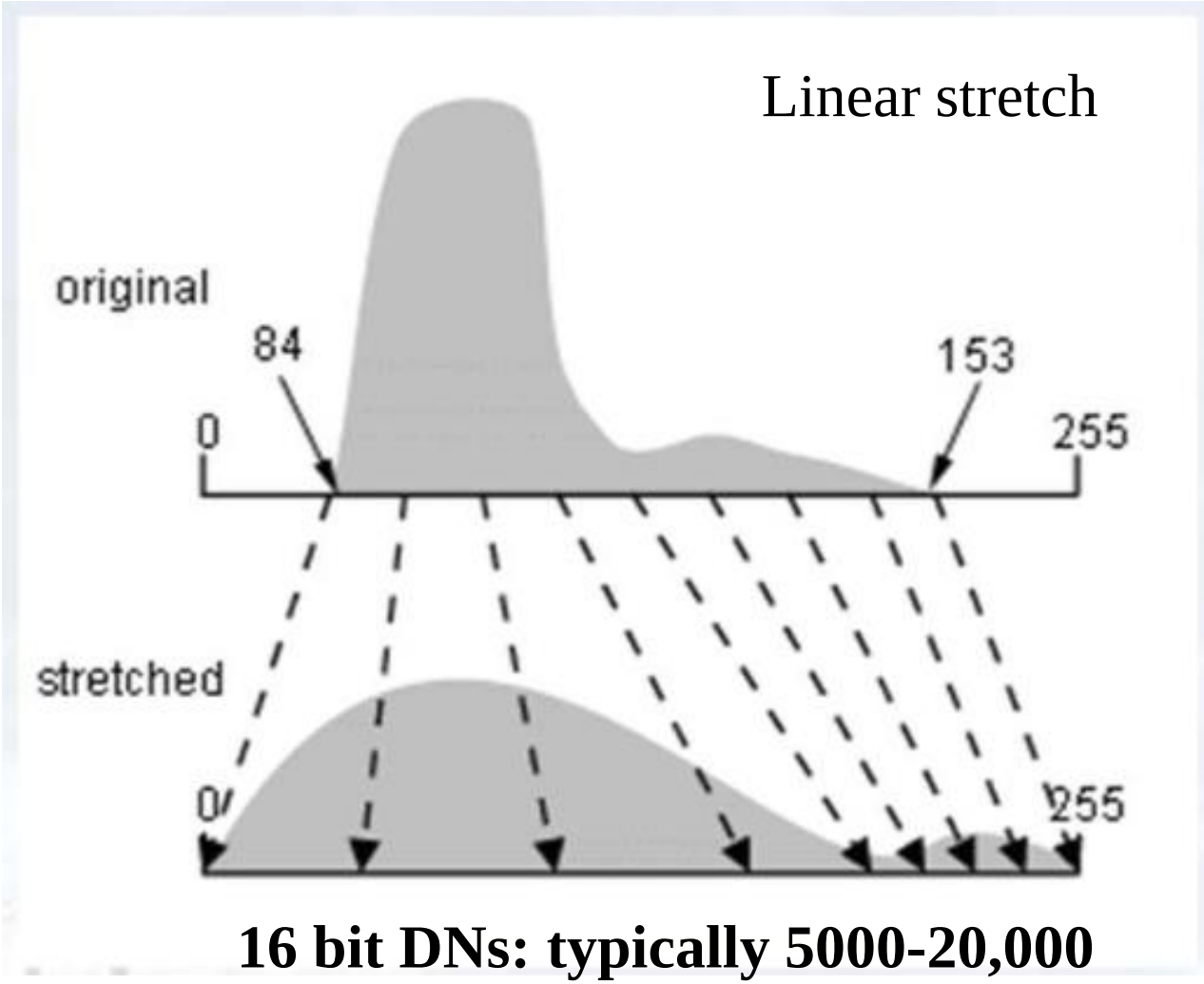


http://www.nrcan.gc.ca/earth-sciences/geography-boundary/remote-sensing/fundamentals/2187

Contrast stretch / enhancement
DNs do not fill the display range







16 bit DNs: typically 5000-20,000

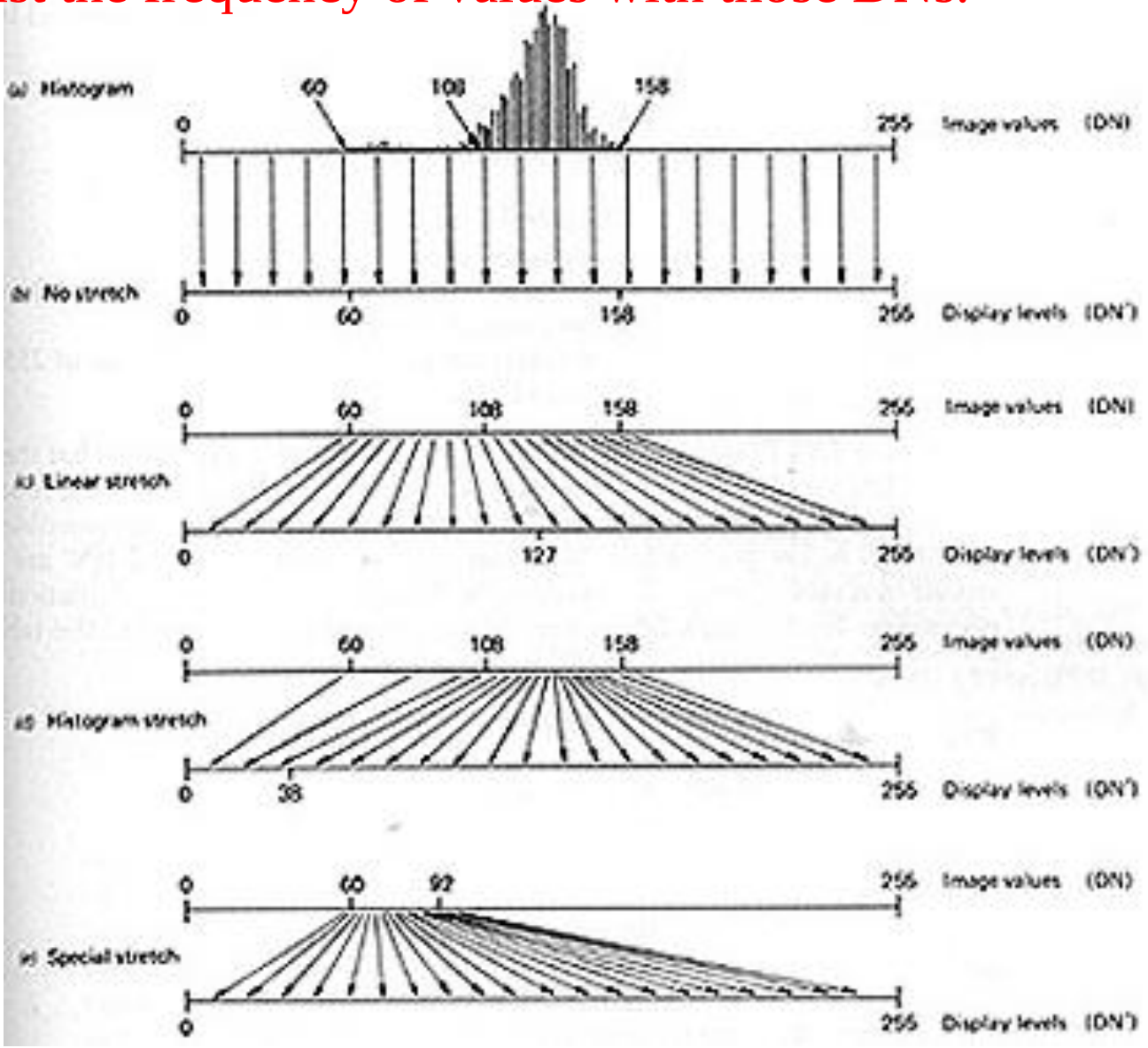
A histogram plots the Digital Numbers (DN) e.g. 0-255, on the x-axis against the frequency of values with those DNs.

None

Linear

Root

Special



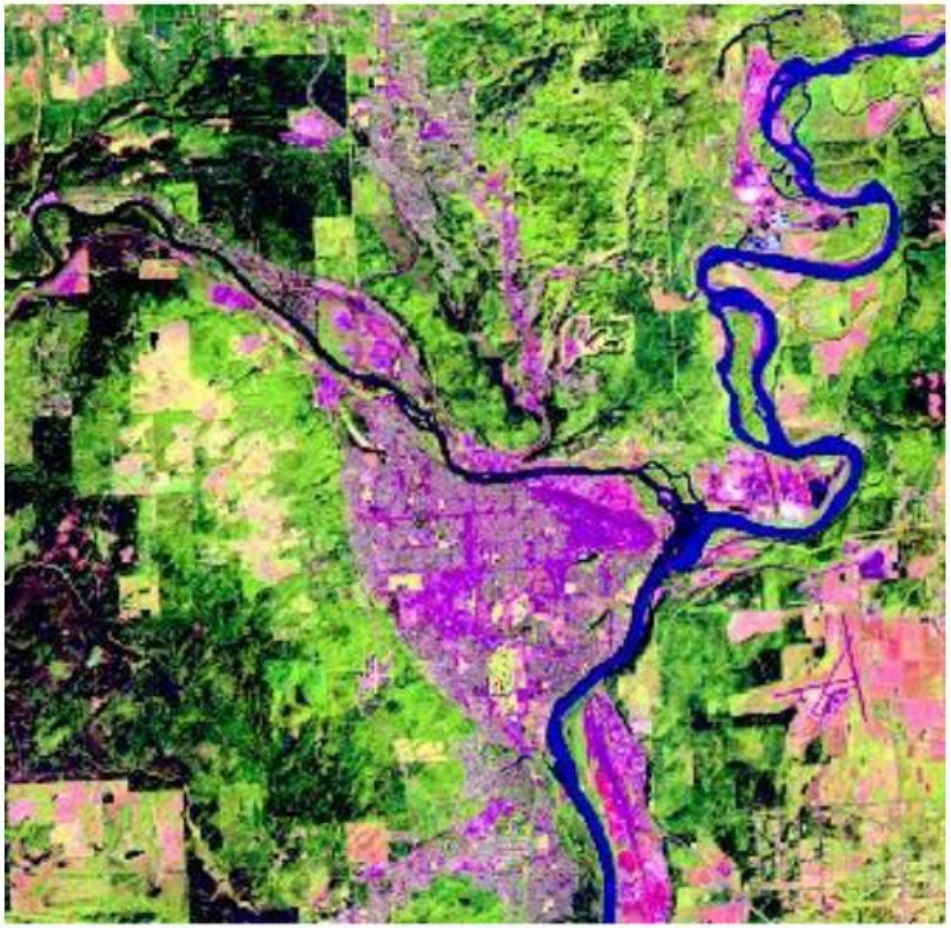
Stretching is the manipulation of display colours to fit the DN ranges:

Enhancement is based on screen display

Based on whole scene

Based on zoom into UNBC campus

Screen enhancement does NOT affect digital numbers - **For visual display only**



Digital data summary

ground, aerial, satellite

1984-2012: mostly 8-bit 0-255

2013-> mostly 16-bit 0-63,536

= higher radiometric resolution

also greater complexity / detail

[e.g. RGB no longer a 1:1 ratio in display (0-255)]

16-bit data enables up to 16 million colours !

(only theoretically possible with 8 bit data)

See next lab (2) –we'll view both 8 bit and 16 bit Landsat data