Band ratios

Spectral Band ratioing is perhaps the simplest of multispectral techniques, *- a type of GIS 'overlay'* … *deriving new information from two data layers*

A band ratio is a new <u>channel</u> of data created by the simple division of two sets of band digital numbers ….. for each pixel

$DN_{new} = DN^{a} / DN^{b}$ for each pixel where a and b are bands

Band ratios

e.g. for a pixel, if band a = 50 and band b = 25, then the ratio DN = 50/25 for that pixel

DN new = 2   (2.0)

if a = 100 and band b = 40, then the band ratio DN = 2.5 (or rounded to 2 if there are only integer DNs)

The Band ratio DNs (8-bit) could hypothetically range from: 0-255

(e.g. if 8-bit band data ranges from 0 or 1 to 255)

But in practice they rarely exceed: 0-5

Ratio DN values

The result is 'naturally' decimal, but can be written to:

a. 32 bit 'real' channel (decimals) - if 'real' DNs are needed

b. 8-bit (Integer) channel

16-bit may be unlikely as DNs won't exceed 255 (16 bit =0-65,535)

A (scalar) multiplier can create values to fill the 8-bit or 16-bit range

e.g if DNs range from 0-5, multiplying them by 50 would give 0-250

- This takes less space than a 32 bit real channel (but do we care anymore ?)

Ratio DN values

<u>So we have 3 options:</u>

1. Retain decimal values e.g. 50 / 12 = 4.167 (32-bit channel)

2. Write to 8-bit: DN ^{a} / DN ^{b} may give a useful 'slice' identifying
   (e.g. new DNs = 0, 1, 2, 3, 4, 5)

3a. Multiply by a scalar value e.g. 10 or 50 to 8-bit range (0-255)

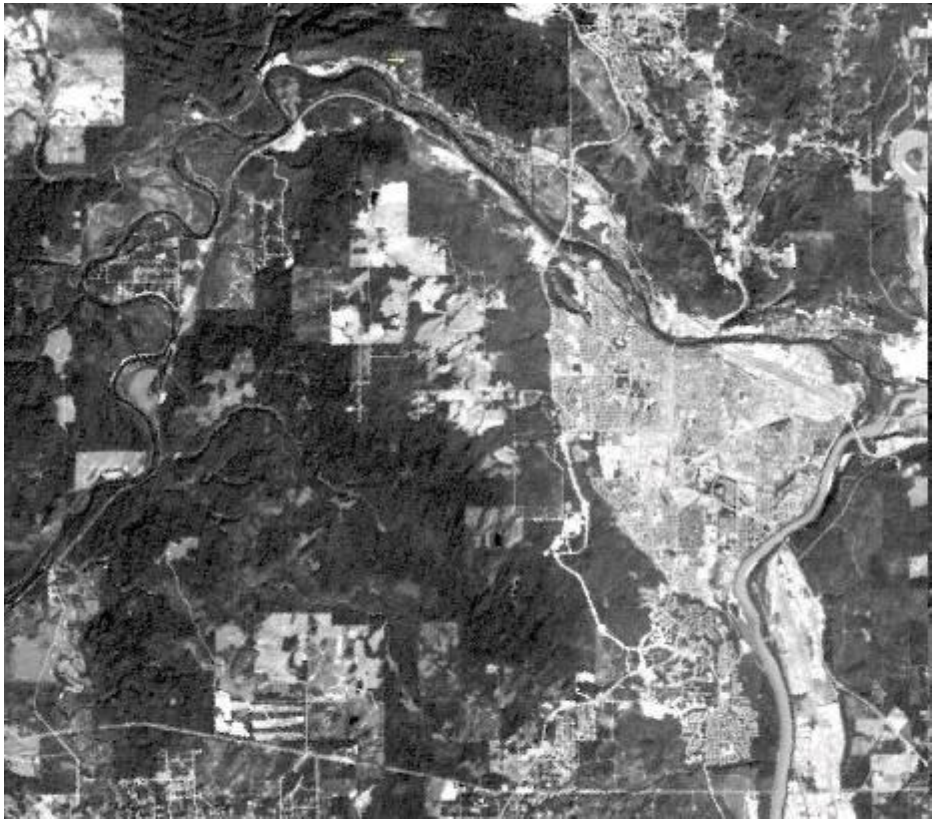
3b. Select a software 'auto' option to fill the 8-bit (16-bit) data range

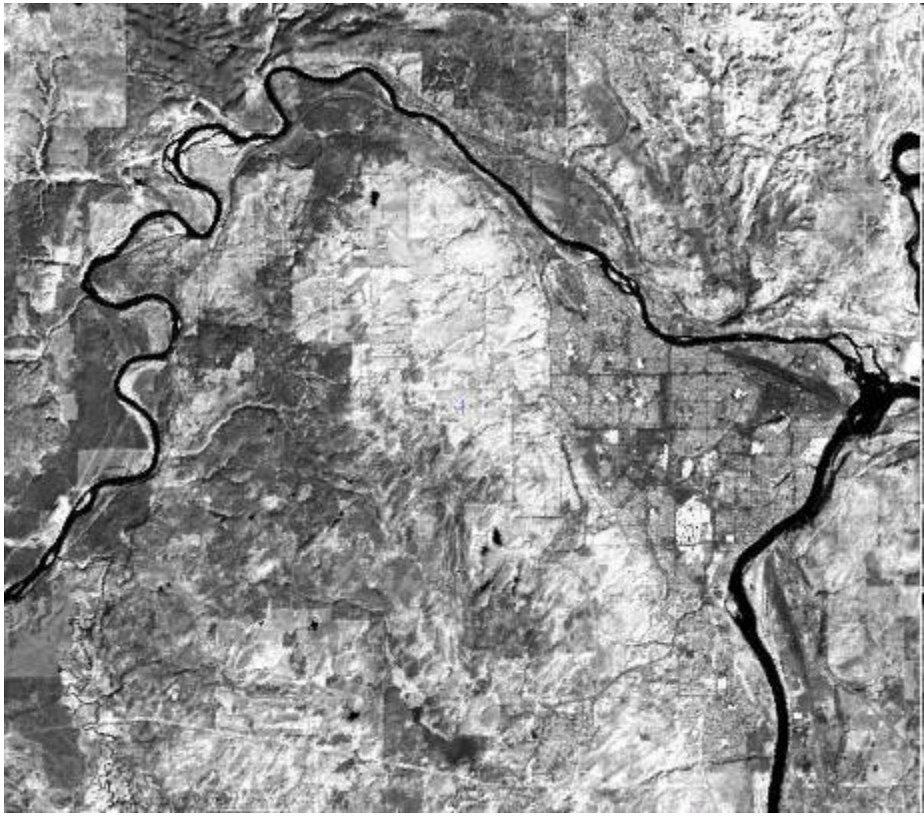
Why use band ratios ?

They create a new set of data that may be used to highlight features.
This cancels or reduces what is common in two images and exaggerates contrasts.

e.g. Band 3 Band 4 (TM 4/3 = NIR/Red = OLI 5/4 is the most common ratio)

(but why is r = 0.0 with the PG 2023 data) ?



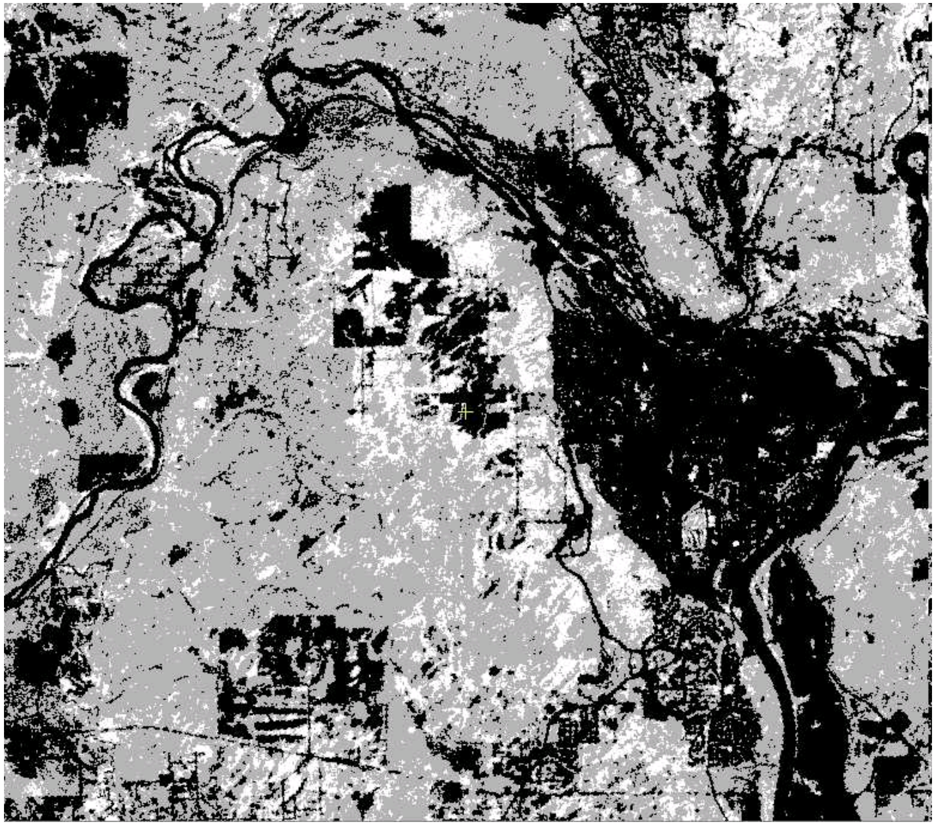


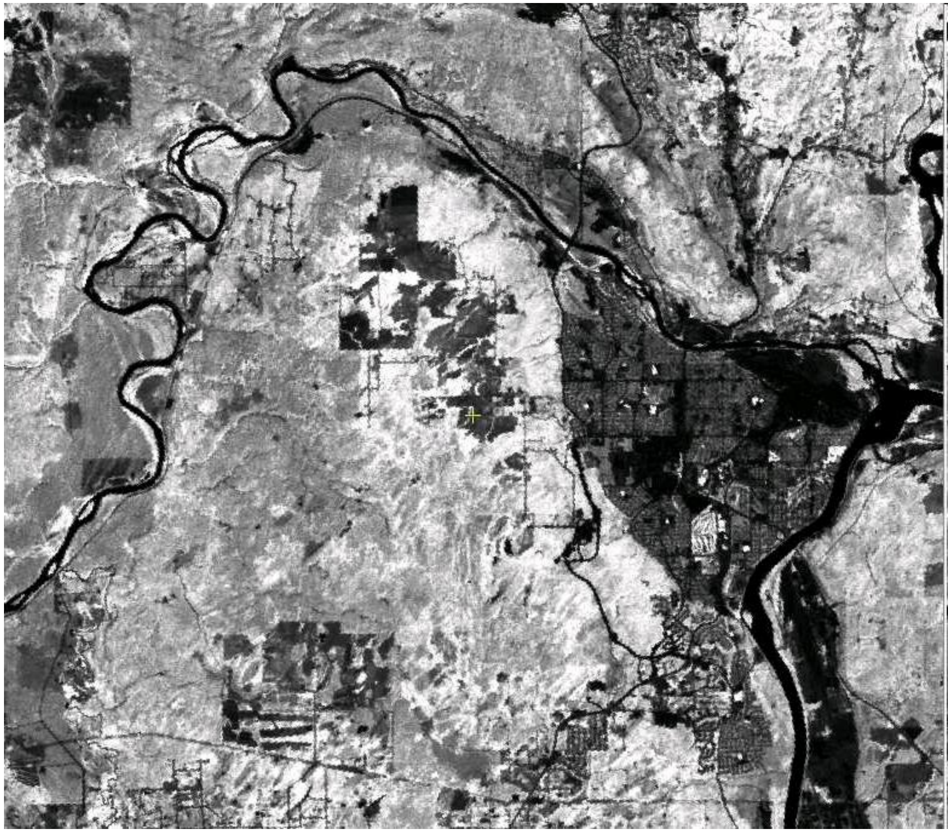
Band ratios

TM4/3 ratio - no scalar (DNs 0-3) Scaled or 32-bit: DNs ~ 0-255

Vegetation > 1; water < 1 continuum of DNs

0: Water, 1: Urban, 2: treed, 3: deciduous ?





Landsat MSS bands 1-4 (also known as = 4-7)

Possible ratios = n (n-1) … 12

Table 4. Some commonly used Landsat MSS ratios and their applications.Adapted from Avery and Berlin (1992, p. 442).

MSS Ratios	Applications
1/2, 1/4, 3/4	Characterizing rocks and soils
1/2 or 2/1	Suspended sediment in water
1/2 or 2/1	Iron-oxide content in rocks
3/1, 3/2	Vegetation and water bodies
4/1, 4/2	Vegetation and water bodies

Note: the inverse ratios create negative images, which may be more pleasing visually for certain features.

http://academic.emporia.edu/aberjame/remote/landsat/landsat_proc.htm

TM: six reflectance bands gives thirty (6 x 5) different ratio combinations
- 15 original and 15 reciprocal.

https://web.pdx.edu/~nauna/resources/10_BandCombinations.htm

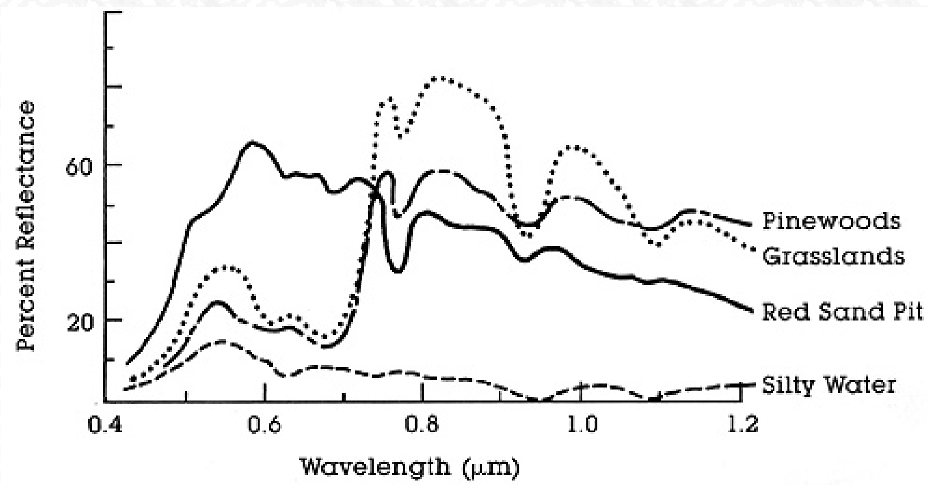
Role of ratios: a. Spectral slope enhancement

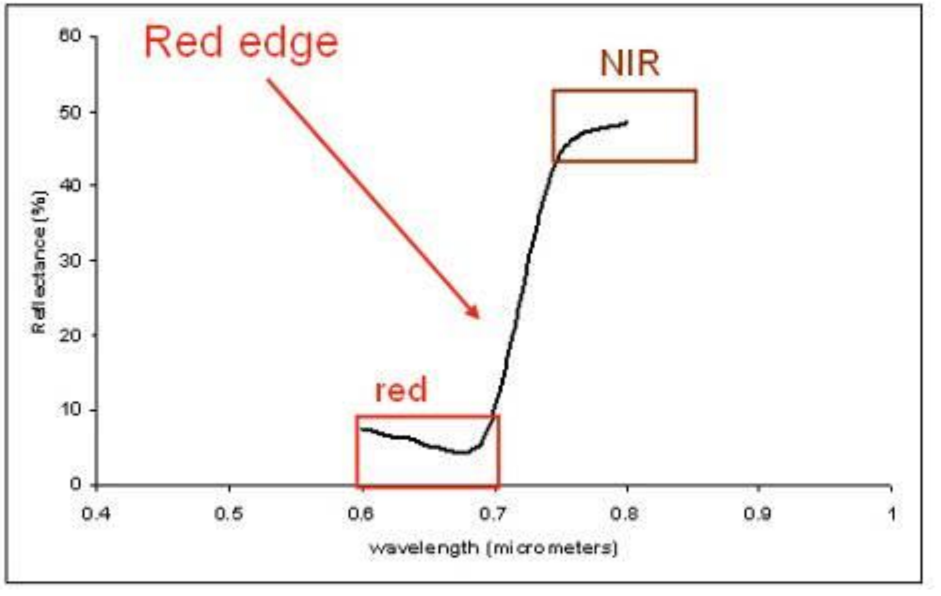
band ratioing can emphasise the <u>difference</u> between (adjacent) spectrum sections in an image, the most common being the Infra-red and red.

Since healthy vegetation has high reflectance in IR and low in red, any IR/Red (or any visible wavelength) will enhance vegetation differences: 'the red edge'

Higher values (NIR/red) = more vegetation (biomass)

… more clear than band 4 alone



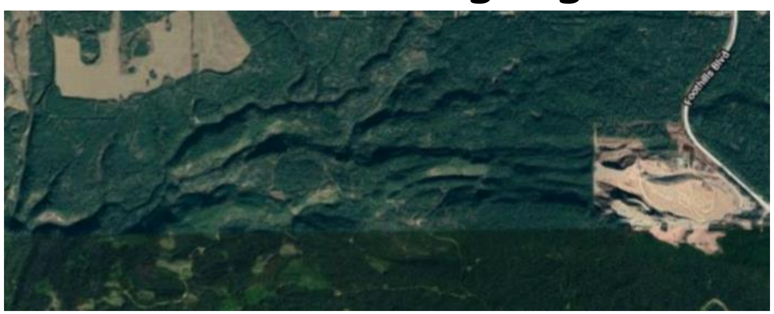


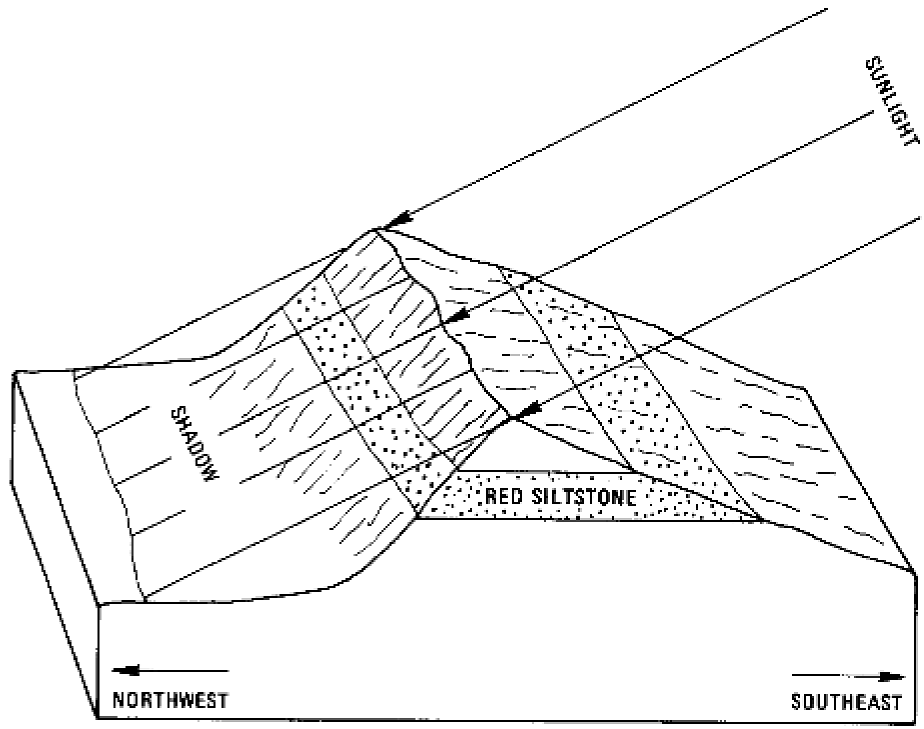
b. reduce topographic effect (shadow)

Digital Numbers may be composed of three elements:

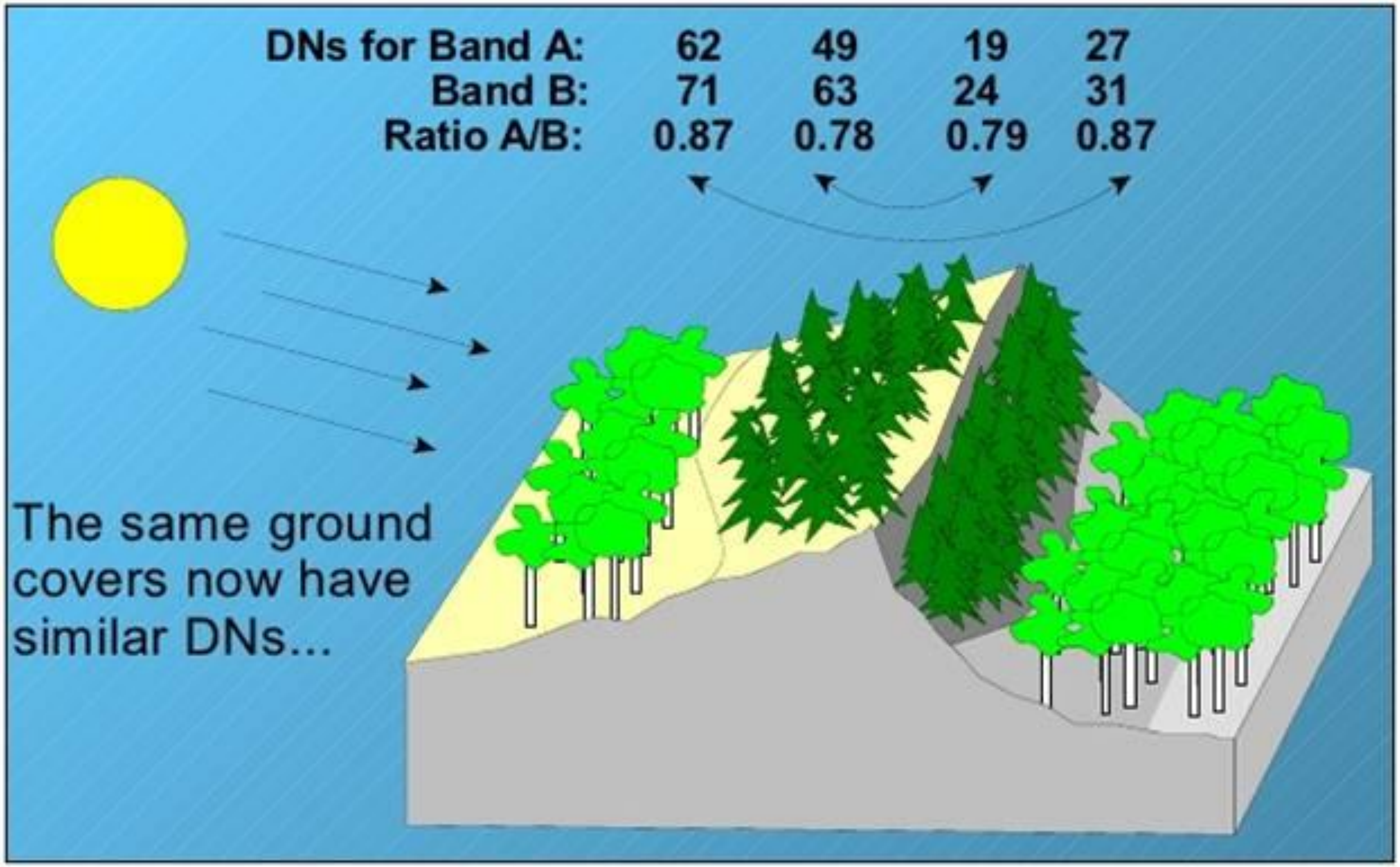
a. Atmospheric interference (e.g. haze)
b. Illumination (angle of reflection)
c. **Albedo (response to surface cover)**

A ratio can reduce the effect of illumination from topography and better highlight the <u>differences</u> in surface cover.



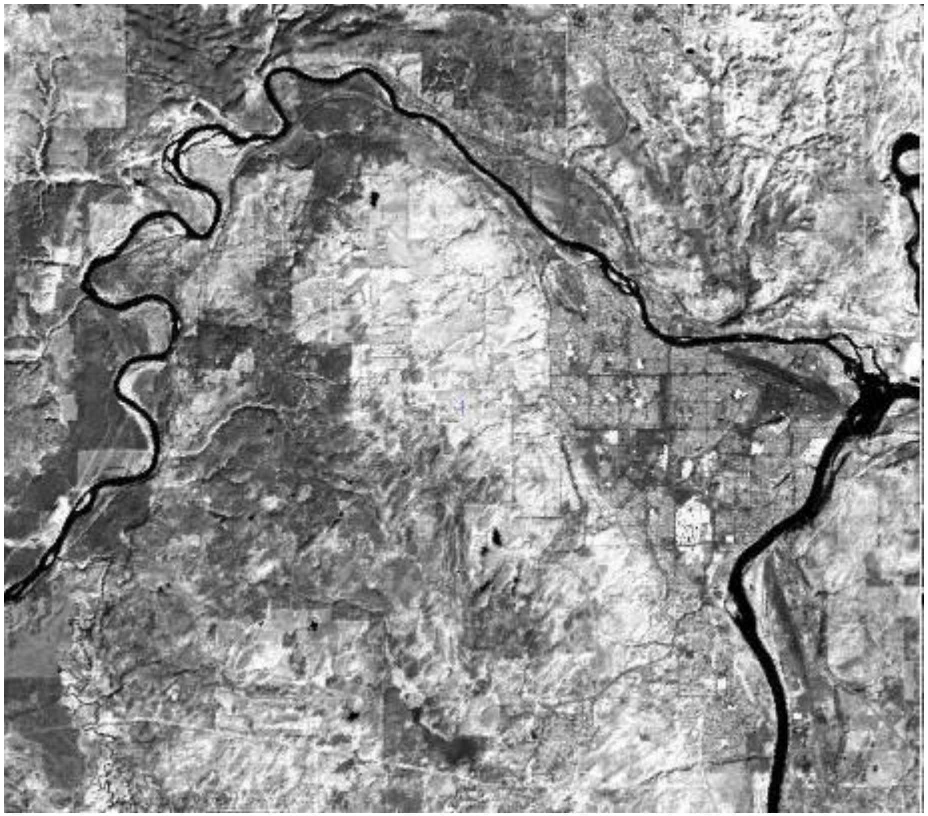


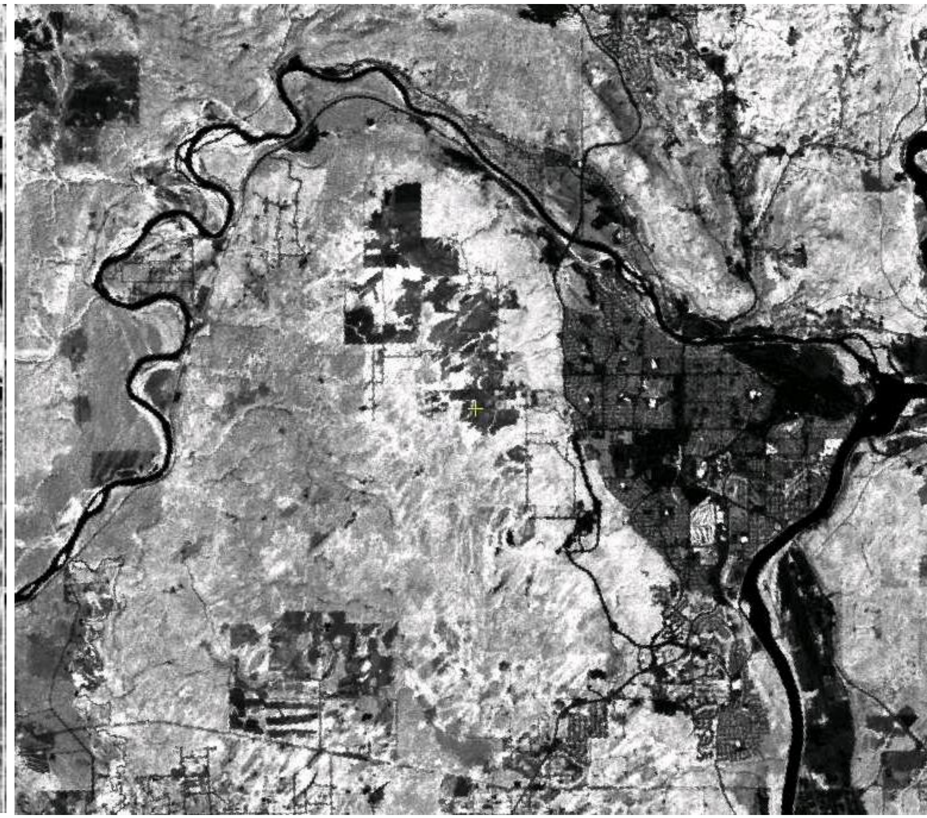
Ratio of Band A to Band B



TM Band 4 **Band 4 / Band 3 ratio**

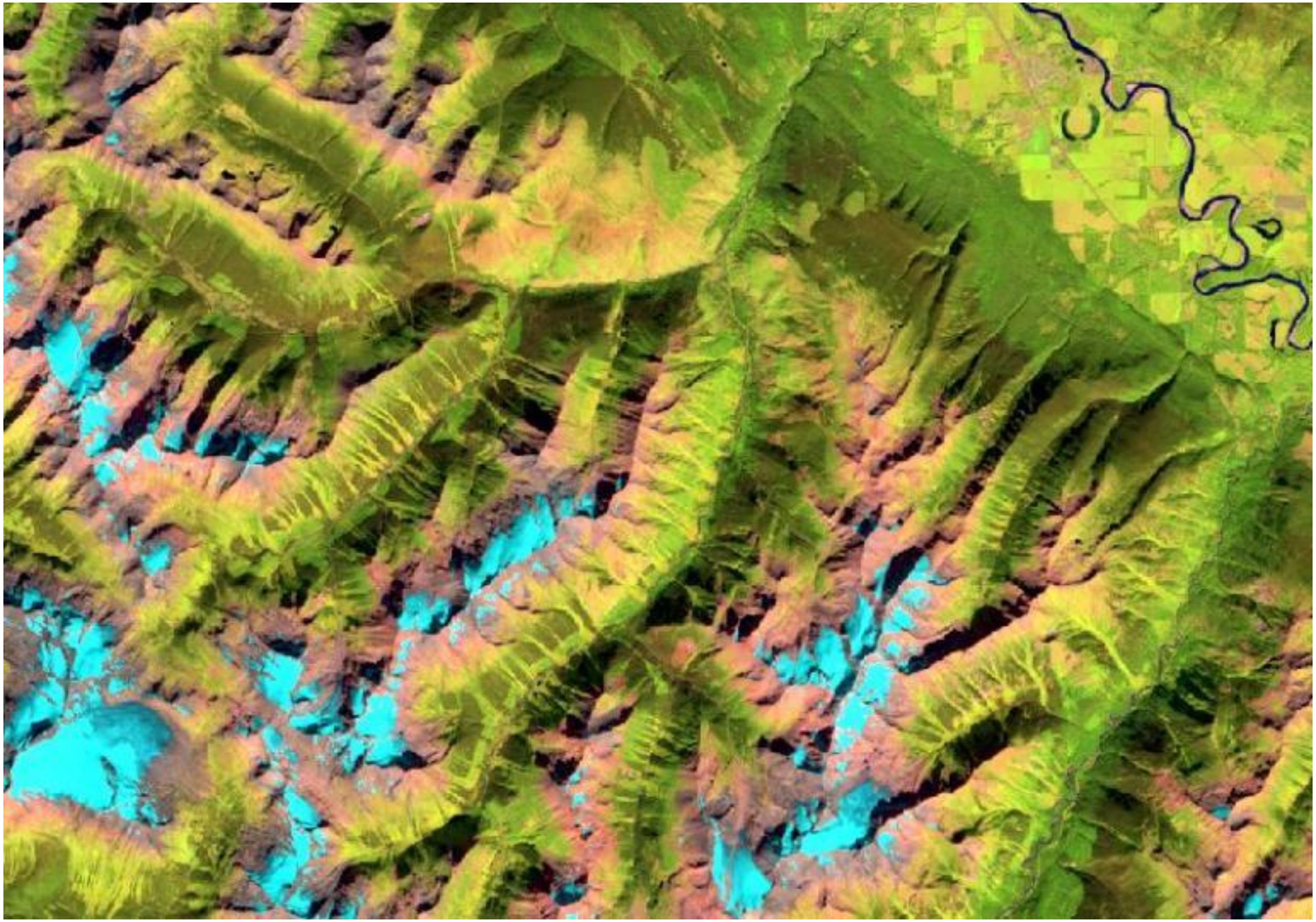
Note suppression of shadows in the ratio (eskers north of the Nechako)



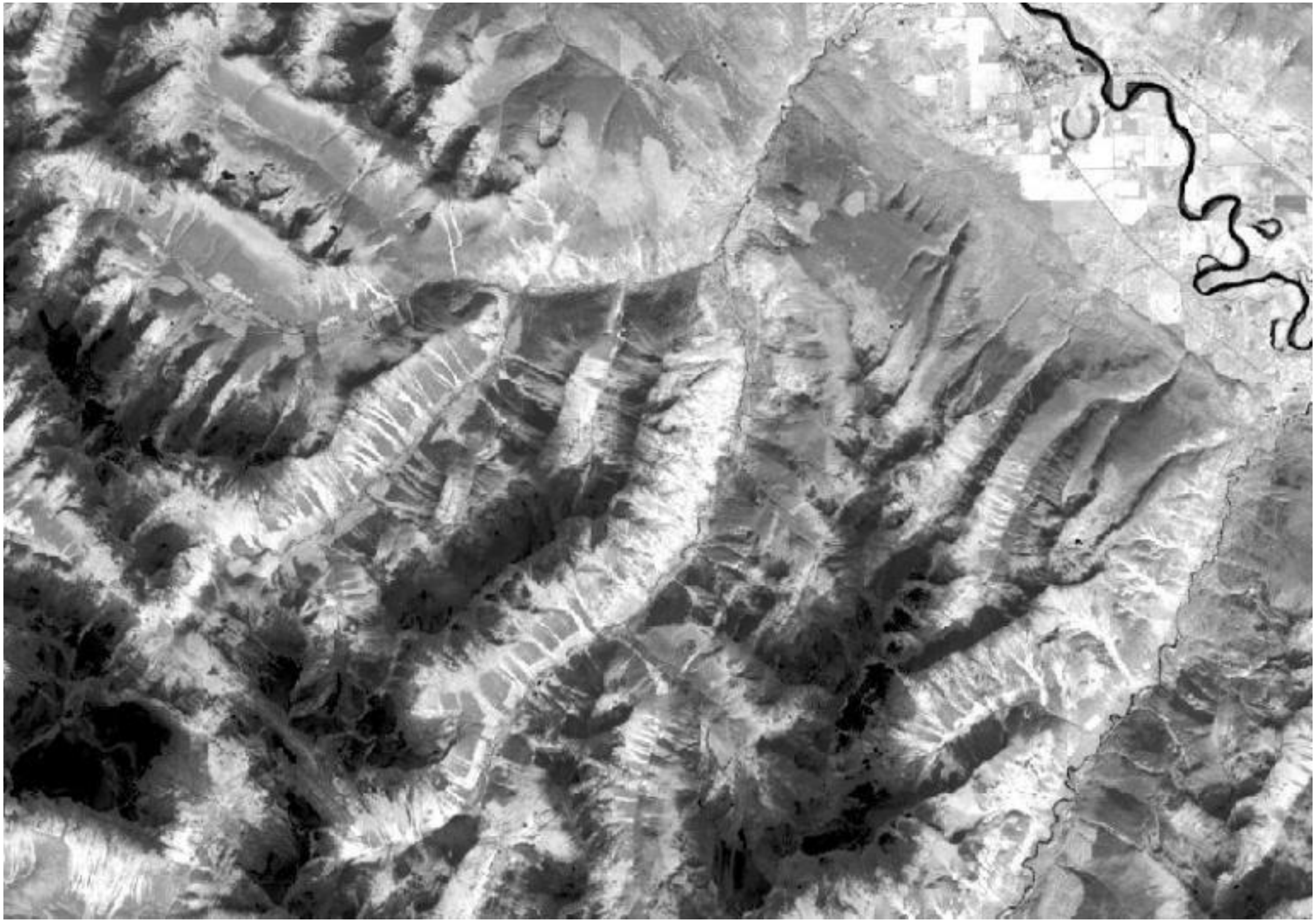


Could this ratio help distinguish the shadows from water … (lab next week)

McBride 2014 Landsat 8 OLI

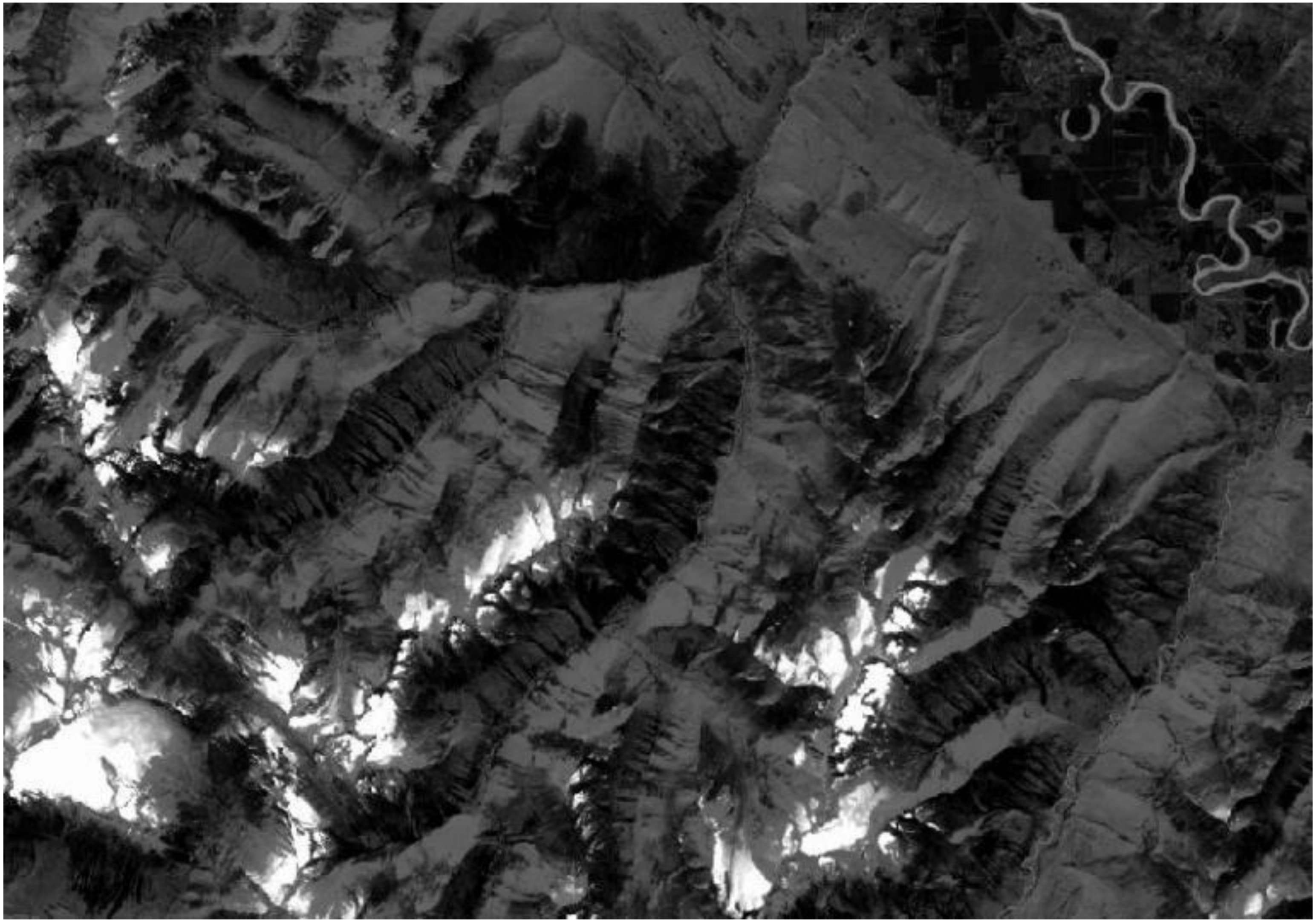


NIR/Red ratio = OLI 5/4 vegetation> 1.0 ??



In mountain landscapes, a ratio may only partly correct for illumination

Red/MIR ratio = OLI 4/6   snow/ice>2.0 (or maybe 1.5)



More on this when we discuss glacier mapping

Use of ratios: c. Threshold for a feature type
0r Include as input to classification

To include ratios as input channels for classification, they maybe should be on a similar numeric scale ?

- **Landsat 5 TM: 8-bit 0-255**
- **Use scalar multiplier ~ 50-100**

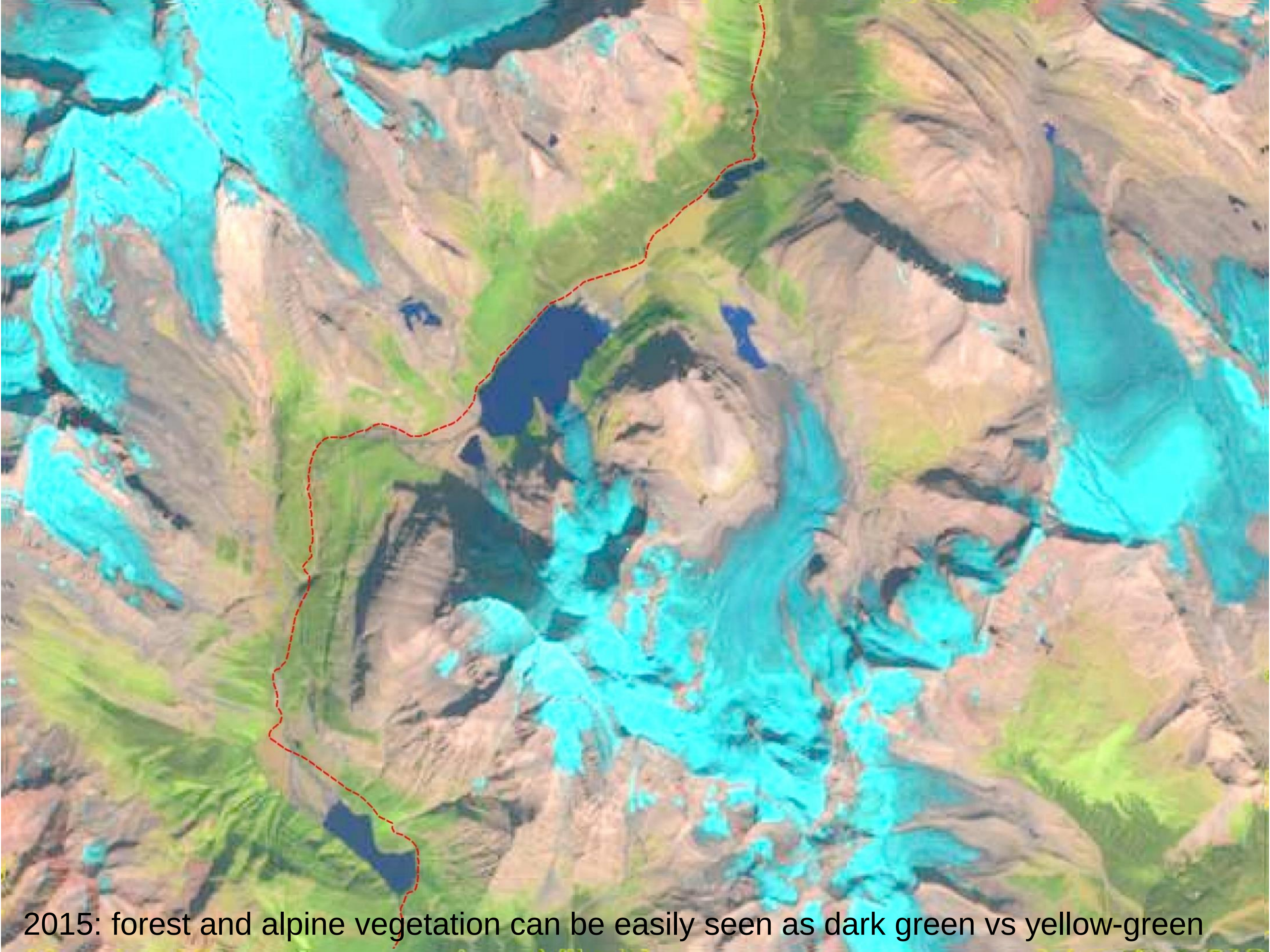
- **Landsat 8 OLI: 16-bit 0-63,354**
- **Use scalar multiplier ~10,000**

Check channel histograms and stats first

d. New layers for analysis/display

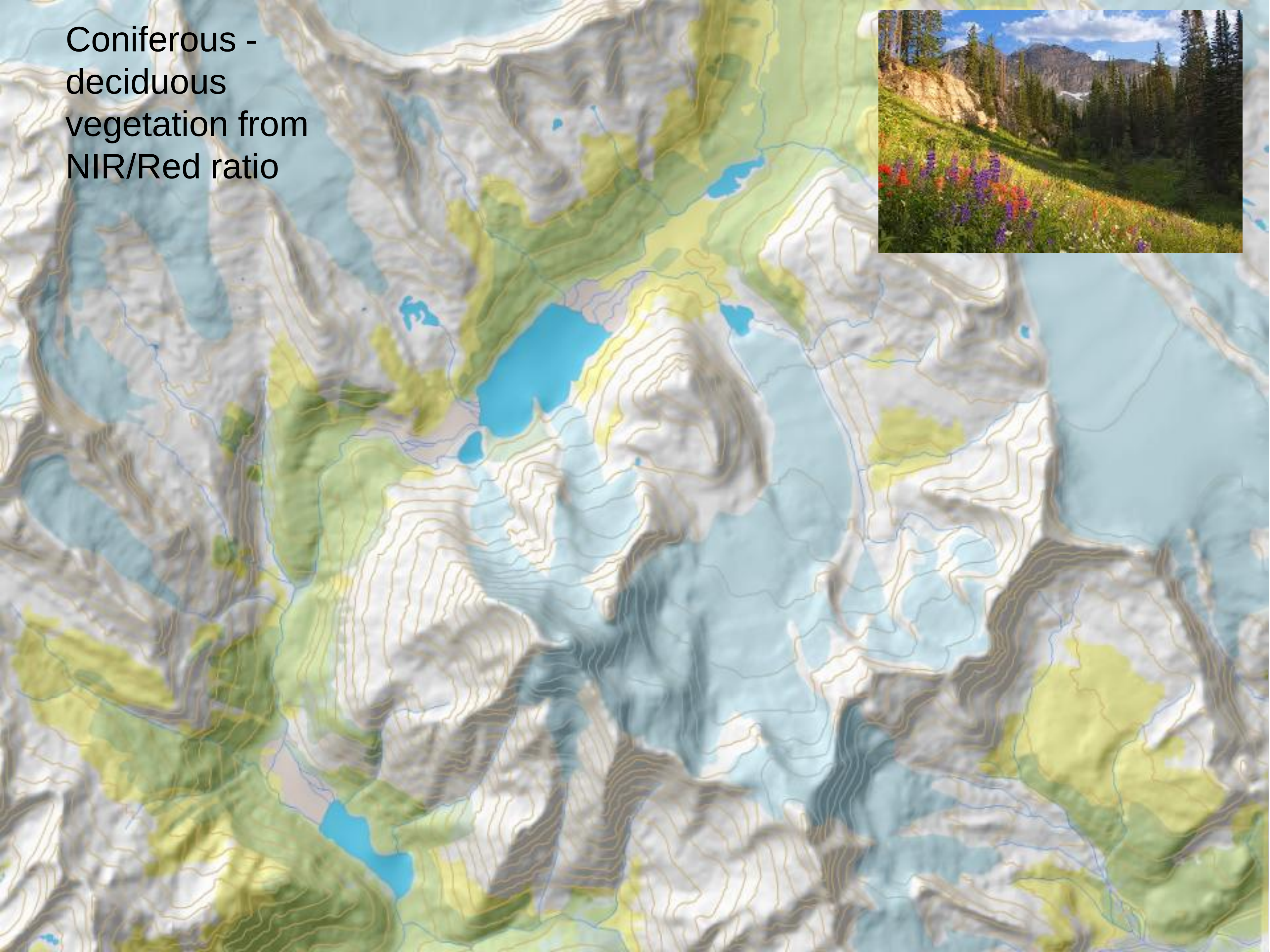
Mt. Robson (1975 / 95)

Topo mapping: maps only include ‘treed’ (>30%)



2015: forest and alpine vegetation can be easily seen as dark green vs yellow-green

Coniferous - deciduous vegetation from NIR/Red ratio



Which other ratios might be useful?

Consider the bands and their place in the spectrum:

	Visible	/ IR	/ MIR
TM	1,2,3	4	5, 7
OLI	1,2,3,4	5	6, 7

Ratios using **different EM sections** enhance **major class differences**,
e.g. coniferous versus deciduous, rock versus vegetated (e.g. IR / Visible)

	SWIR / Visible		NIR / SWIR
TM	7/3 lithology	3/5 snow and ice	4/5 Moisture
OLI	7/4	4/6	5/7

pairs of bands from similar parts of the EM spectrum may show more 'noise'
e.g. TM 2/3, 5/7, 3/1

Which other ratios could be useful?

But there are applications using two bands in the same region, e.g. in geology

MSS: 5/4, 7/6 (4=green, 5=red, 6,7 =NIR)

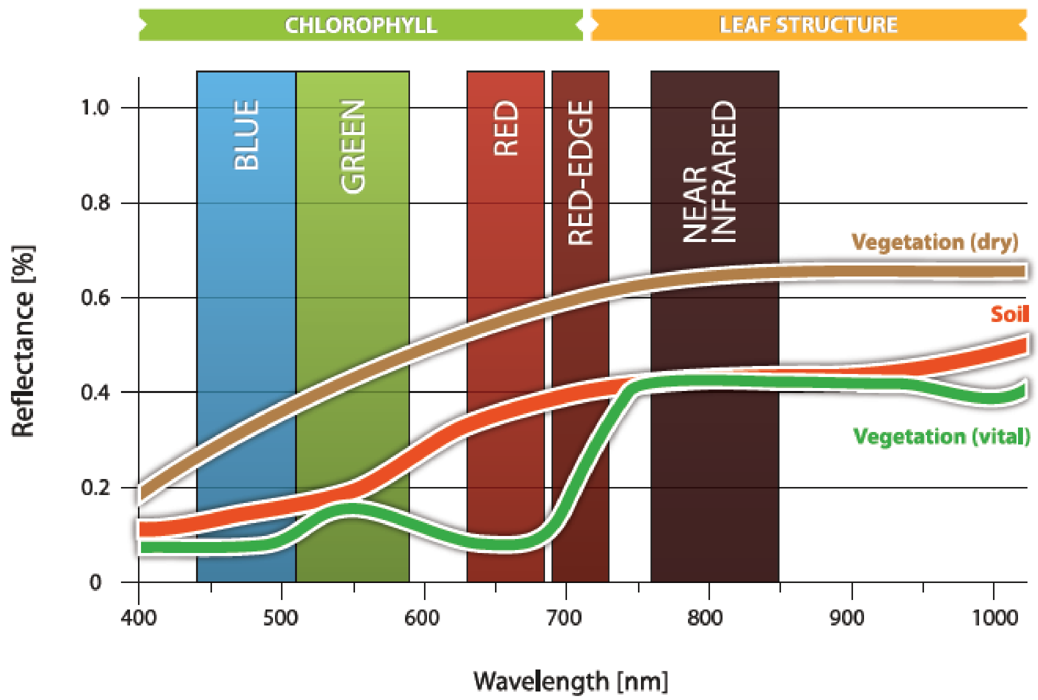
TM: 3/2, 3/1, 5/7 :
mineral enhancement (hydrothermally altered rocks)

Ratio of two bands in the same EM region can distinguish **subtypes** such as soils, and geologic differences

Red-Edge Simple Ratio **(SRre) = NIR / RedEdge** 2008-> (Sentinel 2015->)
e.g. Sentinel 2 band 8 / 5 or … band 8 / (band 5 + Band 6 + band 7)

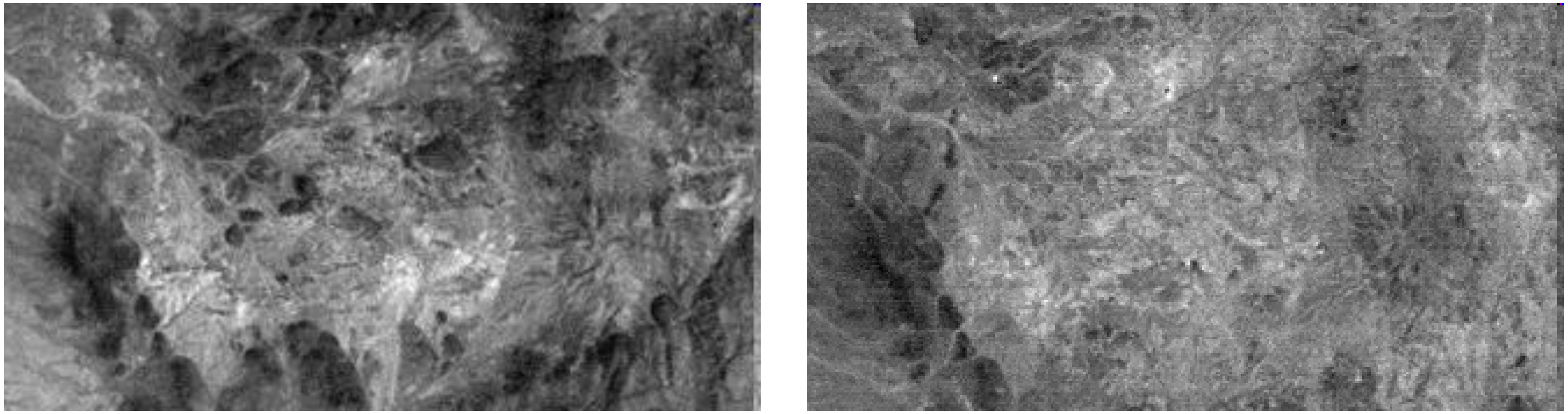
https://pro.arcgis.com/en/pro-app/latest/arcpy/image-analyst/srre.htm

The three 20m ‘red edge’ bands of Sentinel-2 (~670-780nm) multispectral instrument (MSI) provide key information on the state of vegetation.

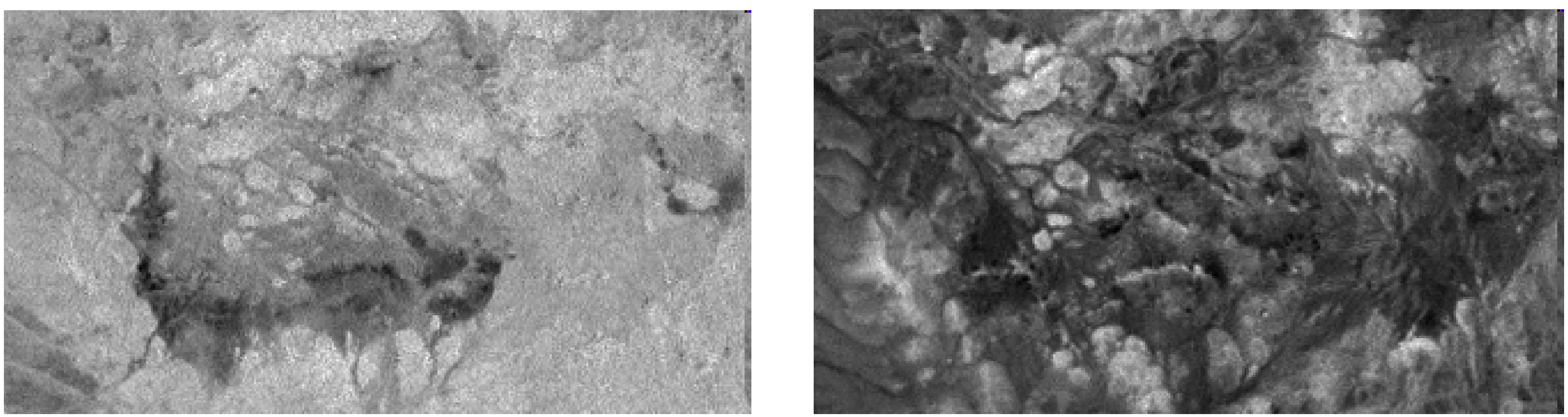


Thematic Mapper ratios, Utah (desert scene)

ratios 3/1 and 4/2



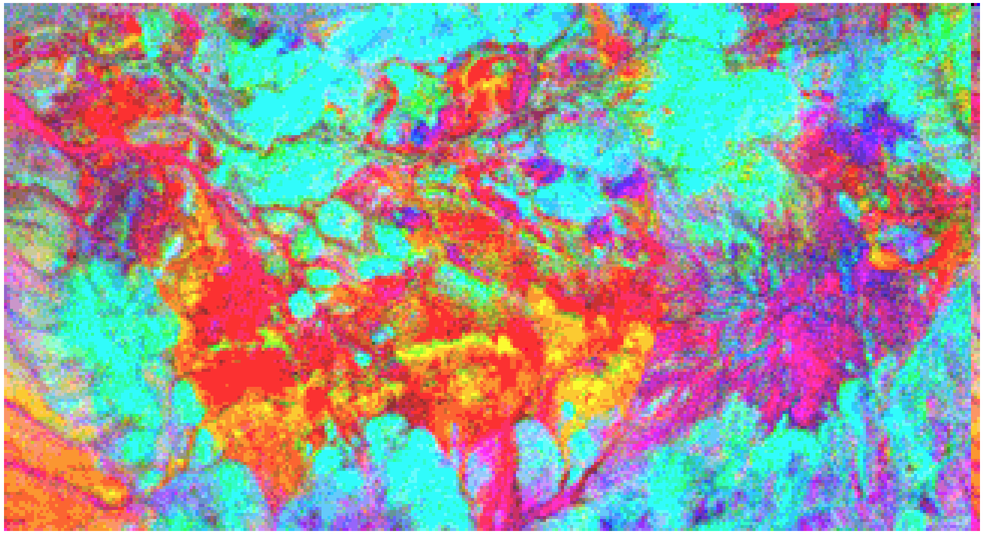
7/5 and 1/7 ratios



Geologists love these when there is no vegetation in the way ….

Ratios: e. Creating Colour Composites

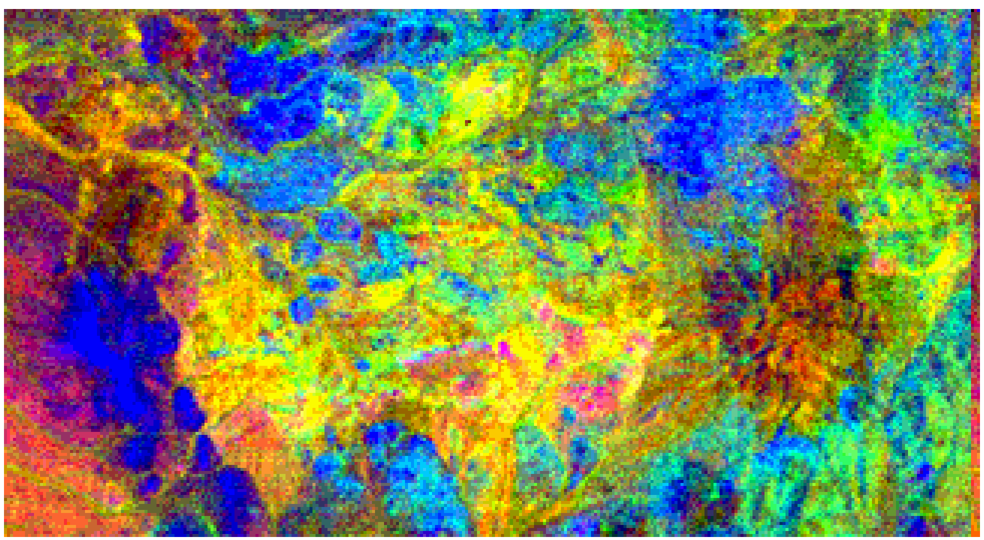
- use any 3 channels, not just bands



7/5 = Blue

1/7 = Green

3/1 = Red



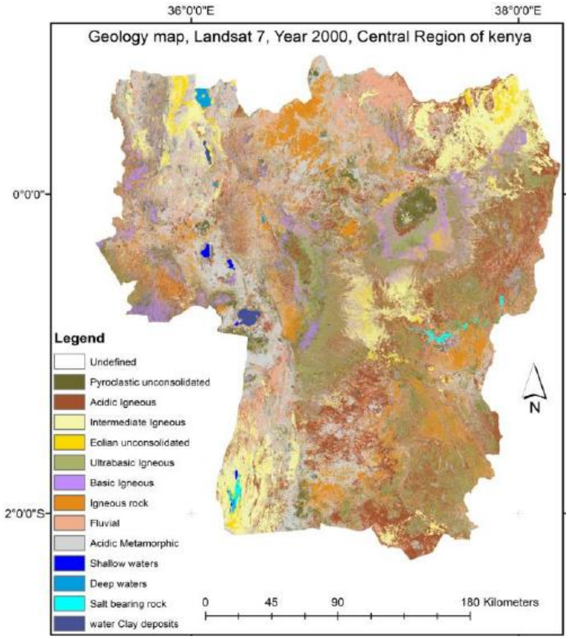
1/7 = blue

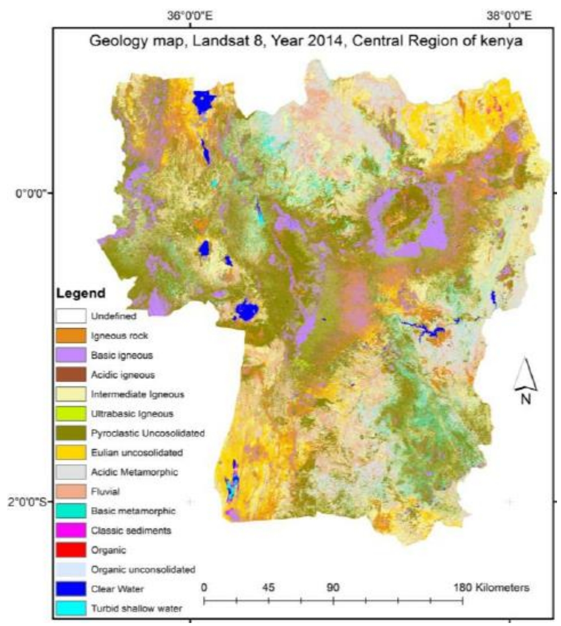
4/2 = green

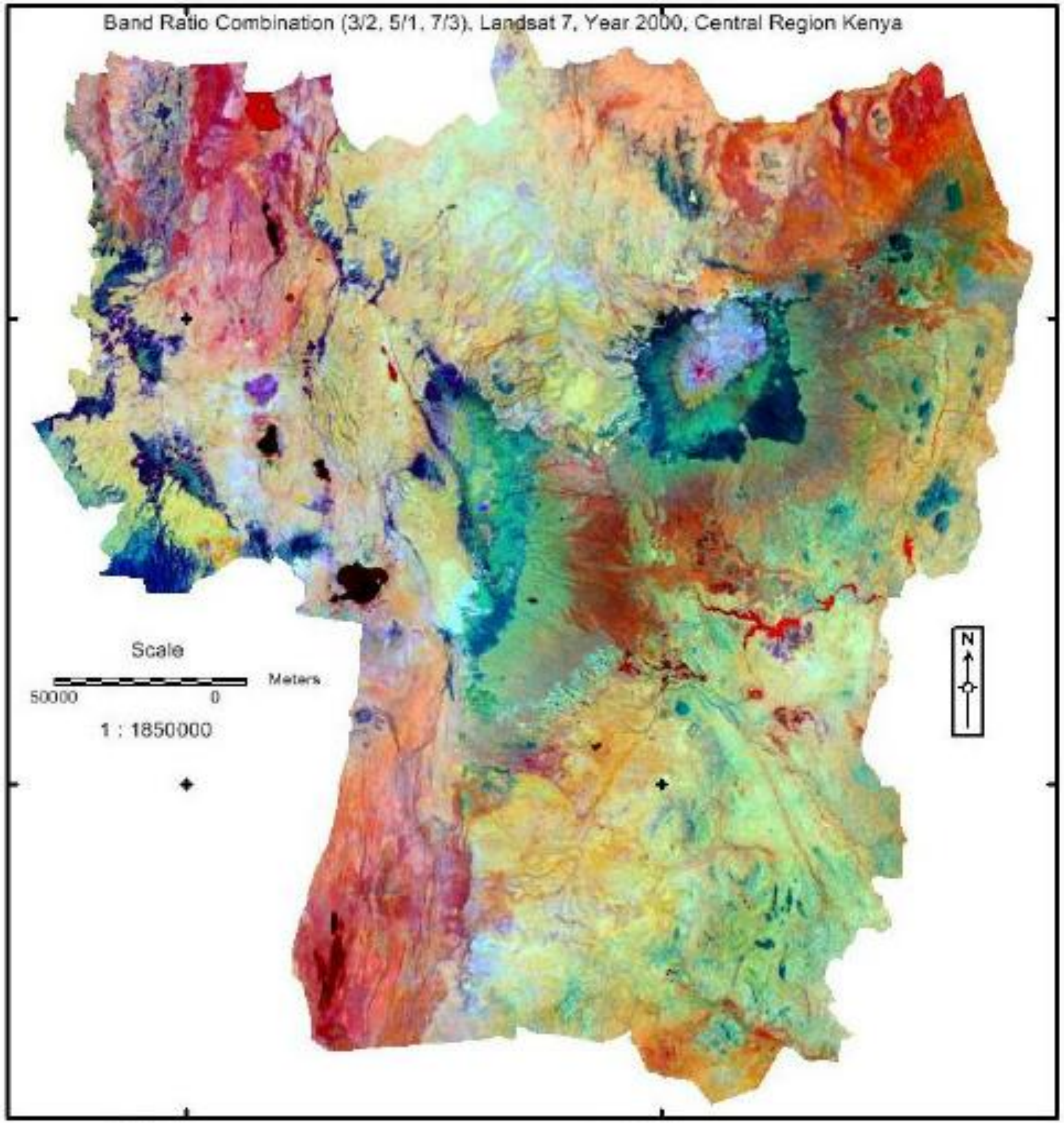
3/1 = red

How many possible colour composites are there from 15 ratios ? (15x14x13=**2730**)

Band ratios







Band ratio combination (3/2, 5/1, 7/3), Landsat 7

https://www.researchgate.net/figure/Geology-classification-map-Landsat-7_fig2_276280545

Other Image Arithmetic (tool: ARI)

also: RTR (ratios) and Raster Calculator

Band ratios are the result of 'division' /

it is also possible to use the other arithmetic operators:

b. Band (image) subtraction -

Yields the difference between two bands; the result will include values that are + and - …… requiring a **16 bit signed channel**:

useful for showing <u>changes through time</u> with two image dates.

- More on this when we discuss change detection

b. Band (image) multiplication *

Used with a **mask**, where one layer is 1 or 0

e.g. land or water …. your water bitmap in lab 2

or forested vs non-forested in the EOSD Canada mapping project

LAND-WATER MASKS: BASIS FOR AUTOMATED PRE- AND THEMATIC PROCESSING OF REMOTE SENSING DATA Erik Borg, Bernd Fichtelmann

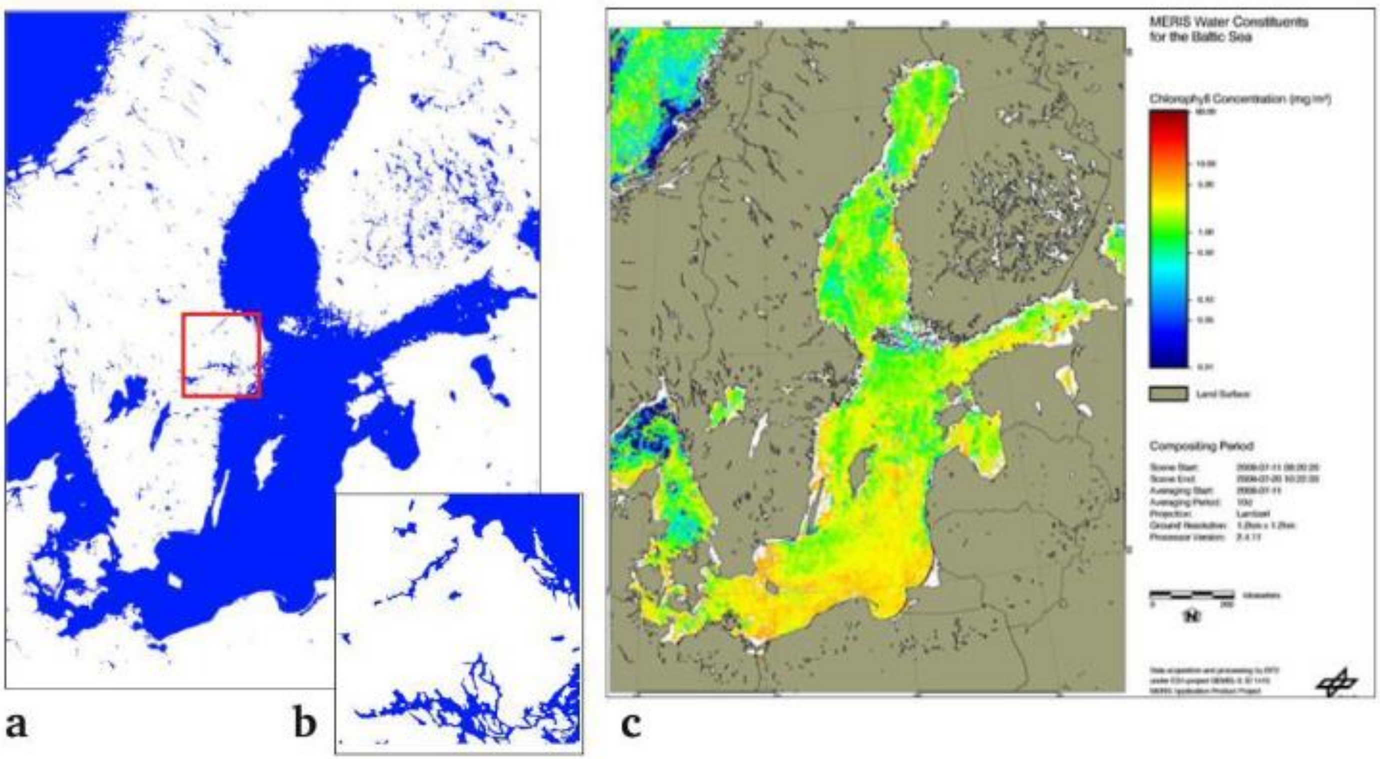


Figure 2: Land-water-mask of limited quality (a). The section shows details of the map around Stockholm (b). Quick-look product "Chlorophyll Concentration in the Baltic Sea" based on MOS data (c).

https://publishup.uni-potsdam.de/opus4-ubp/frontdoor/deliver/index/docId/10345/file/pgp12_77-99.pdf

Other Image Arithmetic

c. Band (image) addition +

Used to create an overall or average image channel,

e.g. (TM1 + 2 + 3) / 3 (=~PAN ?) or (TM5 + TM7) /2

An 'index' uses addition and subtraction (see next lecture)

https://enterprise.arcgis.com/en/portal/10.7/use/band-arithmetic-function.htm

How many ratio options in a multiband (n) dataset:

Total Ratios = n (n-1)

1/2 and 2/1 are just the inverse of each other …… they 'look' different to the human eye, but behave the same in an algorithm

Total Ratios = n (n-1) /2

= 6 (4 bands) for Landsat MSS

15 (6 bands) for Landsat TM (excluding thermal)

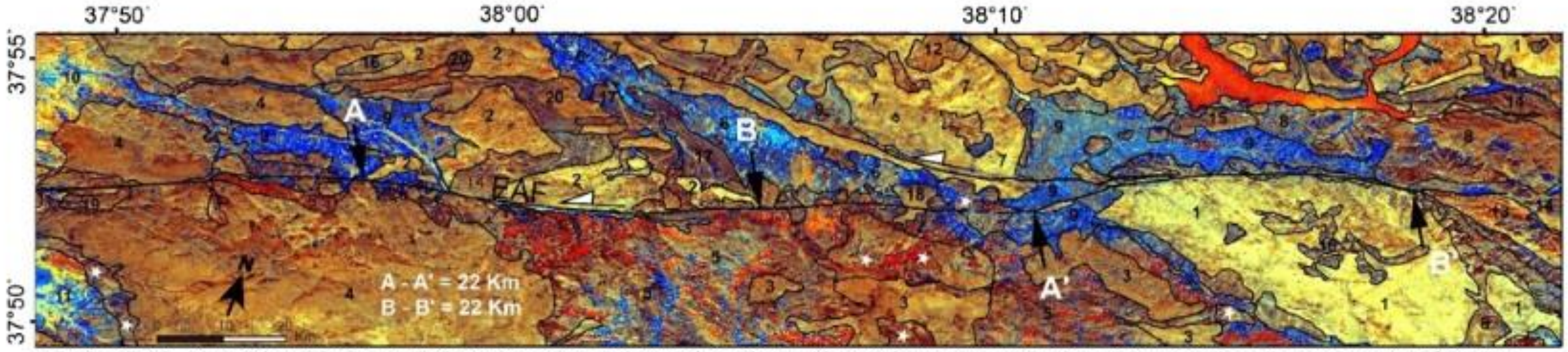
28 (8 bands for Landsat OLI)

55 (11 bands for Sentinel 2-MSI)

91 (14 bands for ASTER)

https://www.facebook.com/arabnubiagroup/videos/applying-different-band-ratio-composites-on-sentinel-2-imagery-which-equivalent-/2520705917991385/

https://www.facebook.com/arabnubiagroup/videos/applying-band-ratios-on-sentinel-2a-multi-spectral-satellite-imagery-could-be-ve/1344438065690657/



1: TrJKk; 2: TrJKk+JKu; 3: Teh; 4: Teh+Teog; 5: TrKko; 6: Qer; 7: Pc; 8: PzPs; 9: Qal; 10: Kbe; 11: Kha; 12: Jku; 13: Kpg; 14: Temk; 15: Temm; 16: Kk; 17: Tra; 18: Qay; 19: Qgf; 20: Dcy

Fig. 5 ASTER band ratio image (1/3-1/9-3/9) in RGB. White stars indicate the landslide

Springer

ASTER spectral band ratios for lithological mapping: a case study for measuring geological offset along the Erkenek Segment of the East Anatolian Fault Zone, Turkey

Arabian Journal of Geosciences (2020) 13:832

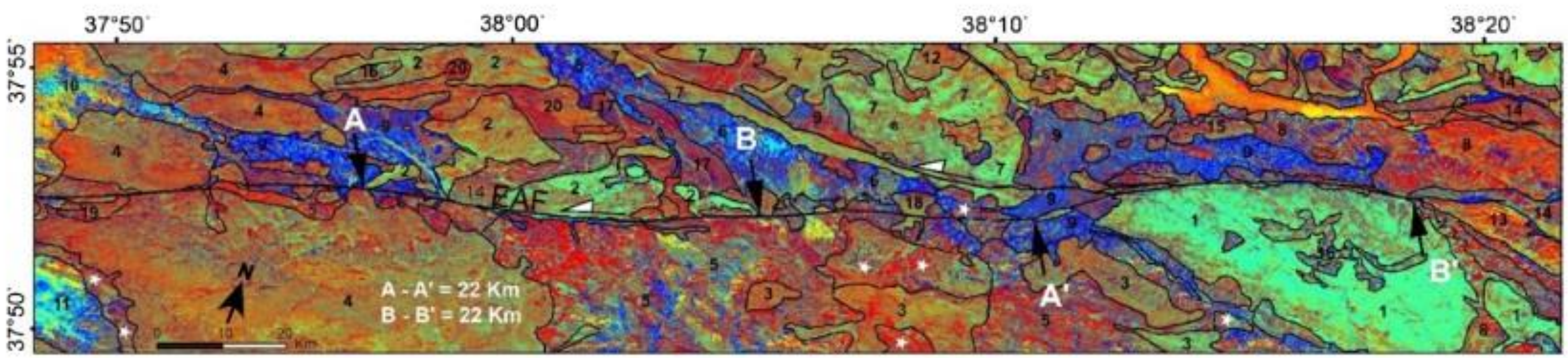


Fig. 6 ASTER band ratio image (7/3-1/7-3/5) in RGB

Also: Detecting areas of high-potential gold mineralization using ASTER data
October 2010 Ore Geology Reviews DOI: 10.1016/j.oregeorev.2010.05.007

ASTER bands

ASTER sensor launched December 1999 (NASA / Japan) – data from 2000

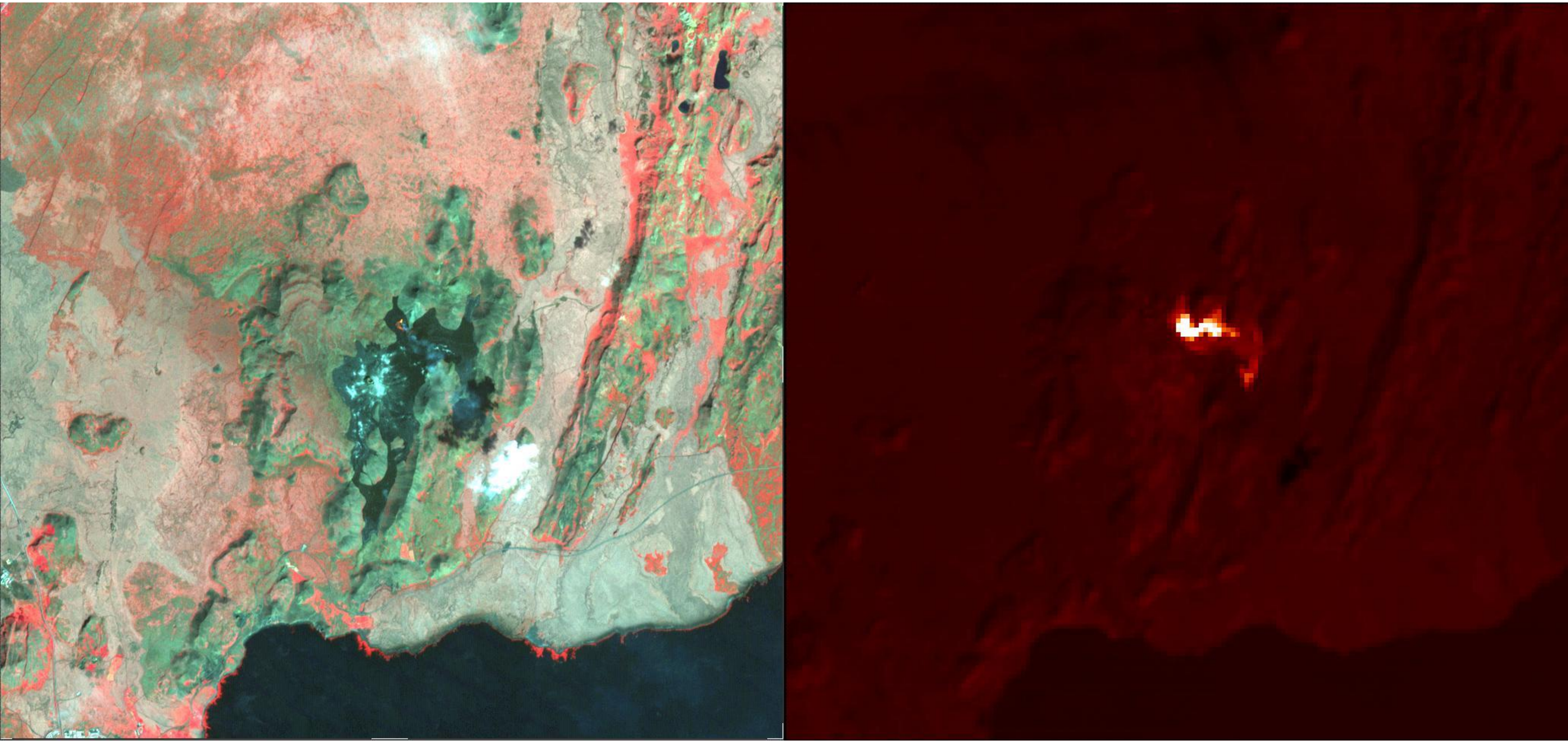
(it may be decommissioned by December 2025, as equator crossing -> 9am)

Band	Wavelength (microns)	Spatial Resolution (m)
	Visible to Near-Infrared Bands	
1	0.52 � 0.60	15
2	0.63 � 0.69	15
3	0.76 � 0.86	15
	Shortwave Infrared Bands	
4	1.60 � 1.70	30
5	2.145 � 2.185	30
6	2.185 � 2.225	30
7	2.235 � 2.285	30
8	2.295 � 2.365	30
9	2.360 � 2.430	30
	~~Mid-infrared~~ (Thermal) Bands	
10	8.125 � 8.475	90
11	8.475 � 8.825	90
12	8.925 � 9.275	90
13	10.25 � 10.95	90
14	10.95 � 11.65	90

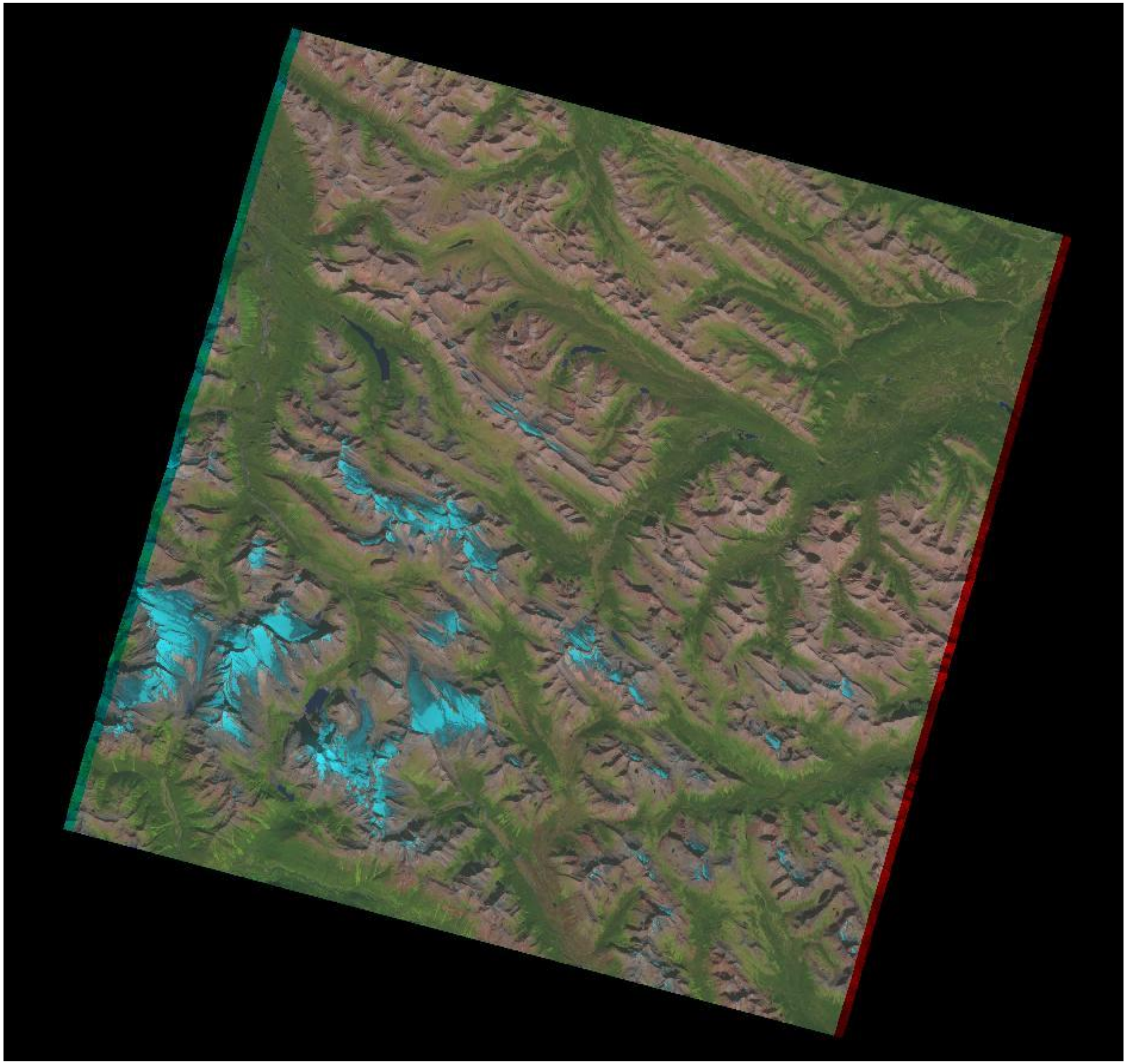
Failed 2008

Geology Applications

ASTER: VNIR and Thermal images, August 2022



The eruption of the Fagradalsfjall volcano in southwest Iceland, August 15, 2022
Bands 321 (NIR-Red-Green) and Thermal (right)



ASTER
NASA / Japan

“Landsat-like”

Landsat 8 OLI resolution 13 years before L8 launch

Mt. Robson

15/30m

Sept 2007

SWIR bands failed, 2008

ASTER sensor launched December 1999 (NASA / Japan) – data from 2000

https://asterweb.jpl.nasa.gov/gallery.asp