Optical Remote sensing systems

· **Panchromatic imaging system:** The sensor is a single channel detector sensitive to radiation within a broad wavelength range. The spectral information or "colour" of the targets is lost. Examples : IKONOS PAN SPOT HRV-PAN

· **Multispectral imaging system:** (Broadband)

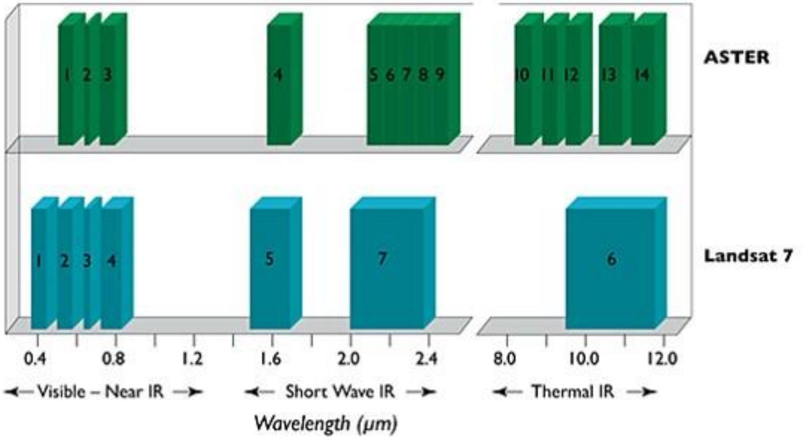
The sensor is a multichannel detector with a few spectral bands. Examples:

- LANDSAT MSS LANDSAT TM SPOT HRV-XS IKONOS MS

Landsat 8 /9: 9 bands + 2 thermal (TIR)

ASTER 14 bands; Sentinel 2 MSI: 13 bands ???

· **Superspectral Imaging Systems**: A superspectral imaging sensor has more spectral channels (typically >10) than a multispectral sensor. The bands have narrower bandwidths, enabling the finer spectral characteristics of the targets to be captured by the sensor. Examples: MODIS 32 bands **Worldview 3:** 16 MS bands + Pan



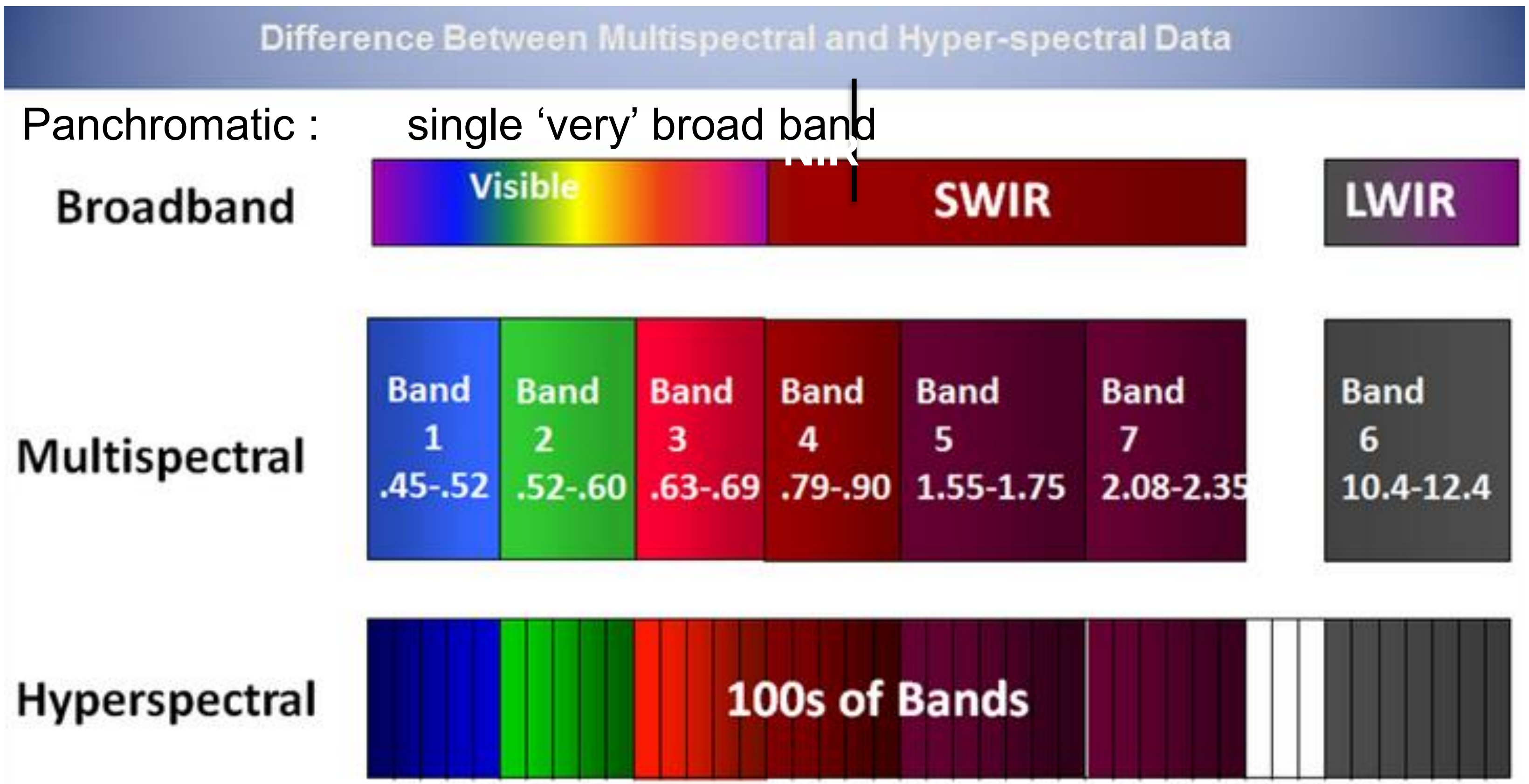
Hyperspectral remote sensing ('Image spectroscopy')

Multispectral systems contain ~3-12 bands … 70-400 nm wide

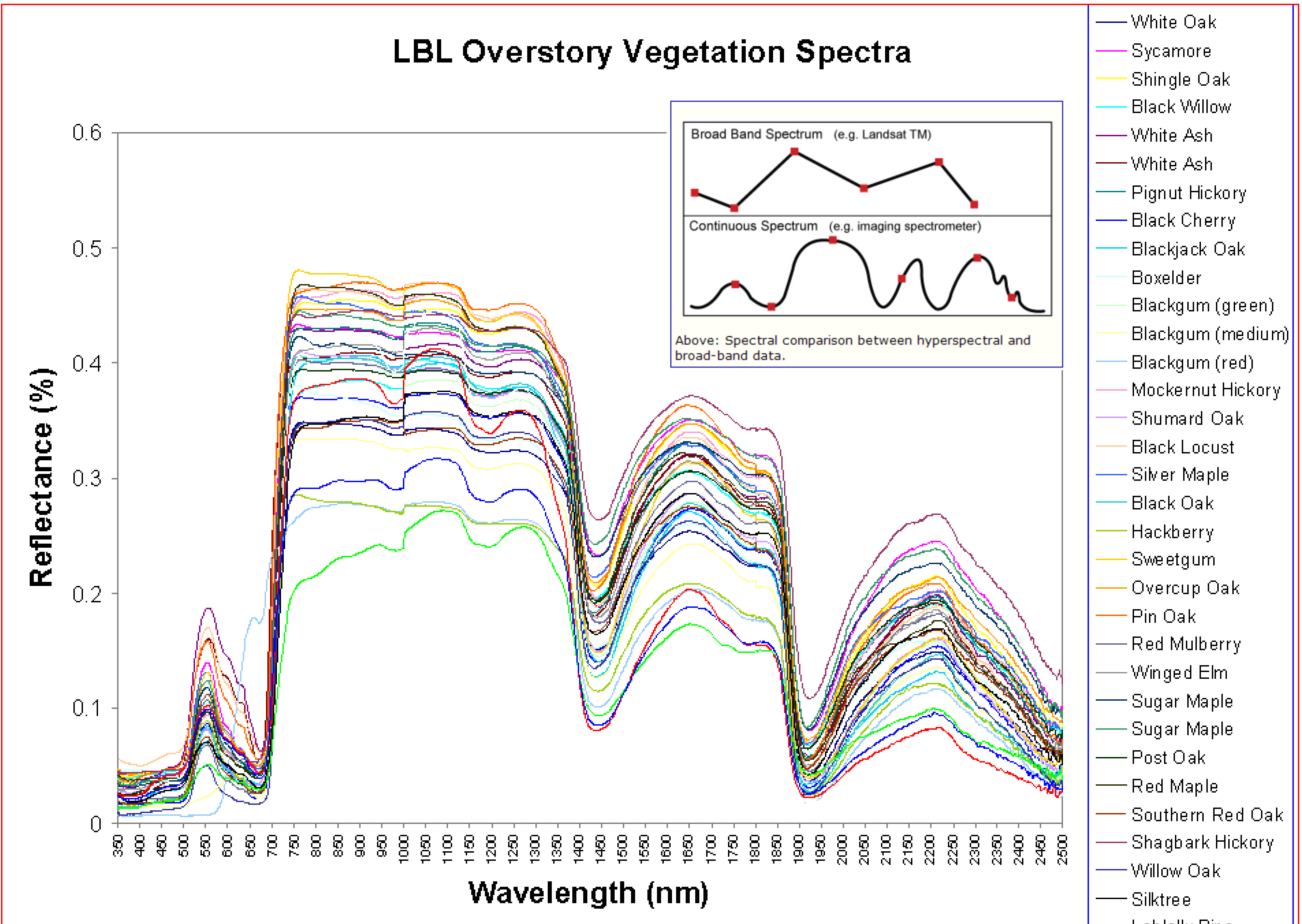
Hyperspectral : 100- 200+ bands 0.38 - 2.5µm … 5-10nm each

Bands are contiguous and high spectral resolution (Visible-NIR-SWIR)

Panchromatic : single 'very' broad band

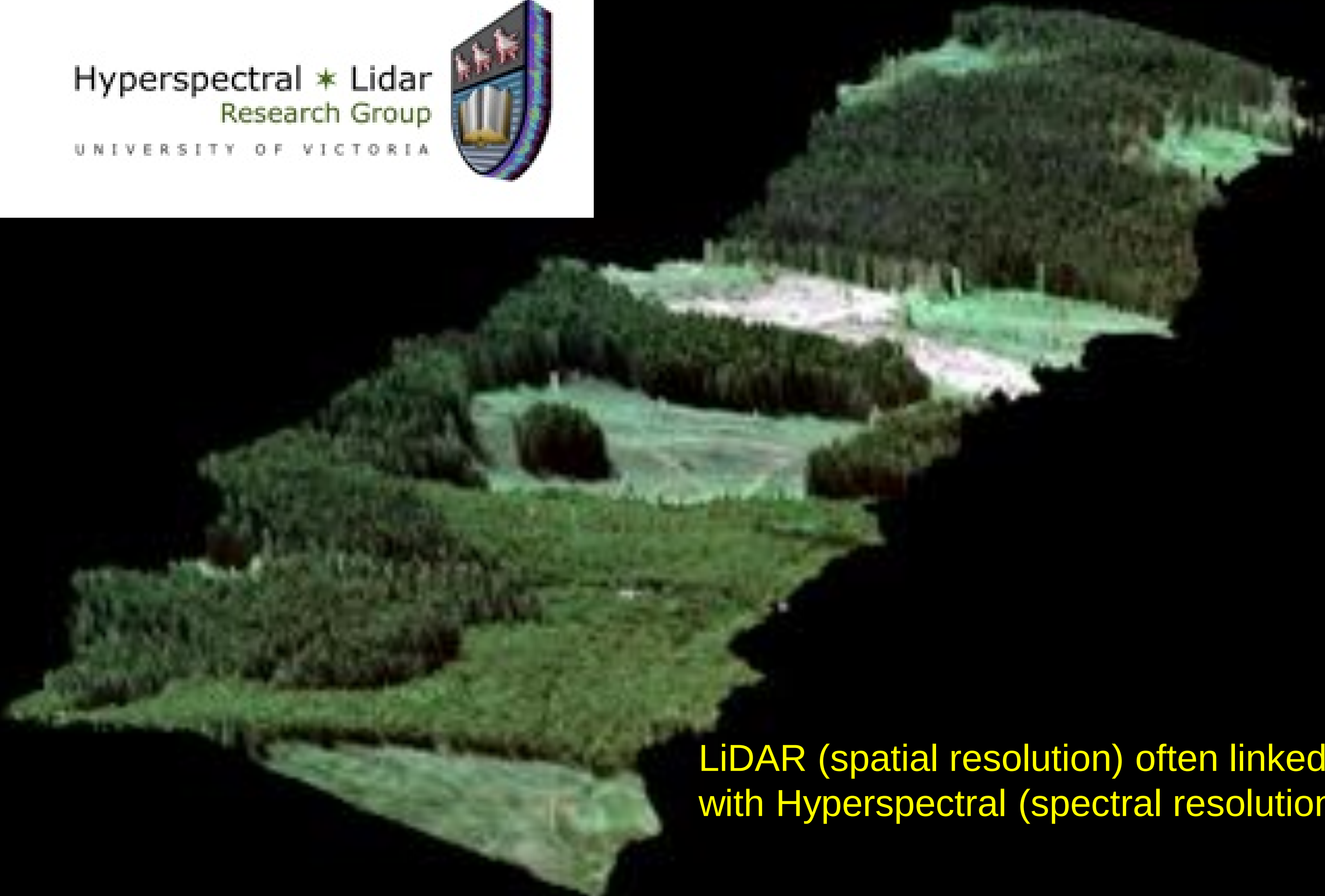


Ultraspectral: thousands of bands



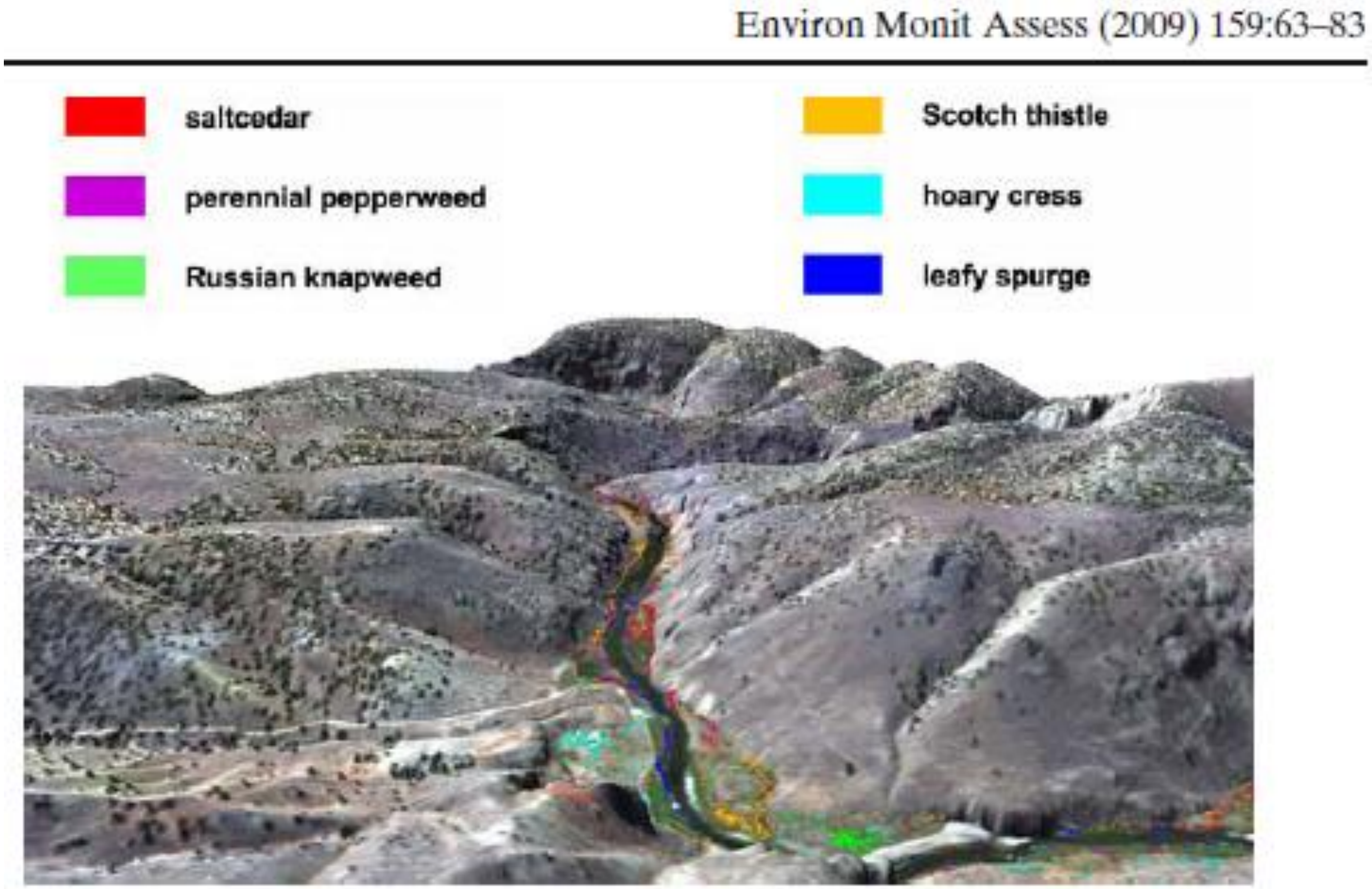
http://www.murraystate.edu/qacd/cos/marc/projects/nasa98/veg_library/lblspec.gif

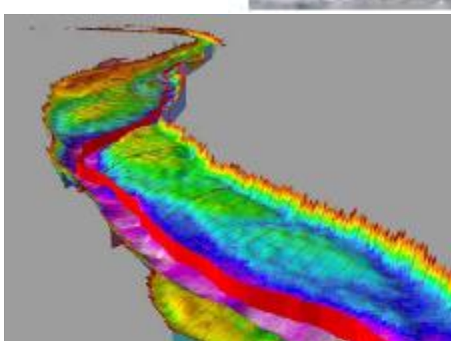
Hyperspectral * Lidar
Research Group
UNIVERSITY OF VICTORIA



LiDAR (spatial resolution) often linked with Hyperspectral (spectral resolution)

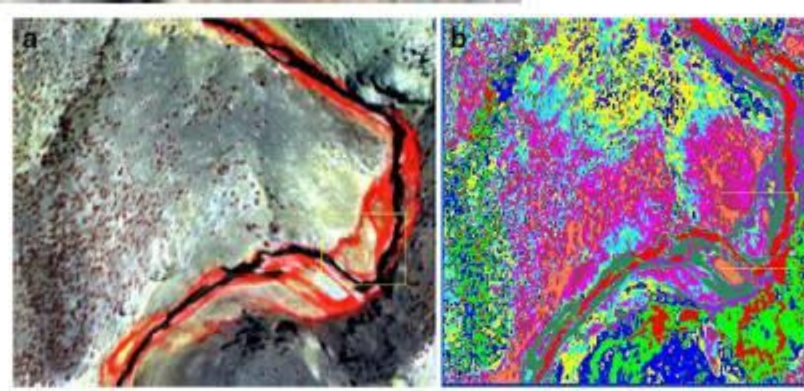
Quantifying structural physical habitat attributes using LIDAR and hyperspectral imagery





<- LiDAR DEM

IR image and 10 class ->
ISODATA classification



Airborne hyperspectral systems – examples (1970s ->)

Sensor	Wavelength (nm)	Band width (nm)	# bands
AVIRIS	400-2500	10	224
TRWIS III	367-2328	6	335
HYDICE	400-2400	10	210
CASI (1500)	400- 900	1.8	288
OKSI AVS	400-1000	10	61
ESSI Probe-1	400-2450	15	128

CASI (Compact Airborne Spectrographic Imager) - ITRES, Calgary – www.itres.com

1989 CASI 1	400-900	0.5-10m pixels,	12 bit data (0-4095)
2002 CASI 2, 3	400-1050		14 bit data (0-16383)
SASI-600	950-2450	100 bands x 15nm	
MASI-600	3-5 µm	64 bands	1m
TASI-600	8-11.5 µm	32 bands	
TABI -1800	8-12 µm	160 bands	320 pixels x 3metre (12 bit data)

MASI-600 flight line, 1m resolution.

Displayed 3 (max) bands:
r: 3571 nm
g: 3952nm
b: 4778nm

SOME APPLICATIONS:

- wetland and coastal vegetation
- mineral composition
- agricultural crops
- forest structure
- soil types

https://itres.com/gallery

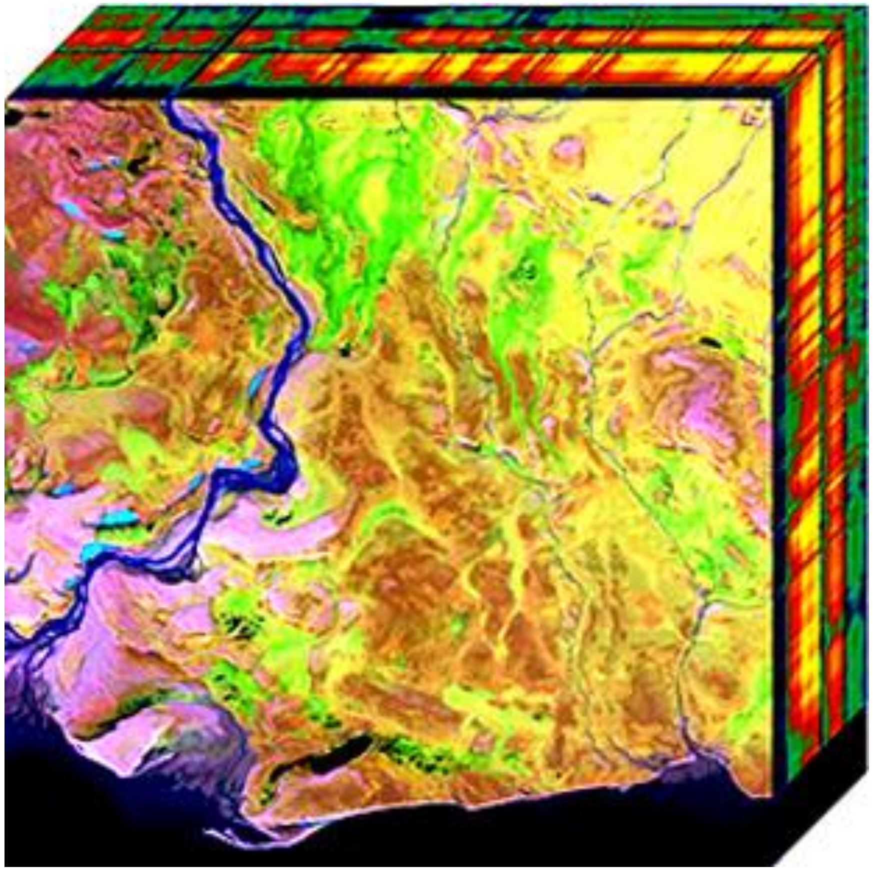
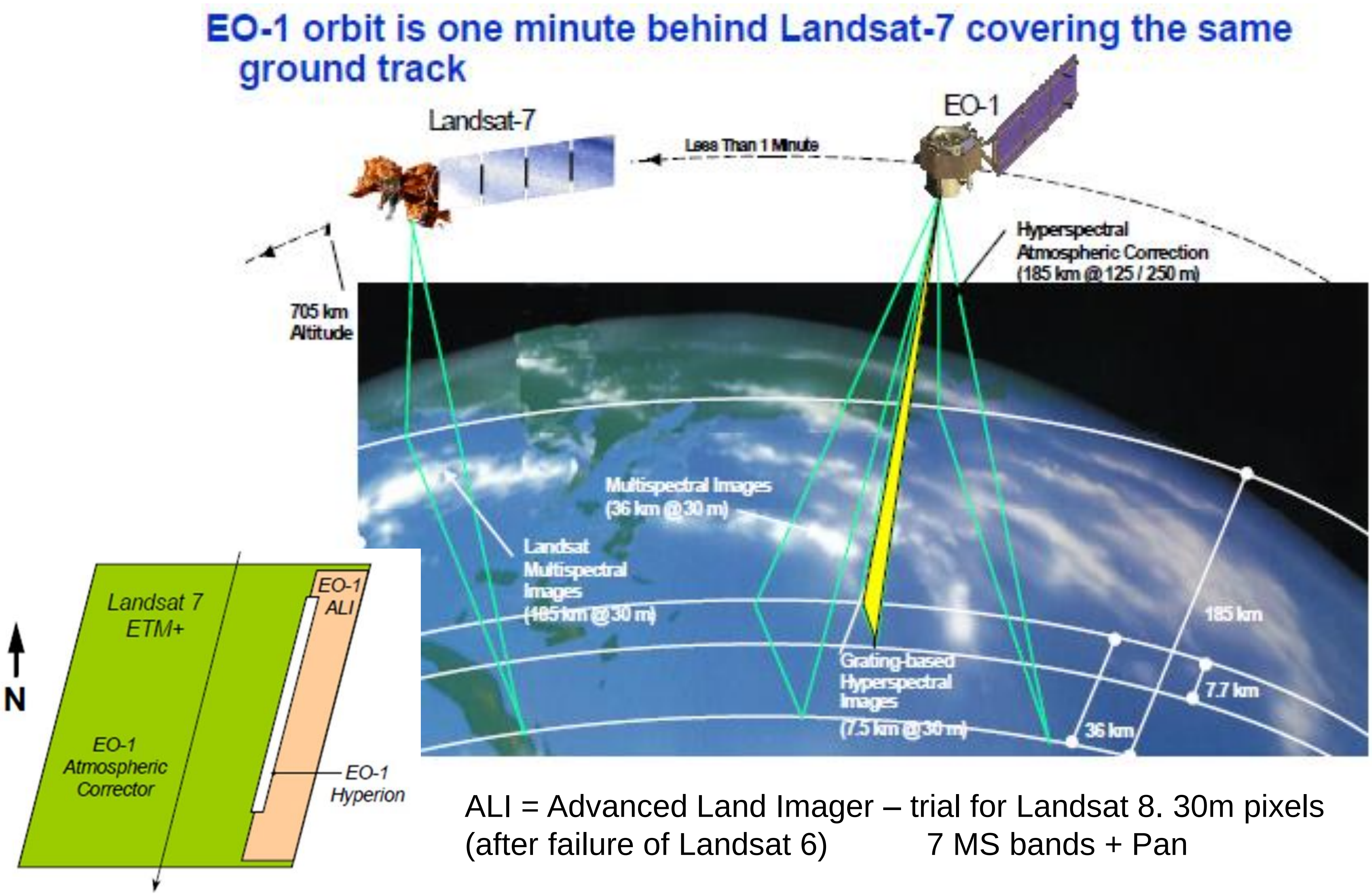


Image Cube

Hyperion kicked off the start of hyperspectral imaging from space, 2000-2017

Download from http://earthexplorer.usgs.gov



ALI = Advanced Land Imager – trial for Landsat 8. 30m pixels (after failure of Landsat 6) 7 MS bands + Pan

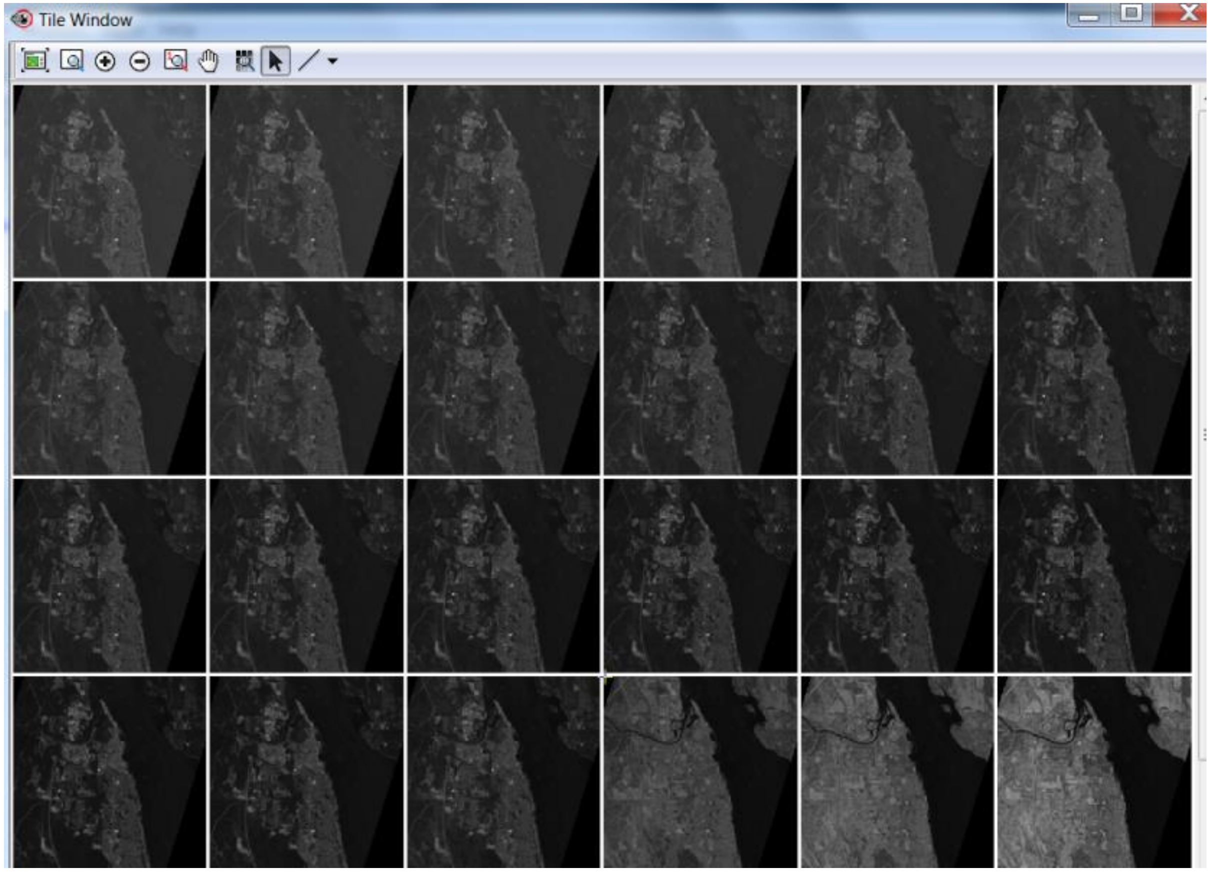
220 spectral bands HYPERION Spectral Coverage (350-2500nm)

ALI Band Comparison		Hyperion Band	Average Wavelength (nm)	Full Width at Half the Maximum FWHM (nm)	Spatial Resolution (m)	Not Calibrated (X)
MS	Pan (nm) 480 - 690 (X)					
		B1	355.5900	11.3871	30	X
		B2	365.7600	11.3871	30	X
		B3	375.9400	11.3871	30	X
		B4	386.1100	11.3871	30	X
		B5	396.2900	11.3871	30	X
		B6	406.4600	11.3871	30	X
		B7	416.6400	11.3871	30	X
		B8	426.8200	11.3871	30	
MS-1		B9	436.9900	11.3871	30	
MS-1		B10	447.1700	11.3871	30	
MS-1'		B11	457.3400	11.3871	30	
MS-1'		B12	467.5200	11.3871	30	
MS-1'		B13	477.6900	11.3871	30	
MS-1'	X	B14	487.8700	11.3784	30	
MS-1'	X	B15	498.0400	11.3538	30	
MS-1'	X	B16	508.2200	11.3133	30	
	X	B17	518.3900	11.2580	30	
MS-2	X	B18	528.5700	11.1907	30	
MS-2	X	B19	538.7400	11.1119	30	

Hyperion, 7.6km swath, 30m

Download from http://earthexplorer.usgs.gov

PCI Catalyst: View -> Thumbnails (file-utilities-transfer)



Satellite borne hyperspectral systems 2

CHRIS: Compact High Resolution Imaging Spectrometer
on PROBA (2001)

CHRIS provides 19 bands in the VNIR range (400 - 1050 nm) at 17 m. Each nominal image forms a square of 13 km x 13 km.

CHRIS can be reconfigured to provide 63 spectral bands at a spatial resolution of 34 m and can provide up to 150 channels.

The Niau atoll, in the central South Pacific Ocean, acquired by ESA's Proba satellite on 6 October 2005 from CHRIS.

Venice by CHRIS

(Compact High Resolution Imaging Spectrometer)

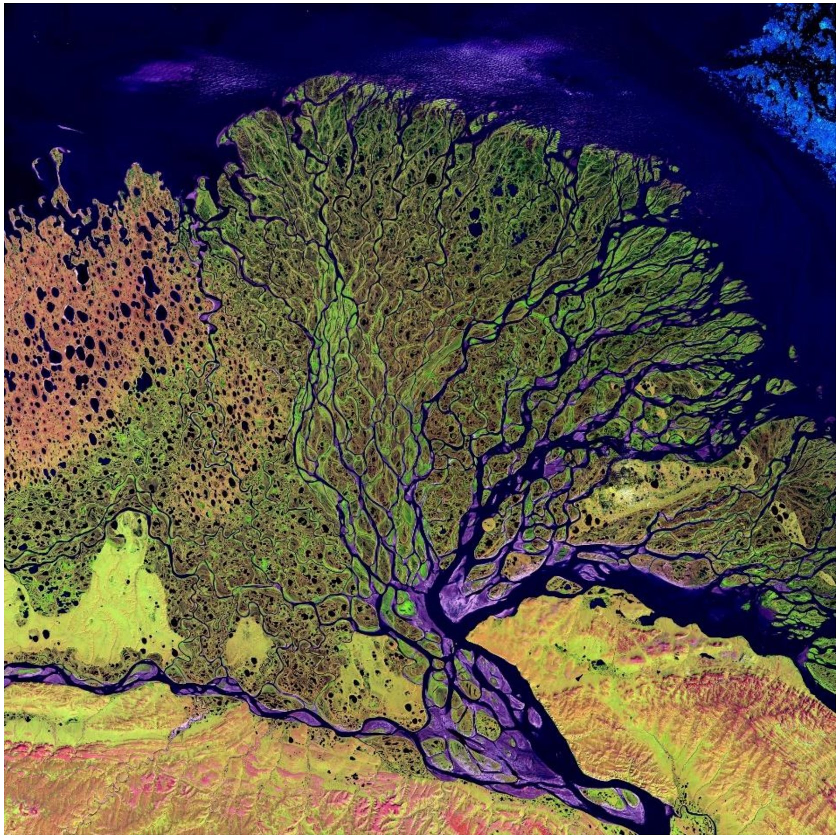
on PROBA (2001)

CHRIS provides 19 bands in the VNIR range (400 - 1050 nm) at 17 m. Each nominal image forms a square of 13 km x 13 km.

CHRIS can be reconfigured to provide a spatial resolution of 34 m and up to 150 channels.

https://earth.esa.int/eogateway/instruments/chris

SOME APPLICATIONS:



- wetland /coastal vegetation
- mineral composition
- agricultural crops
- forest structure
- soil types
- there is a clear link with PCA and so many bands:

https://towardsdatascience.com/pca-on-hyperspectral-data-99c9c5178385

As many component channels as there are input bands .....

Hyperion kicked off the start of hyperspectral imaging from space.
Other hyperspectral imaging missions from space include:

- •PROBA-1 (ESA) in 2001: https://earth.esa.int/eogateway/instruments/chris

- •PRISMA (Italy) in 2019: https://www.asi.it/en/earth-science/prisma

- •EnMap (Germany) in 2020: https://www.enmap.org

- •HISUI (Japan) in 2020: https://www.jspacesystems.or.jp/en/project/observation/hisui

……………………………………………………………………..

- •HyspIRI (United States) in 2024: 380-2500nm https://hyspiri.jpl.nasa.gov

- •SHALOM (Israel/Italy) 2025: Spaceborne Hyperspectral Applicative Land and Ocean Mission https://en.wikipedia.org/wiki/SHALOM_(satellite)

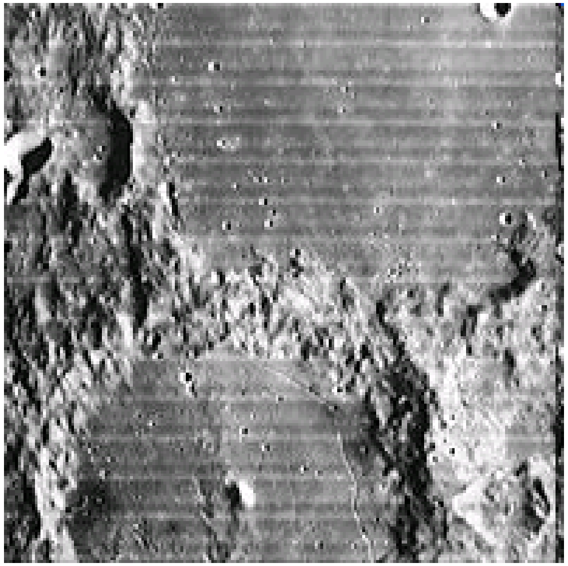
Summary: Hyperspectral RS

Pre-2000-> all were airborne

2000-> satellite sensors

2015-> UAV / RPAS sensors – often with LiDAR

Image pre-processing / correction



Digital Satellite Image Processing can be divided into:

- **Pre-processing**:**radiometric/geometric** correction
- **Enhancement and Transformations**
- **Classification and Feature extraction**

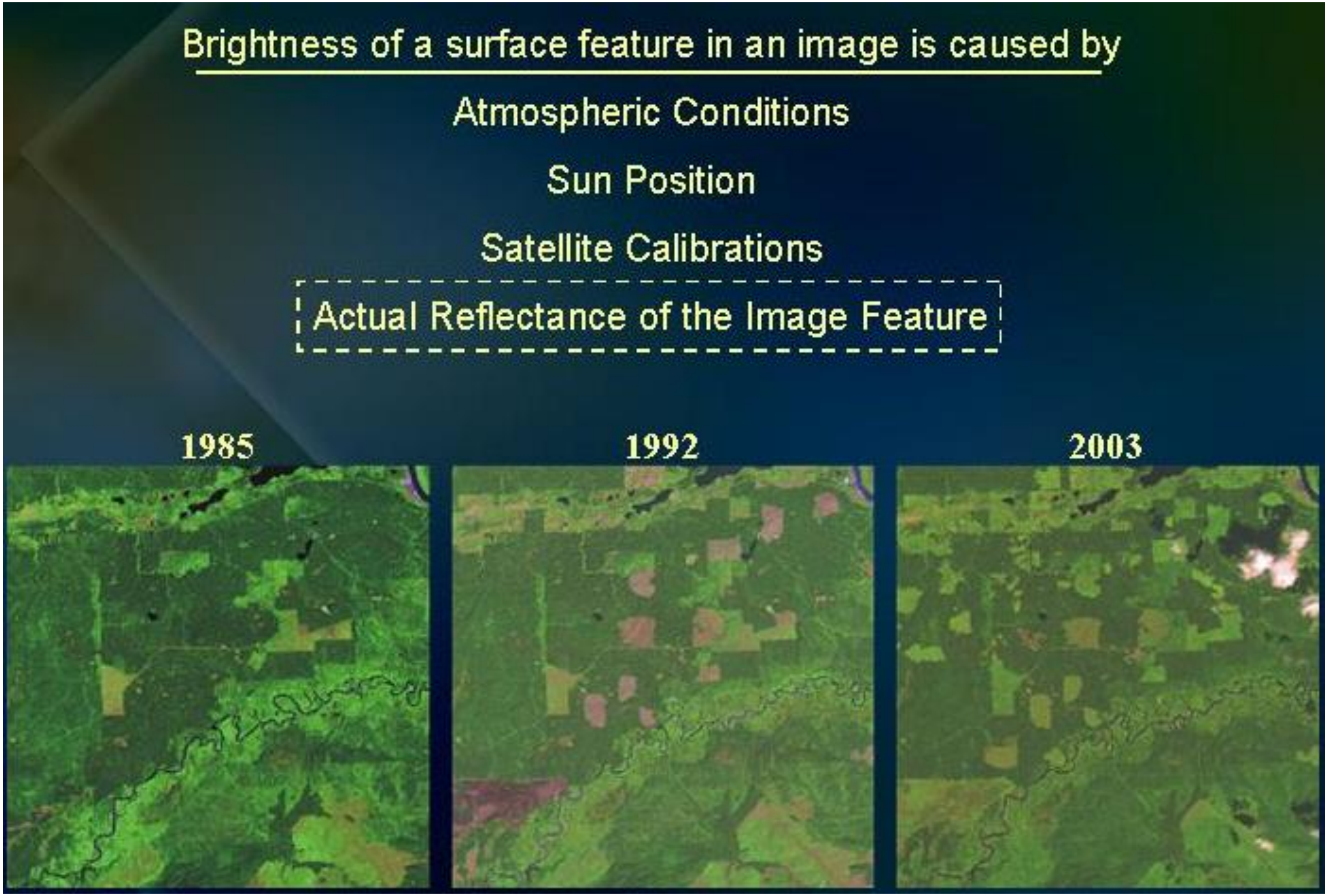
Radiometric Correction: removal of sensor or atmospheric 'noise‘ in DNs, to more accurately represent ground conditions - improve image ‘fidelity’:

- correct data loss and remove haze
- enable mosaicking and comparison

Geometric correction: conversion of data to ground coordinates
… by removal of **spatial** distortions from sensor

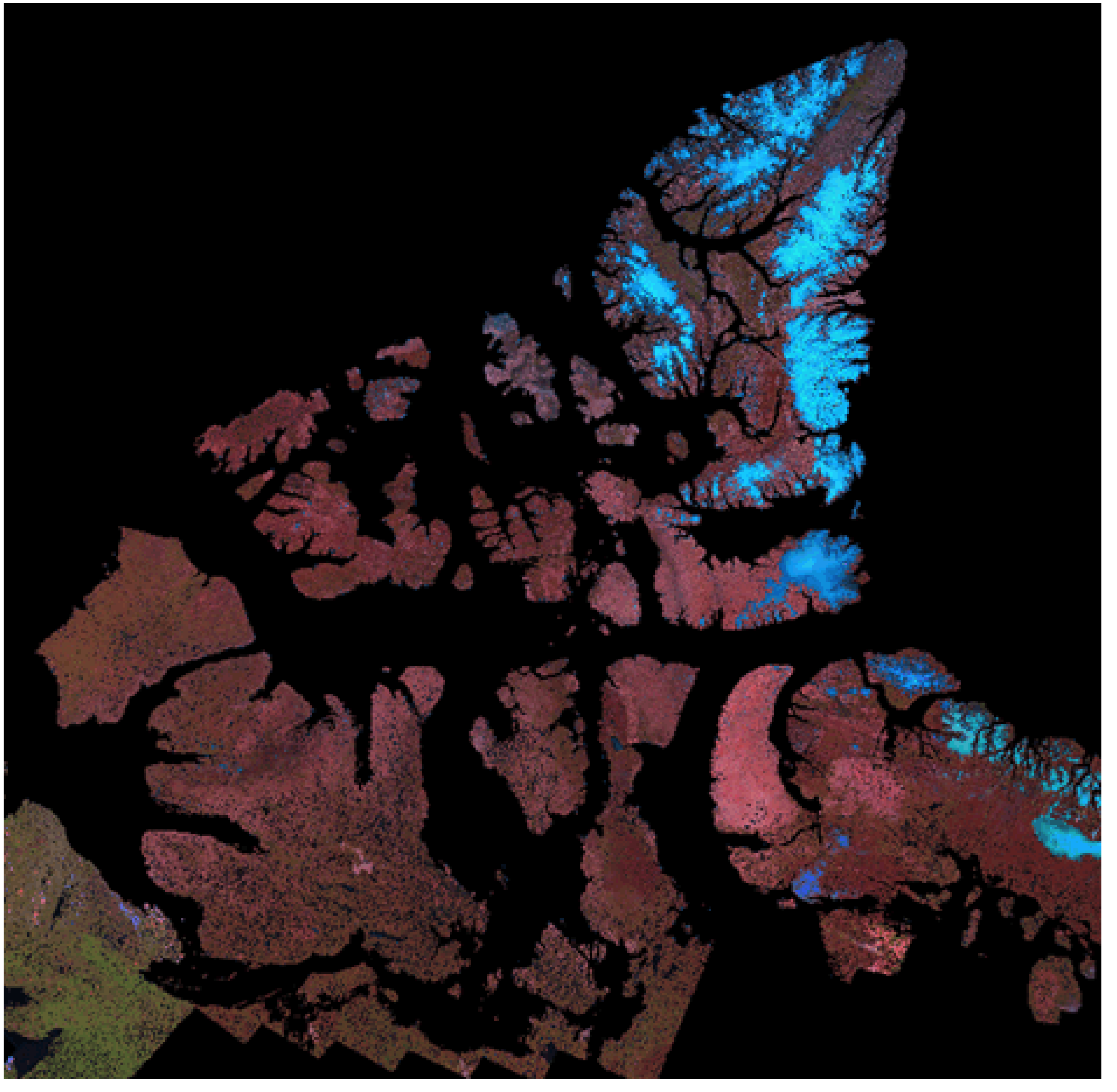
- enable mapping relative to data layers
- also enable mosaicking and comparison

Radiometric correction: modification of DNs



Darren Janzen, MSc UNBC .. -> CCRS

Canadian Arctic mosaic



Scenes must be corrected radiometrically and spatially
to mosaic   e.g. google maps, pgmap, lrdw.ca/imap etc..

Radiometric correction

Radiometric correction is used to modify DN values to account for **noise,**
i.e. contributions to the DN that result from:

a. the intervening atmosphere

b. the sun-sensor geometry

c. the sensor itself – errors and gaps

We may need to correct for the following reasons:

a. Variations within an image (e.g. striping)

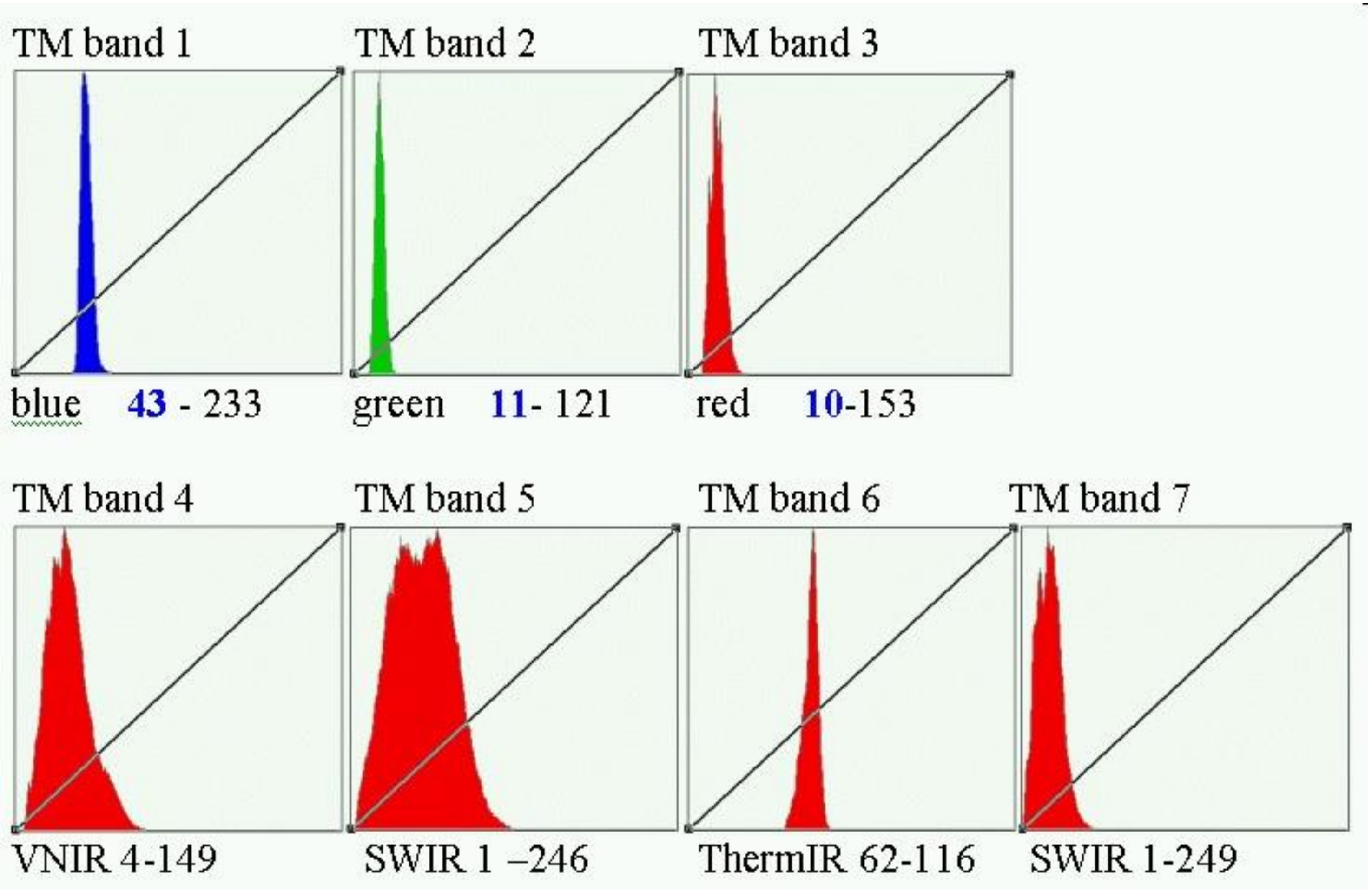
b. between adjacent / overlapping images (for mosaicing)

c. between bands (for some multispectral techniques)

d. between image dates (temporal data) and sensors

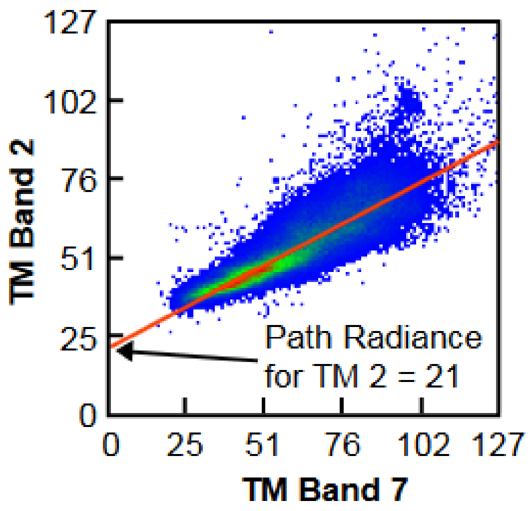
Atmospheric Interference - haze

Lower wavelengths are subject to **haze**, which falsely increases the DN. The simplest correction is dark object subtraction which assumes there is a pixel with a DN of 0 (if there were no haze), e.g. deep water in near infra-red. An integer is subtracted from all DNs so this pixel =0



http://geology.wlu.edu/harbor/geol260/lecture_notes/Notes_rs_haze.html

A more reliable estimate can be found for Landsat TM bands by using the Raster Correlation tool to display a scatterplot of brightness values for the selected band and the longer-wavelength middle infrared band (TM7) for which path radiance should be essentially 0. Because of path radiance, the best-fit line through the point distribution (computed automatically using the Regression Line option) does not pass through the origin of the plot. Instead its intersection with the axis for the shorter-wavelength band approximates the band's path radiance value (illustration at left).



Introductory readings – remote sensing
http://www.microimages.com/documentation/Tutorials/introrse.pdf

Matching for differential illumination:

- Comparison or mosaicing from a series of images – dates and years
- Overall, DN mean and SD for the same bands should be the same
- For perfect comparison / mosaicing, mean / SD should be 'normalised'

Advanced slide: Reflectance to Radiance Conversion

DN reflectance values can be converted to absolute radiance values.

This is useful when comparing the actual reflectance from different sensors e.g. TM and SPOT, or TM vs ETM vs OLI (Landsat 5 vs 7 vs 8)

DN = aL + b where a= gain and b =n offset

- Values for a, b, Lmin and Lmax are given in .mtl text file

The radiance value (L) can be calculated as:

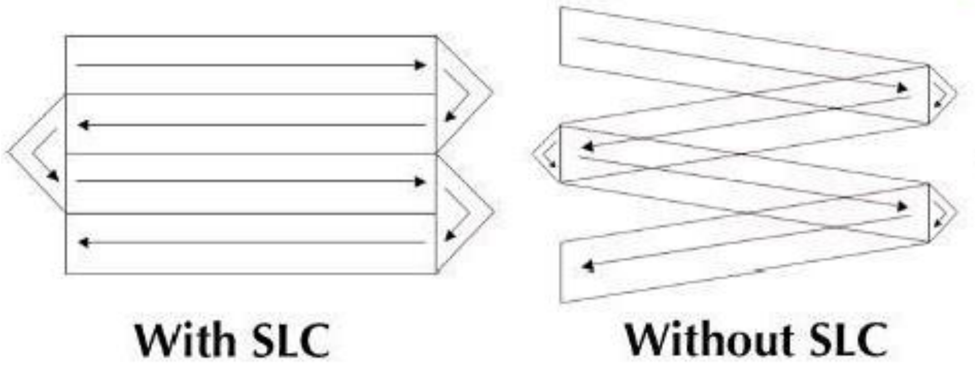
L = [Lmax - Lmin]*DN/255 + Lmin

where Lmax and Lmin are known from the sensor calibration.

This will create 32-bit (decimal) values (watts / m^2)

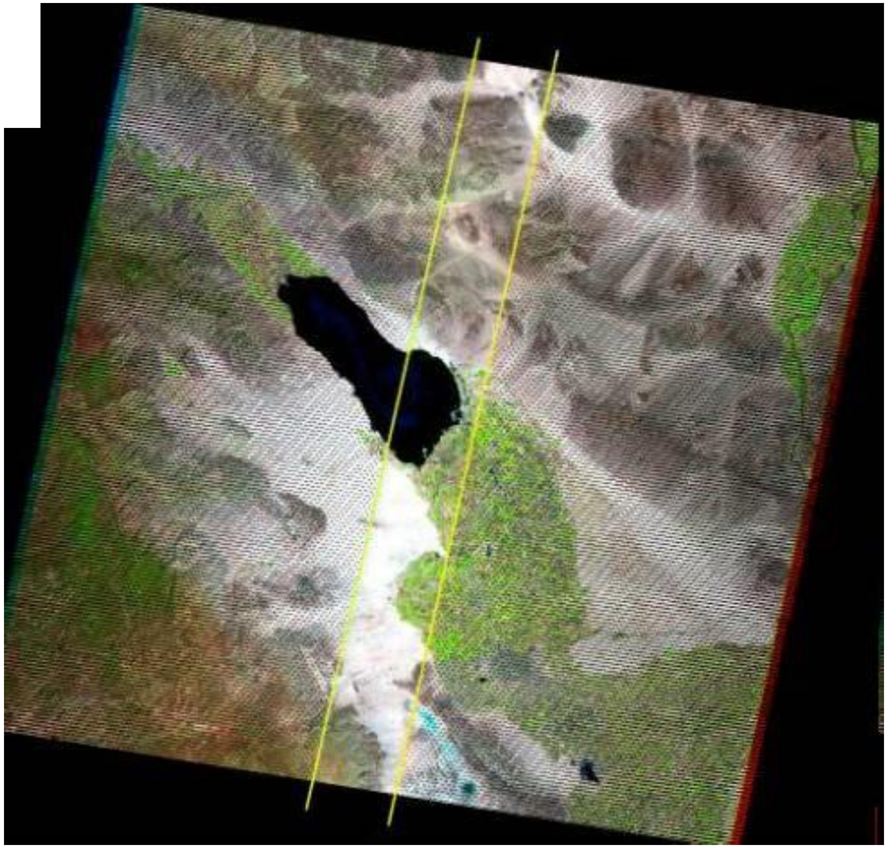
Errors: Sensor Failure & Calibration

e.g. Landsat 7 ETM+ scan line corrector (SLC) – failed May 31 2003

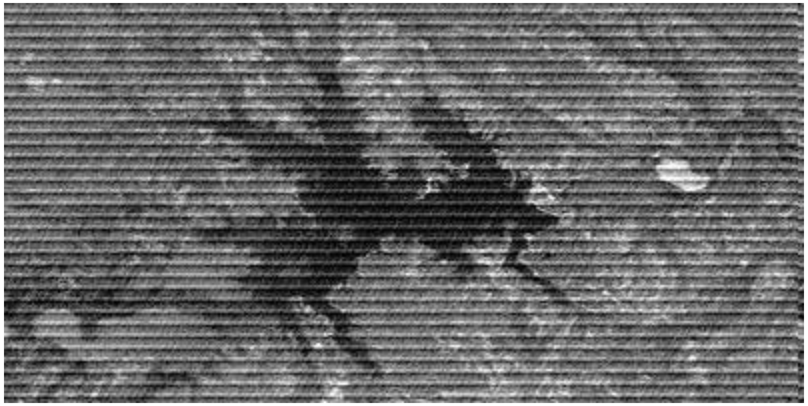


SLC compensates for forward motion of the scanner during scan

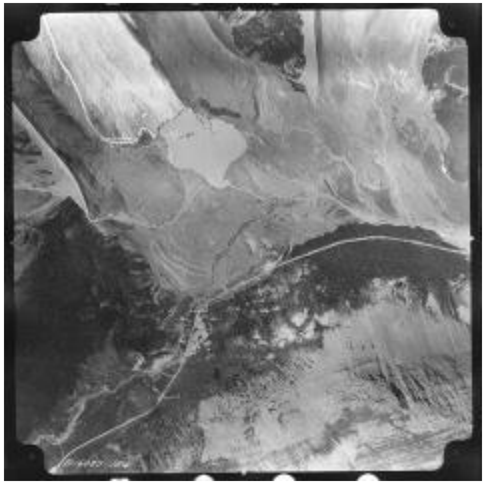
Some attempts to 'fix' by filling in from other scenes



Early Landsat MSS: "6 line" striping was common with sensor issues



Geometric Image distortions



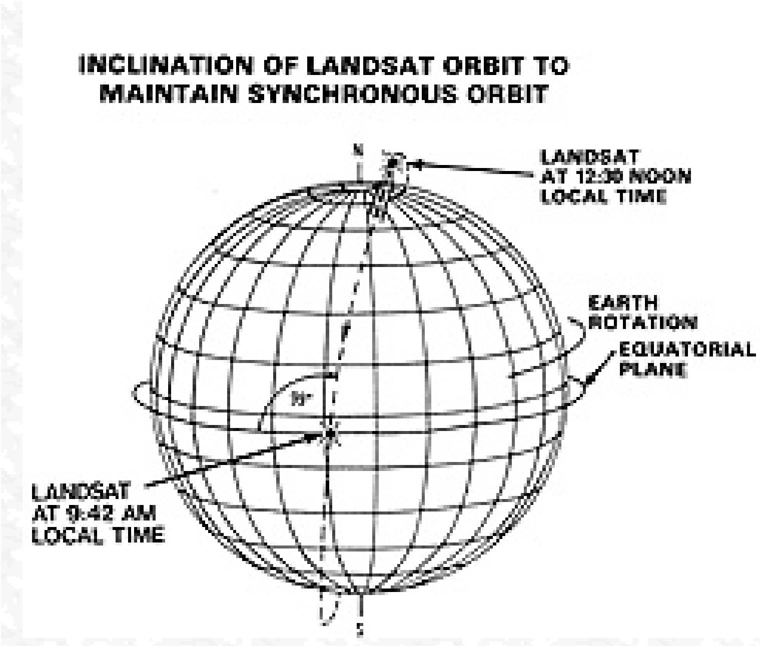
In **air photos**, geometric (spatial) distortions include:

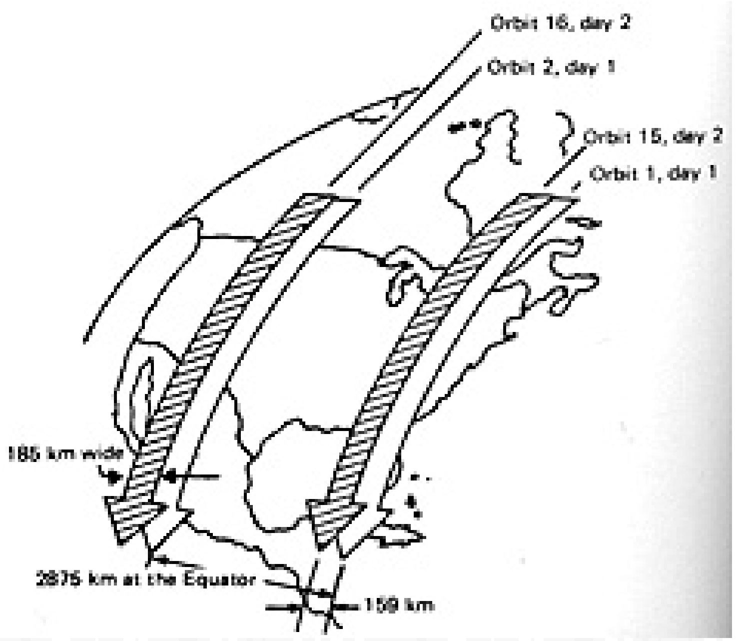
topographic and radial displacement;

airplane tip, tilt and swing (roll, pitch and yaw).

These are less in satellite data due to altitude and stability.

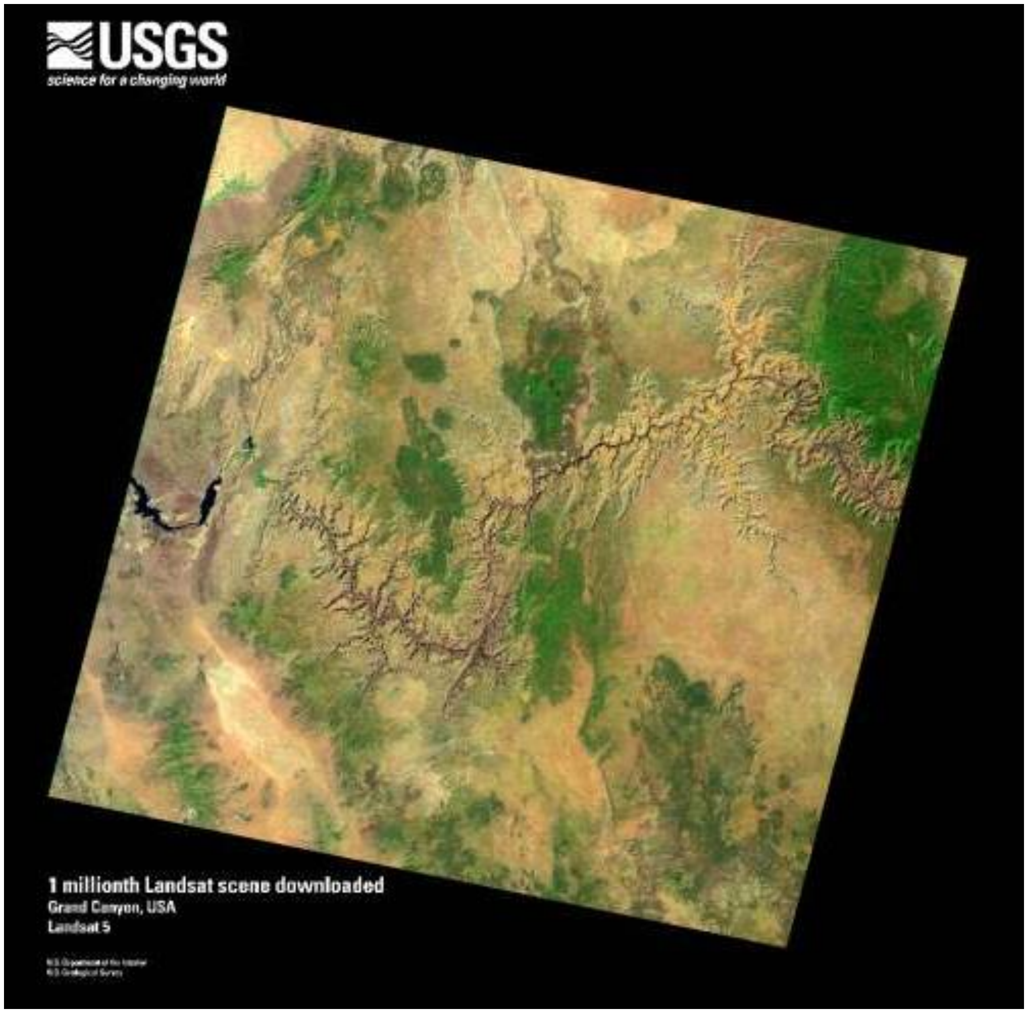
The main source of geometric error in satellite data was path orientation (non-polar)





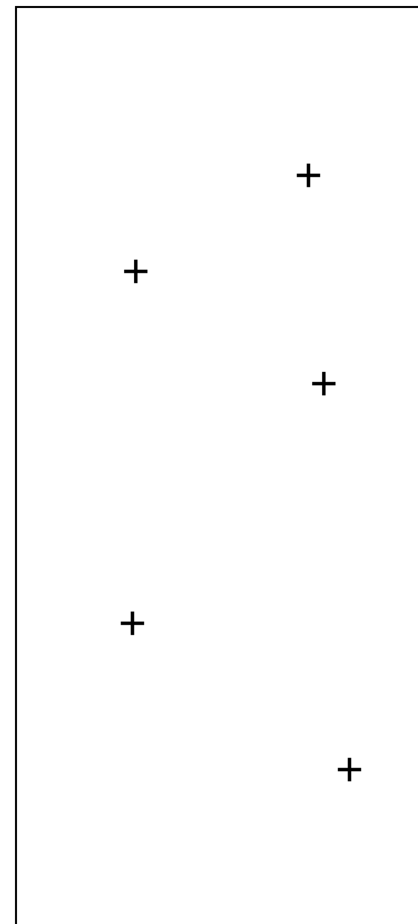
Geometric Correction

Corrected image scene orientation ‘map’



Uncorrected data ‘path’

Pixels and rows



Why is geocorrection needed ?

Raw remote sensing data contain distortions preventing overlay with map layers, comparison between image scenes, and with no geographic coordinates

- **To provide georeferencing**
- **To compare/overlay multiple images**
- **To merge with map layers**
- **To mosaic images**

*** Most imagery now comes already rectified … YEAH !!

But you could still acquire e.g. a hardcopy (scanned) aerial photo or old image

Geocorrection

Data pixels must be related to ground locations, e.g. UTM coordinates

Rectification – assigning coordinates to known locations - GCPs

GCP = Ground Control Point

Done manually up to 2008, automatically since then;
Manually there was often an error of several pixels (image shift) ..
Especially due to mountain topography

Resampling - resetting the pixels (rows and columns) to match the GCPs

Ortho-rectification = this process (since ~2000) enables the use of a DEM to take into account the topography

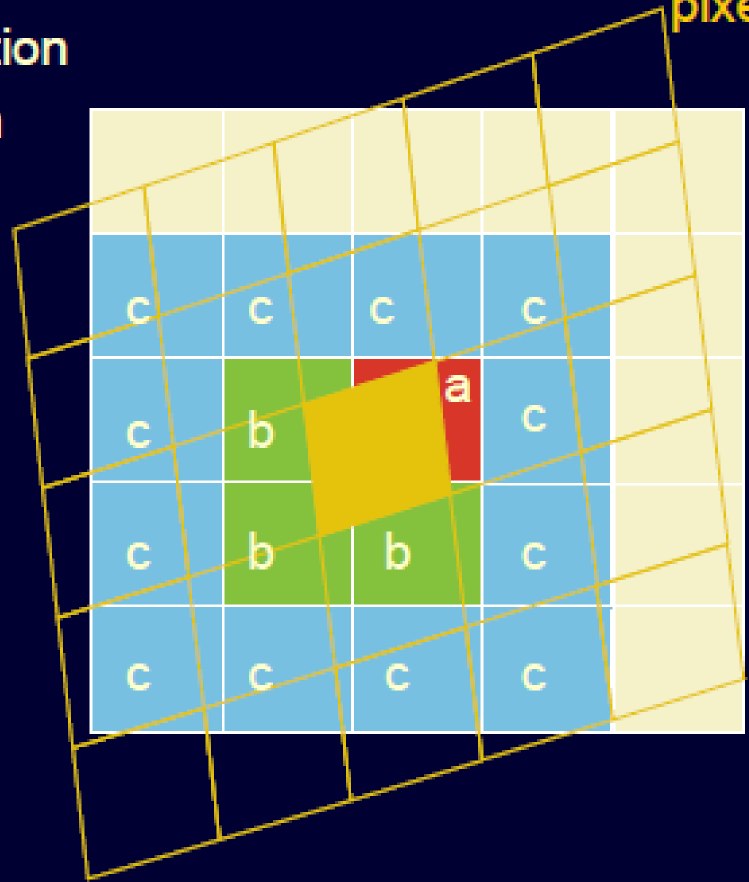
Resampling

After the transformation, a **resampling** of the pixel values is performed

- nearest neighbour
- bilinear interpolation
- cubic convolution

pixel arrangement 2

pixel arrangement 1



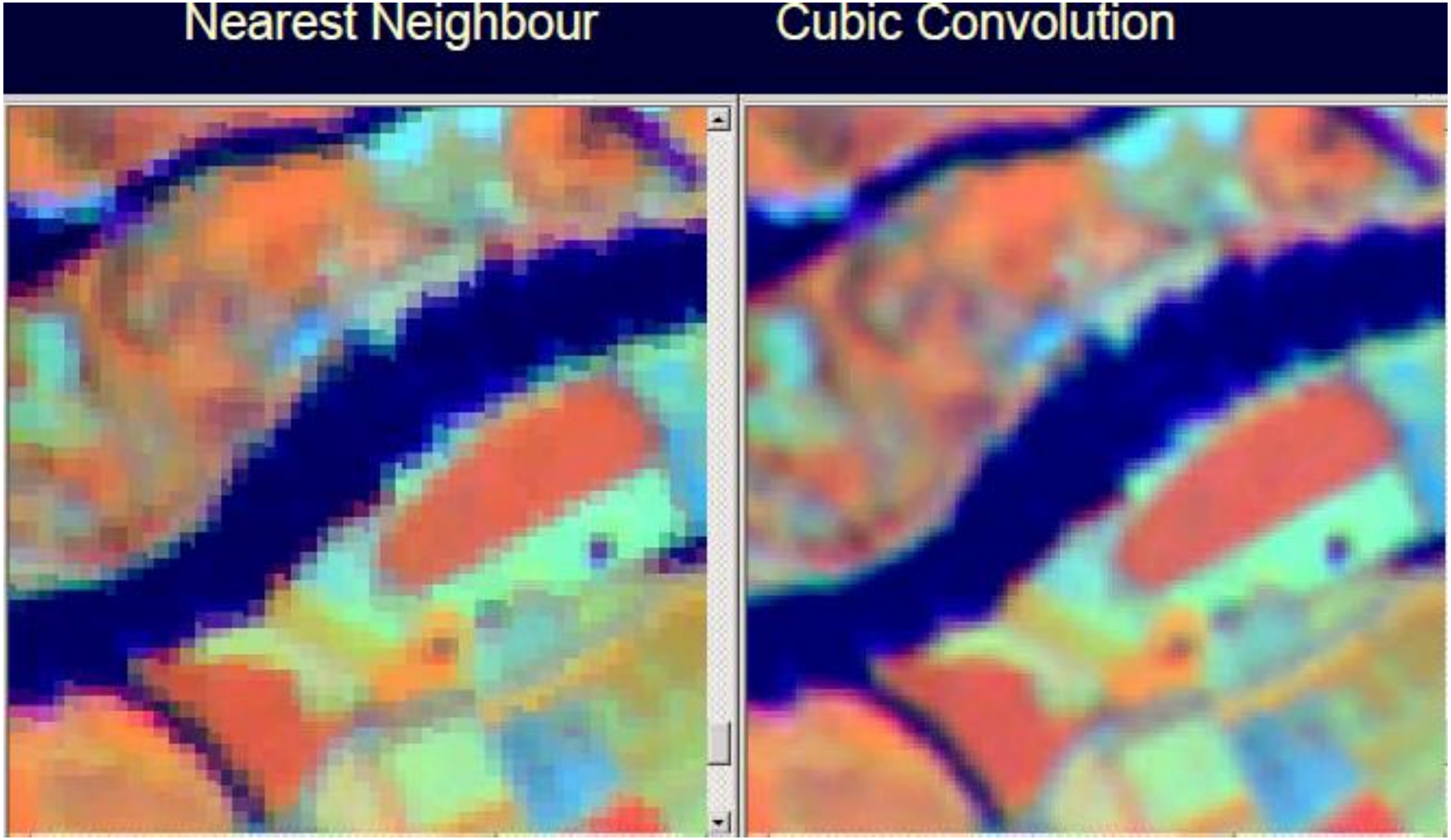
NN is quickest
BI is intermediate
CC is smoothest

This is also done when changing pixel size e.g. to match datasets from sensors 15m to 10m etc..

pixel arrangement 1 = input (distorted)
pixel arrangement 2 = output (corrected)

http://www.geo-informatie.nl/courses/grs20306/course/Schedule/Geometric-correction-RS-new.pdf

Resampling



http://www.geo-informatie.nl/courses/grs20306/course/Schedule/Geometric-correction-RS-new.pdf

Good rectification is required for image registration – no 'movement between images

Geocorrection milestones

Pre 2000: Landsat image scenes 'uncorrected' $5000
corrected (within 200m) $7000

2000-2008 UMBC free download, corrected to within 100m

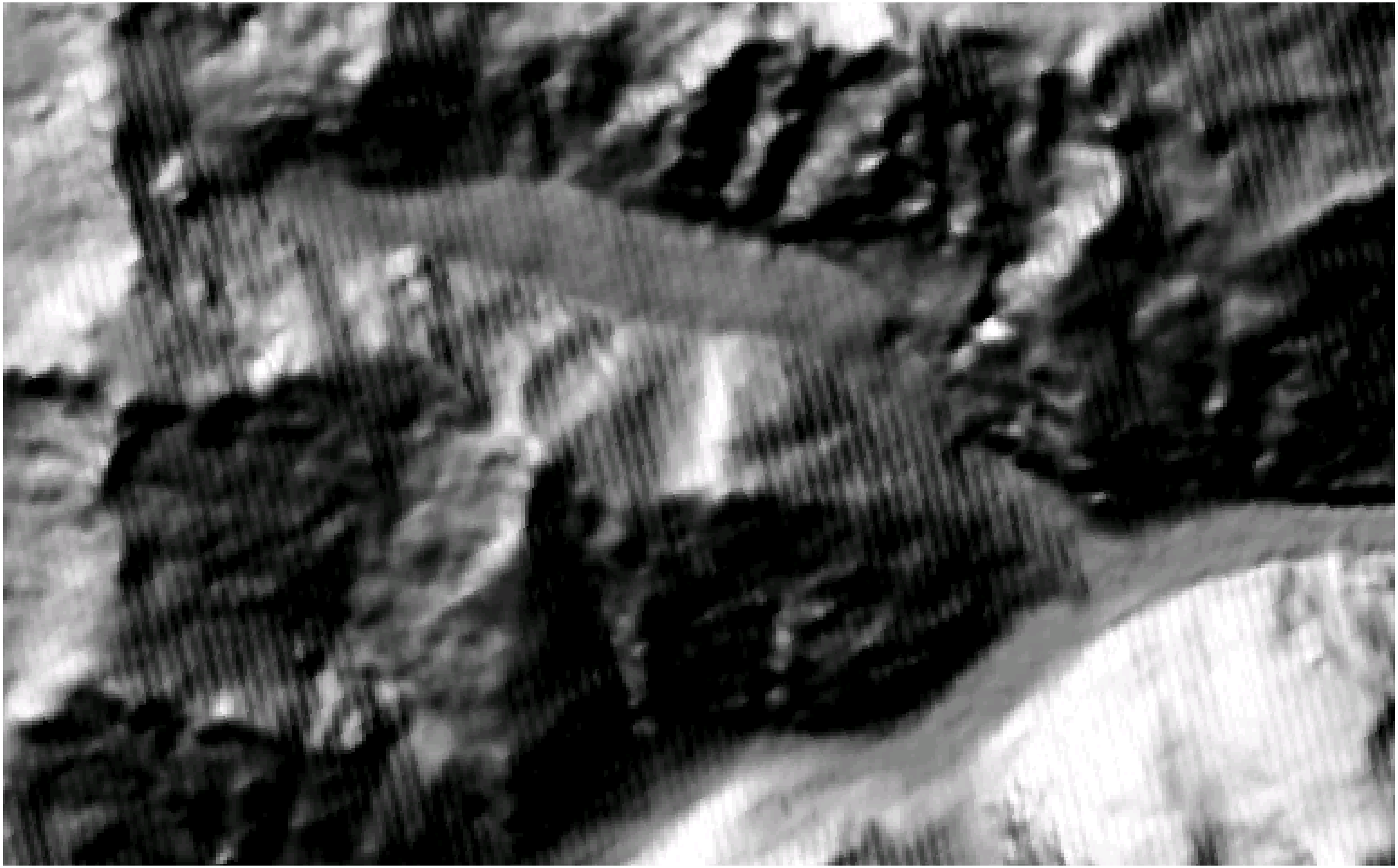
Many users bought PCI Catalyst for photo **Ortho**-rectification
= using DEM for 'correction' of projected vs surface areas

2009-> USGS free download, auto corrected using DEM

2010-> Airborne data auto-corrected using GPS and DEM data – airplanes and 'unmanned' (RPAS)

Reprojection may also be needed to match datasets from different sources

- Global data may be downloaded as *geographic* (lat/long) or by UTM zone
- involves resampling every pixel (*nearest neighbour*, bilinear or cubic convolution)



Reprojection – error stripes

Reprojection geographic WGS84 -> UTM/Albers

ALWAYS Pick Cubic Convolution for resampling …