GEOG 357

LECTURE 3

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Digital Imagery and Data Display

- Much of the early remote sensing was done with photographs or photolike images
  - Referred to as analog because brightness in the photograph is proportional (analogous) to the brightness in the captured scene
- In contrast, a digital image has a graticule of individual values known as pixels ("picture elements").
  - Discrete numbers (digital numbers) can be subjected to arithmetical and statistical operations
  - Provides compact storage; easy and inexpensive retrieval, transmission, display

Presentation Title 2

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Digital Imagery

- A pixel represents the brightness of a small region on the Earth's surface,
  - recorded digitally as a numeric value
  - separate values for each of several regions of the electromagnetic spectrum. Same patch on the ground, multiple values for the different wavelengths of the EM spectrum
  - images are composed of several such arrays of the same ground area, each representing brightnesses in a separate region of the spectrum.

Digital Imagery

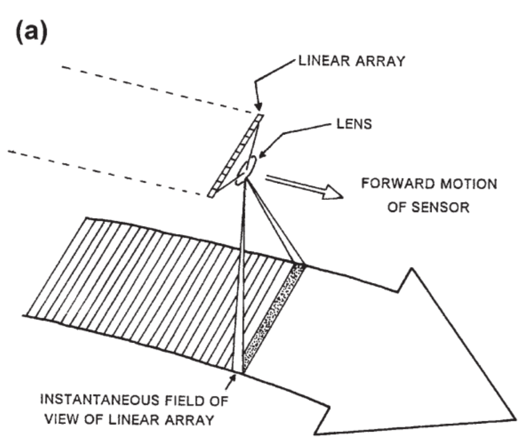
- Digital images are generated by several kinds of instruments
  - charged-coupled devices (CCDs)
    - Linear or two dimensional array of detectors, all exposed at the same time
    - Each detector collects photons that strike its surface and accumulates an electrical charge proportional to the intensity of the radiation it receives.
    - The digital value is derived from the electrical charge
  - complementary metal oxide semiconductor (CMOS) chips
    - An array of detectors, exposed one line at a time.
    - Therefore, the pixels representing a scene are not exposed at the same instant.

Digital Imagery

- Digital images are generated by several kinds of instruments
  - optical-mechanical instruments
    - physically move mirrors, or prisms, to systematically capture a scene
    - Radiation from the earth's surface directed to detectors that generate an electrical current that varies in intensity analogous to the earth's surface
    - Filters or diffraction gratings split the radiation into several segments to define separate spectral channels/bands
    - the electrical signal is subdivided into distinct units to create the discrete values necessary for digital analysis.

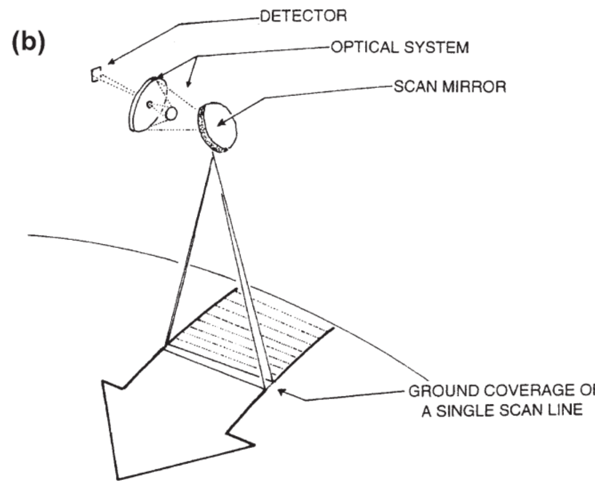
Digital Imagery

- Digital images are generated by several kinds of instruments
  - optical-mechanical instruments
    - The conversion from the continuously varying analog signal to the discrete values is accomplished by sampling the current at a uniform interval, a process known as ***analog-to-digital***.
    - Because the values within this interval are represented as a single average, all variation within this interval is lost.
    - The process of averaging the continuous signal corresponds to sampling the terrain at a set spatial interval
      - Therefore, the choice of sampling interval establishes the spatial detail recorded by the image.



LINEAR ARRAY

e.g of a CCD design



OPTICAL–MECHANICAL SCANNER

Oscillates from side to side

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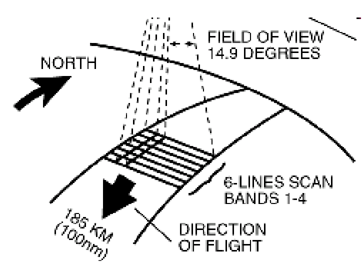
Satellite image data – capture

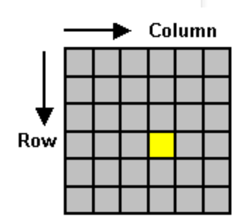
- Onboard scanners capture the energy reflected by band (wavelength) for each pixel (picture element) by row and column (captured row by row)

http://earthnow.usgs.gov

- Data are recorded in a continuous swath and then cut into scenes several thousand pixels in x and y.
- Electronic sensors must be operated within the limits of their design capabilities.
  - Altitudes and speeds of aircraft and satellites must be selected to match the sensitivities of the sensors, so that detectors view a given ground area (pixel) long enough to accumulate enough photons to generate reliable signals.

Landsat 1





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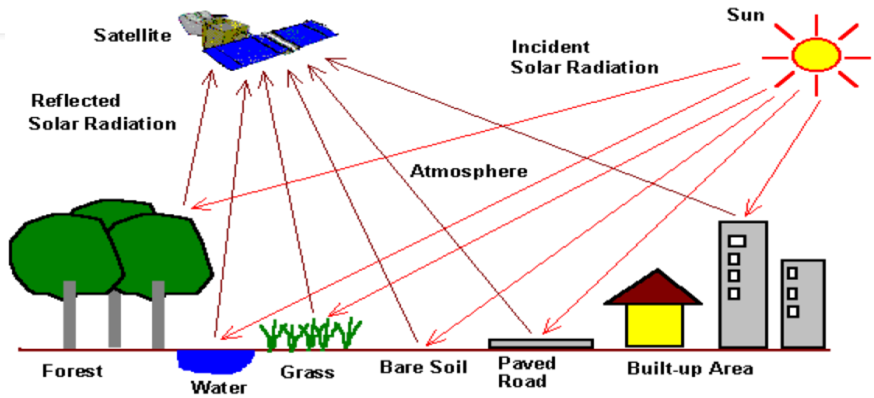
Data = digital measure of energy reflected/emitted from ground
(or reflection recorded on film in the case of photographs)



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

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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 +)

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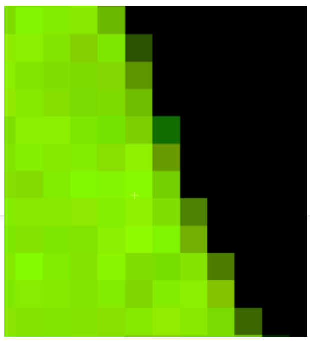
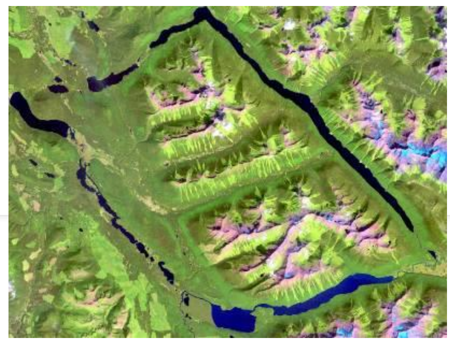
Side note: Pure and Mixed Pixels

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



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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 .. *commonly 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 (for 8 bit data)
- They can be converted back to radiance in 'real' numbers if required.

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

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Digital Numbers

- 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).
- Each bit records an exponent of a power of 2, with the value of the exponent determined by the position of the bit in the sequence.
  - For the sake illustration, consider a system designed to record 7 bits for each digital value.

Digital Numbers

- Example with 7 bits of data
  - 7 binary places are available to record the brightness
  - "1" signifies specific powers of 2 determined by its position in the sequence, "0" signifies a zero in that position
    - "1111111" => $2^6 + 2^5 + 2^4 + 2^3 + 2^2 + 2^1 + 2^0$
      $= 64 + 32 + 16 + 8 + 4 + 2 + 1$
      $= 127$.
    - "1001011" => $2^6 + 0^5 + 0^4 + 2^3 + 0^2 + 2^1 + 2^0$
      $= 64 + 0 + 0 + 8 + 0 + 2 + 1$
      $= 75$.

Digital Numbers

- These are integer numbers .. *commonly 8-bit (256 values)* for easier handling and smaller overall file size.
    - one value per pixel per band
- Eight bits constitute a byte, intended to store a single character.

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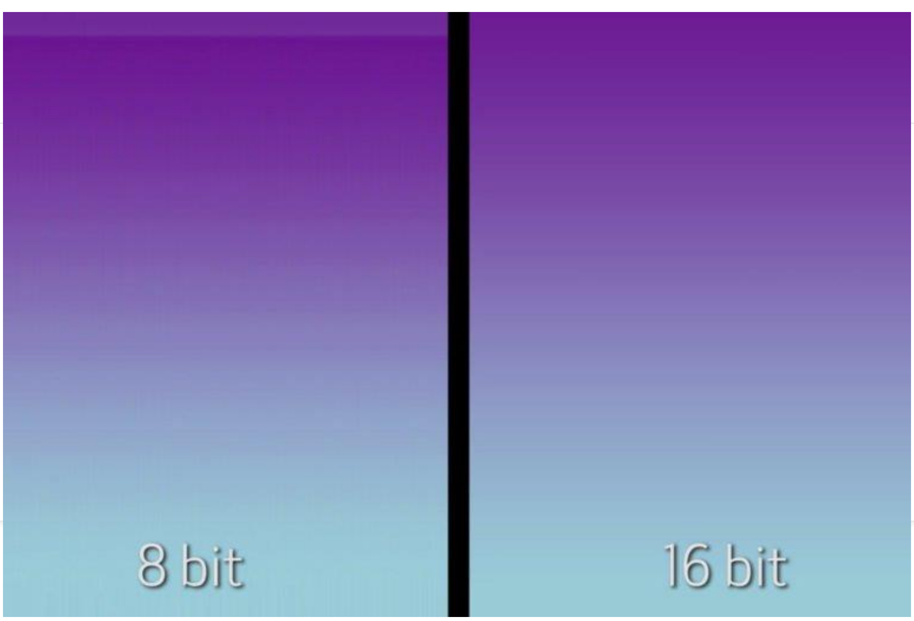

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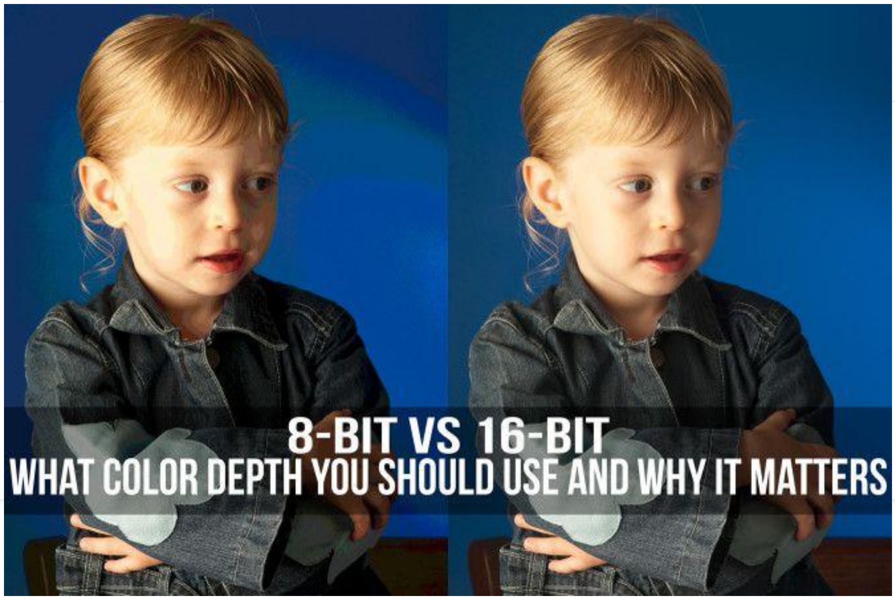

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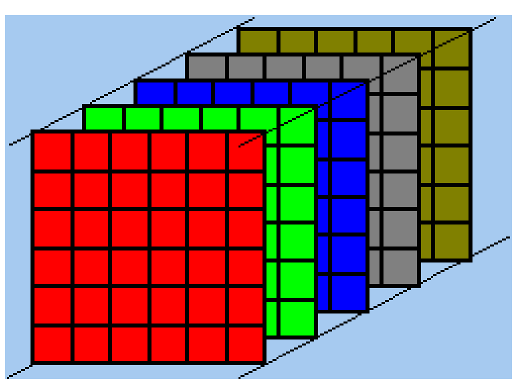
Digital Numbers (DN)

- Each 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



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Landsat 4,5 Thematic Mapper bands (1982-2011)
- also Landsat 7 1999-> present (?)

Band No.	Wavelength Interval (µm)	Spectral Response	Resolution (m)
1	0.45 - 0.52	Blue-Green	30
2	0.52 - 0.60	Green	30
3	0.63 - 0.69	Red	30
4	0.76 - 0.90	Near IR	30
5	1.55 - 1.75	Mid-IR	30
6	10.40 - 12.50	Thermal IR	120
7	2.08 - 2.35	Mid-IR	30

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

1984-2011

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Data Display

- Effective display of an image is critical for remote sensing.
  - *Band combinations* is the term used to refer to the assignment of colors to represent brightnesses in different regions of the spectrum. It is for visual display

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Display: Bands, Channels, and RGB Guns

Bands scanned by the sensor (limited by the data captured)
e.g. 1-7 for Landsat TM, 1-11 for Landsat 8 OLI

Channels data layers (including bands) stored in a database: no limit

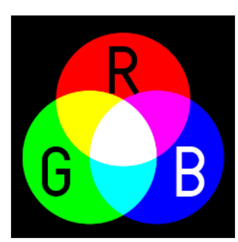
PCI: .pix
Esri: .img [.grd]
Other: .tif (geotiff)

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

CRT – display guns; LCD – essentially filters

A monitor has 3 primary colors (RGB), so only 3 bands can be displayed at the same time

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



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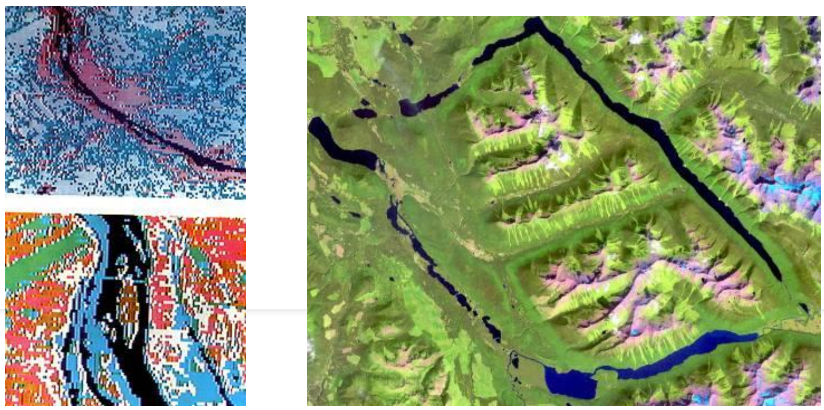
Data display

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)



Note: we can display more vector than raster layers as they are 'discrete'

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Display Modes
A: Colour composites (Band Combinations)

- 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 4-3-2 combination is similar to false colour film.
- 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/

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

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

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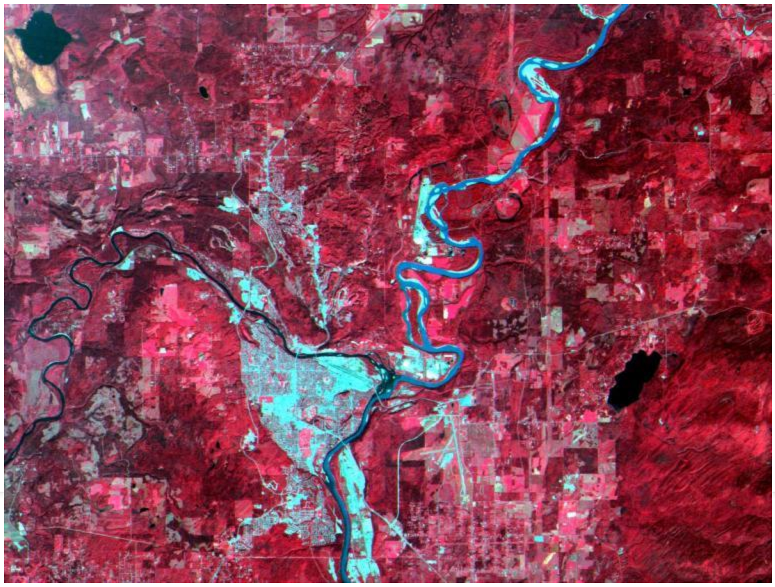
‘False’ colour (4-3-2)



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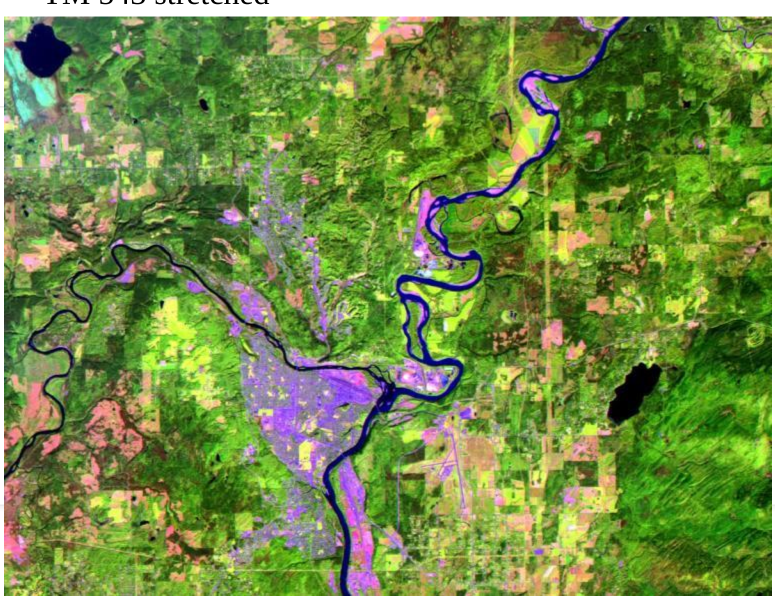
TM 543 stretched



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RGB screens (Red-Green-Blue)

Default display: 1-2-3 to RGB

Band	**Colour gun**	Flip B and R !
Blue ->	Red	
Green ->	Green	
Red->	Blue	

False colour (camouflage film)
Near-IR -> Red
Red -> Green
Green -> Blue

Maximum contrast
Mid-IR -> Red
Near-IR -> Green
Red -> Blue

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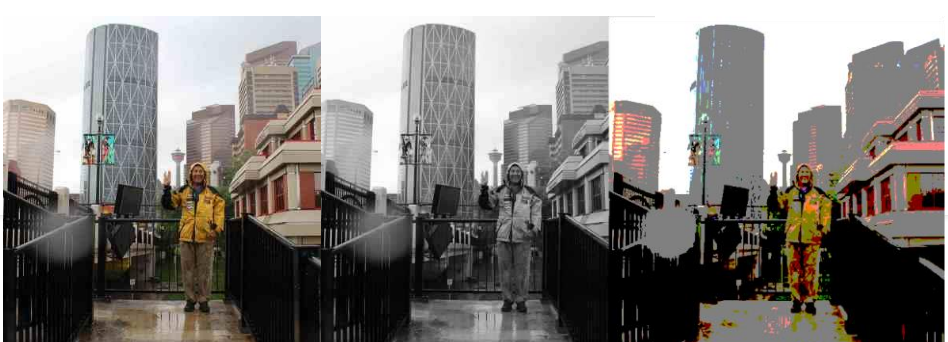
Other display modes: Single band displays B. Grayscale C: Pseudocolour

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



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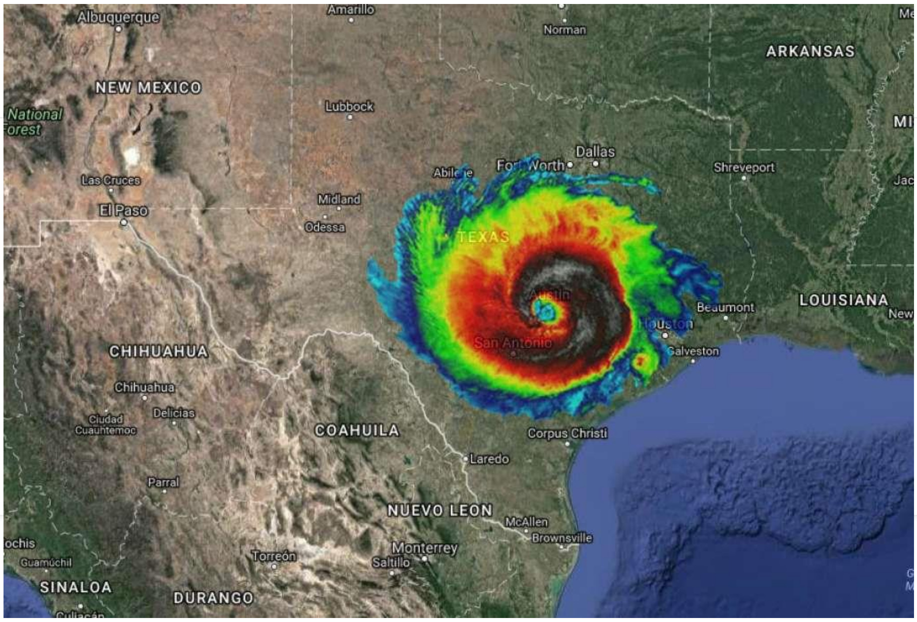
Pseudocolour display – Hurricane Harvey; colours represent temperature



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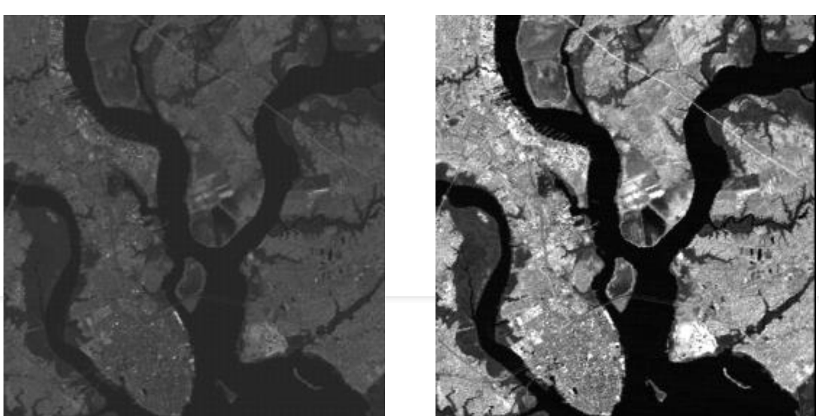
Enhancement / Histogram Stretching

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



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False colour Unstretched

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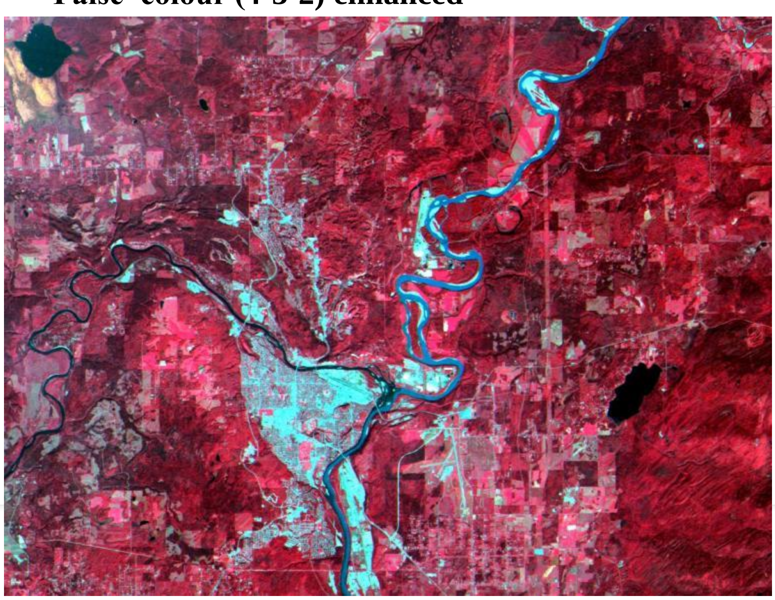
‘False’ colour (4-3-2) enhanced



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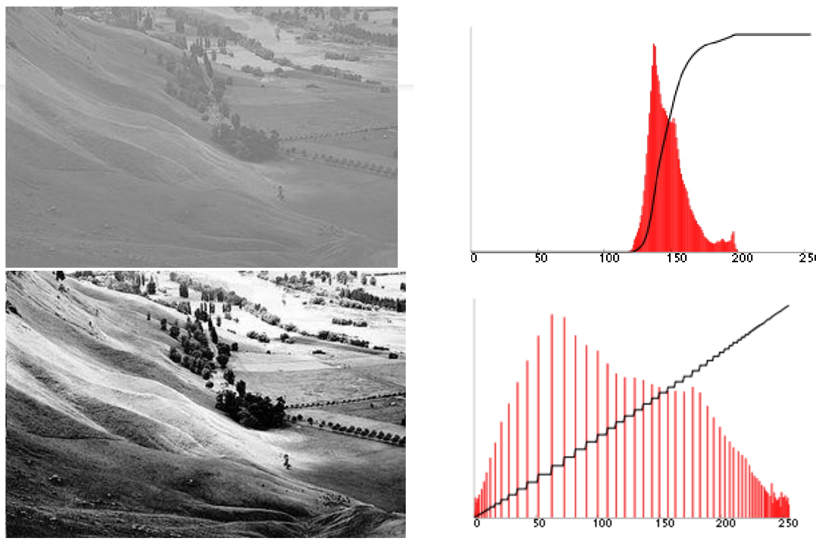
Histogram equalization / contrast stretching / image enhancement

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

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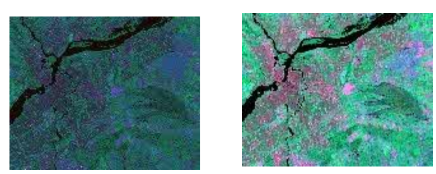
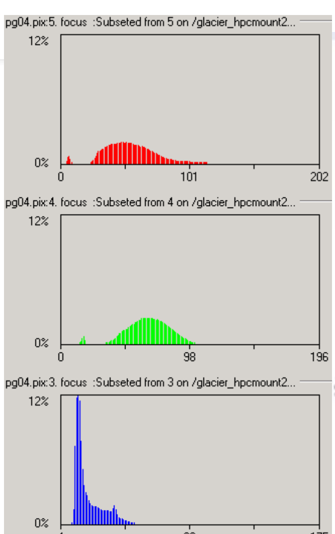
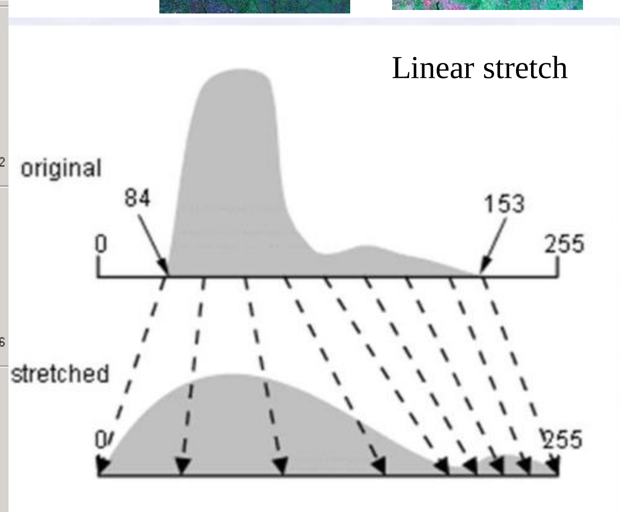
Contrast stretch / enhancement
DNs do not fill the display range







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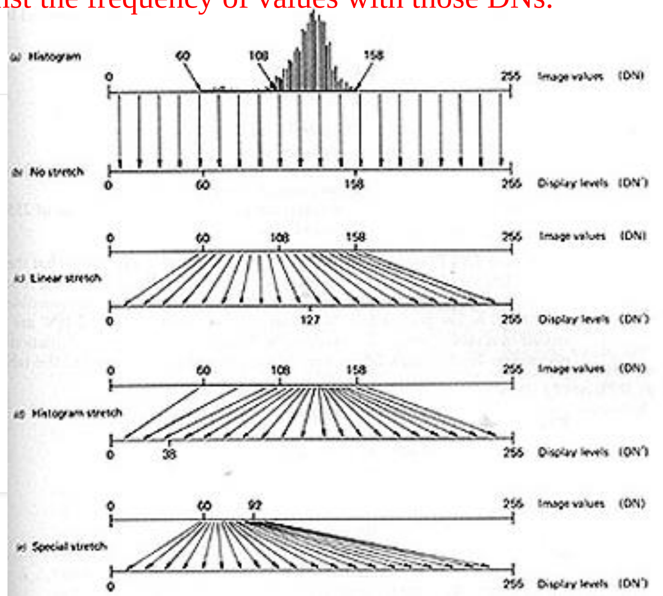
A histogram plots the Digital Numbers (DN) e.g. 0-255, on the x-axis against the frequency of values with those DNs.

None

Linear

Root

Special



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

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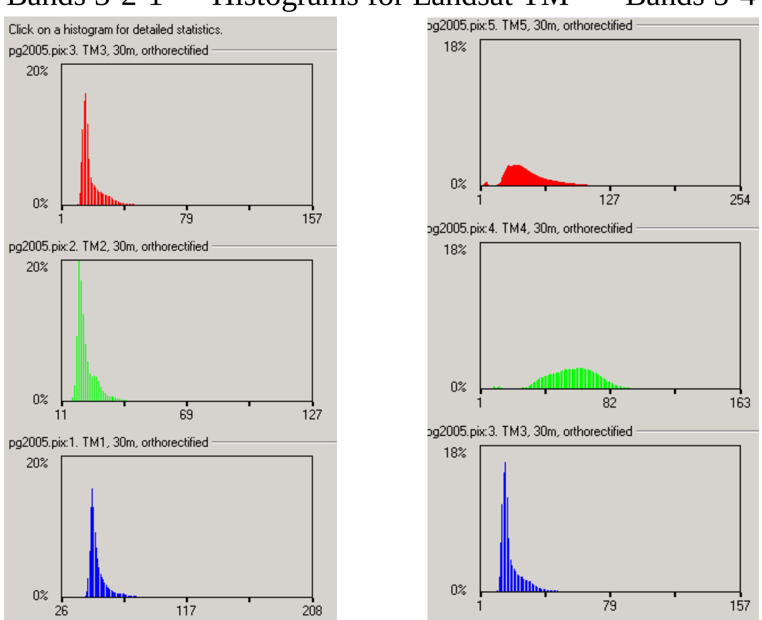
Bands 3-2-1 Histograms for Landsat TM Bands 5-4-3



> **2013: Landsat 8 DNs: typically are 5000-20000**

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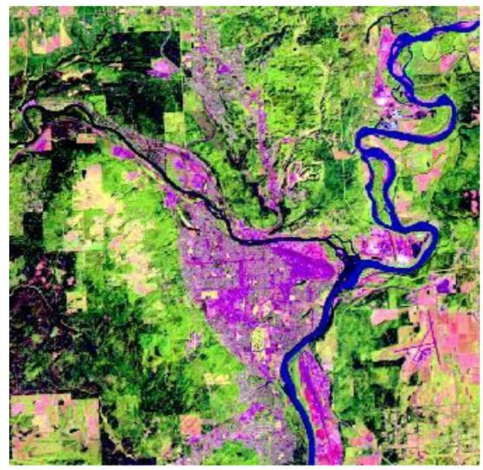
Enhancement is based on screen display

Based on whole scene | Based on zoom into UNBC campus

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



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