Band ratios

Spectral Band ratioing is perhaps the simplest of multispectral techniques, and the earliest example of Digital Image Processing
- a type of GIS 'overlay' ... deriving new information from two data layers

A band ratio is a new channel 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

e.g. for a pixel, if band a = 50 and band b = 25,
then the ratio DN = 50/25 for that pixel DN ratio = 2.0

if a = 100 and band b = 40, then the band ratio DN = 2.5 32-bit real channel

- or rounded to 2 down if there are only integer DNs = 2 8 or 16-bit channel

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

16 bit data 0-65,535

But in practice they rarely exceed: 0-5

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

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

b. 8-bit / 16 bit (Integer) – not usually 16-bit as DNs won't exceed 255

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

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 ?)

Early Landsat MSS bands 1-4 (also known as = MSS 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.

MSS Bands

1: Green
2: Red
3: NIR1
4: NIR4

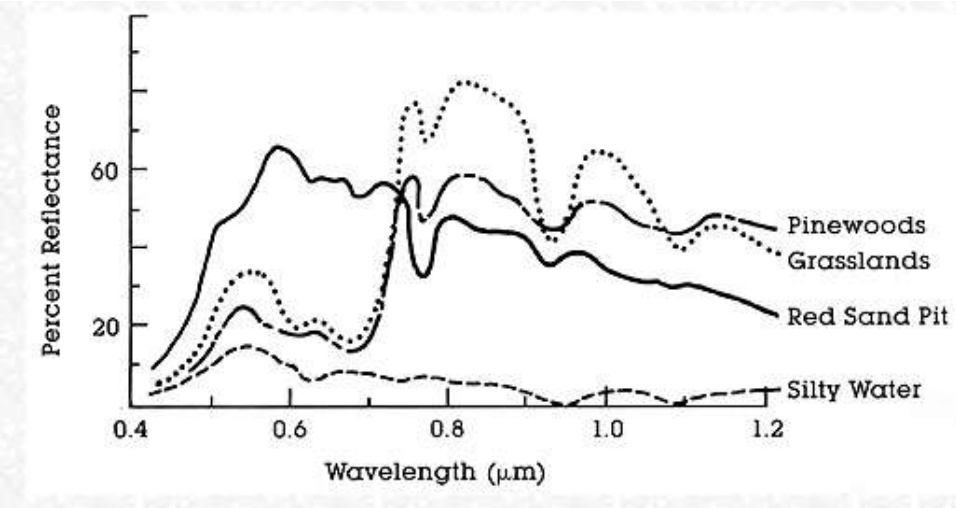
Landsat TM sensor : six reflectance bands (excluding the thermal Band 6)
-> 30 (6 x 5) ratio combinations - 15 original and 15 reciprocal.

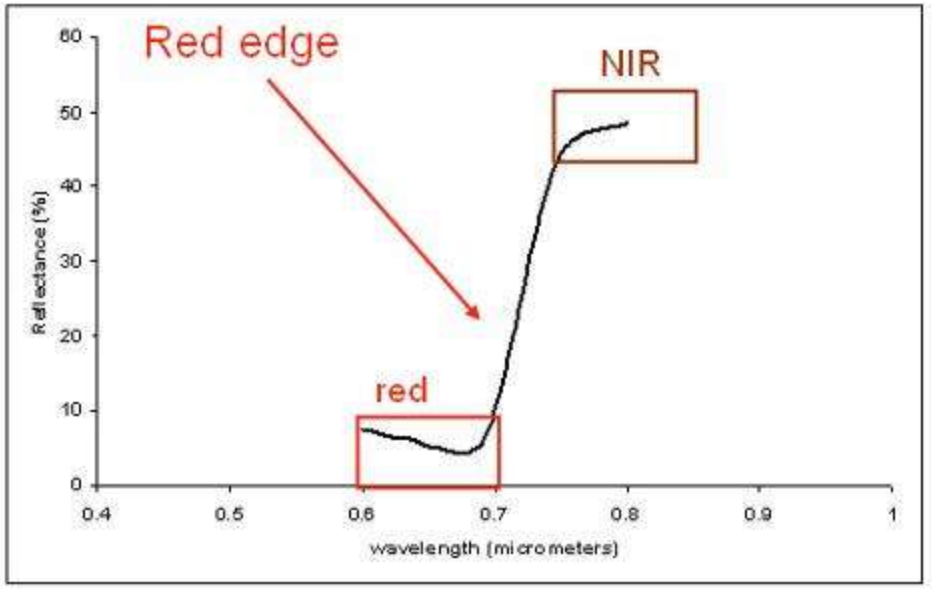
Role of ratios: a. Spectral slope enhancement

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

Healthy vegetation has high reflectance in NIR and low in red, NIR/Red (or any visible wavelength) will enhance vegetation differences and hence 'the red edge'

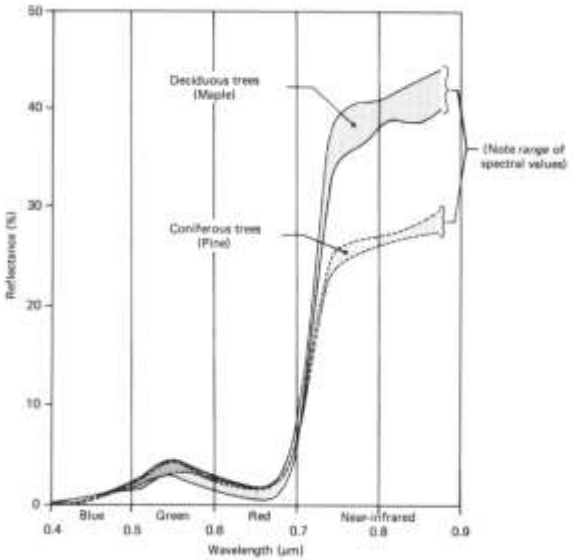
Higher values (NIR/red) = more vegetation (biomass)
… more clear than NIR band alone



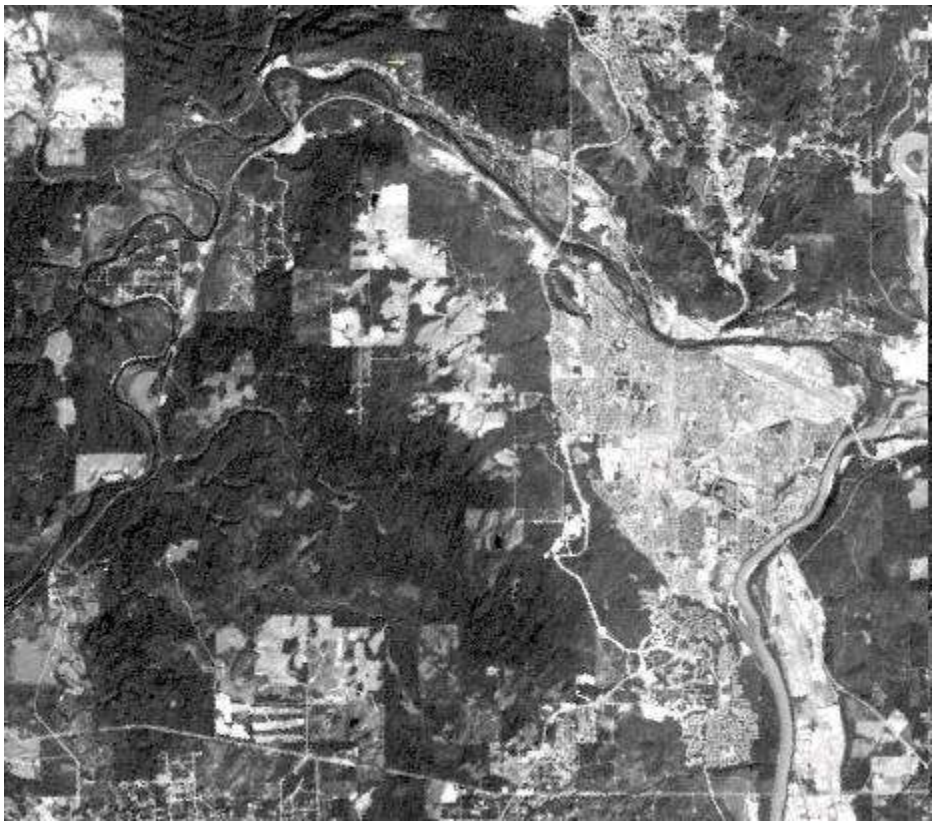


Why use band ratios ?

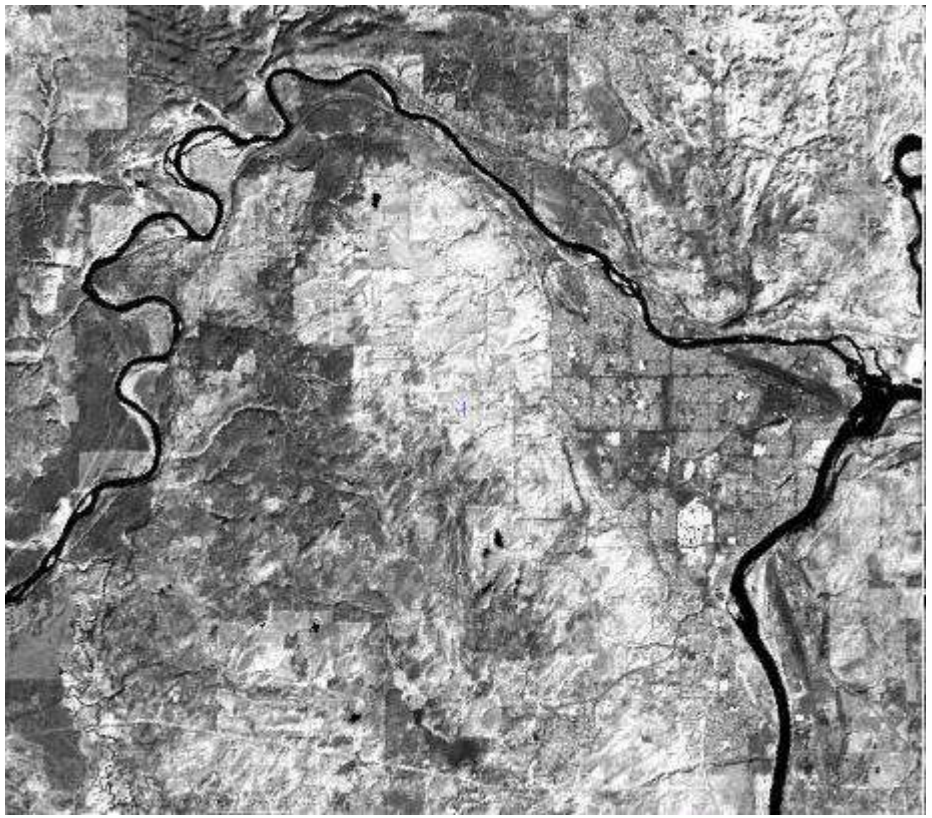
They create a new set of data that may highlight features.
Principle: this cancels or reduces what is <u>common</u> in two images and exaggerates <u>contrasts</u>.
e.g. NIR/Red is a common ratio = TM 4/3 or OLI 5/4



Red Band



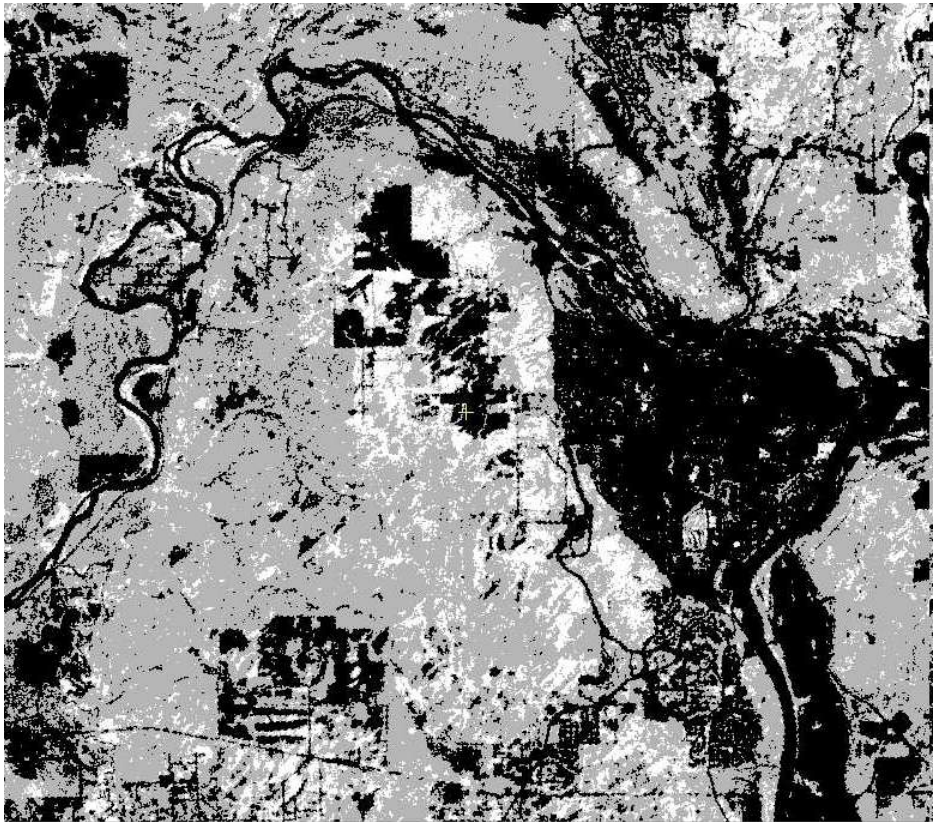
Near IR



TM4/3 ratio - no scalar (DNs 0-3)

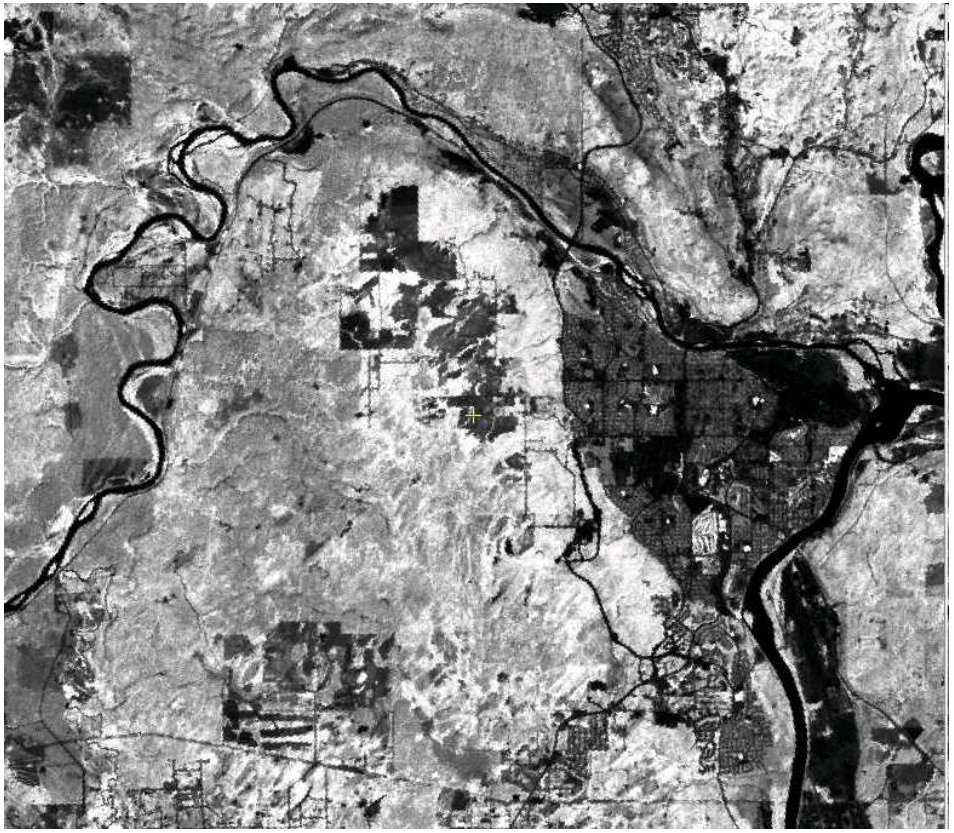
Vegetation > 1; water < 1

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



32-bit real (or scaled: DNs ~ 0-255)

continuum of DNs



b. reduce topographic effect (shadow)

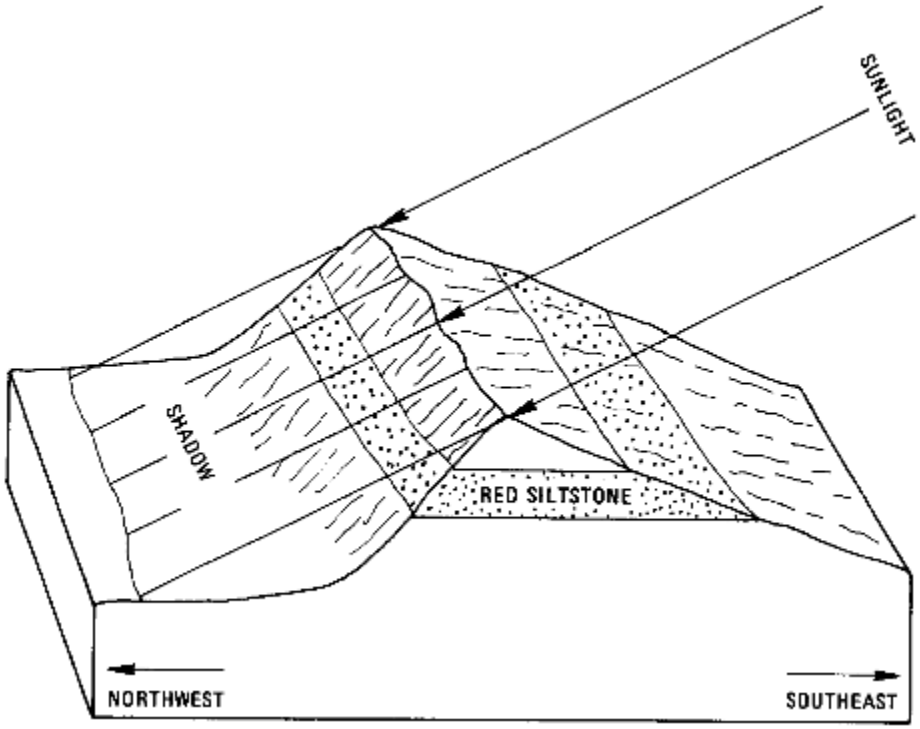
Digital Numbers can be composed of three elements:

a. Atmospheric interference (e.g. haze)

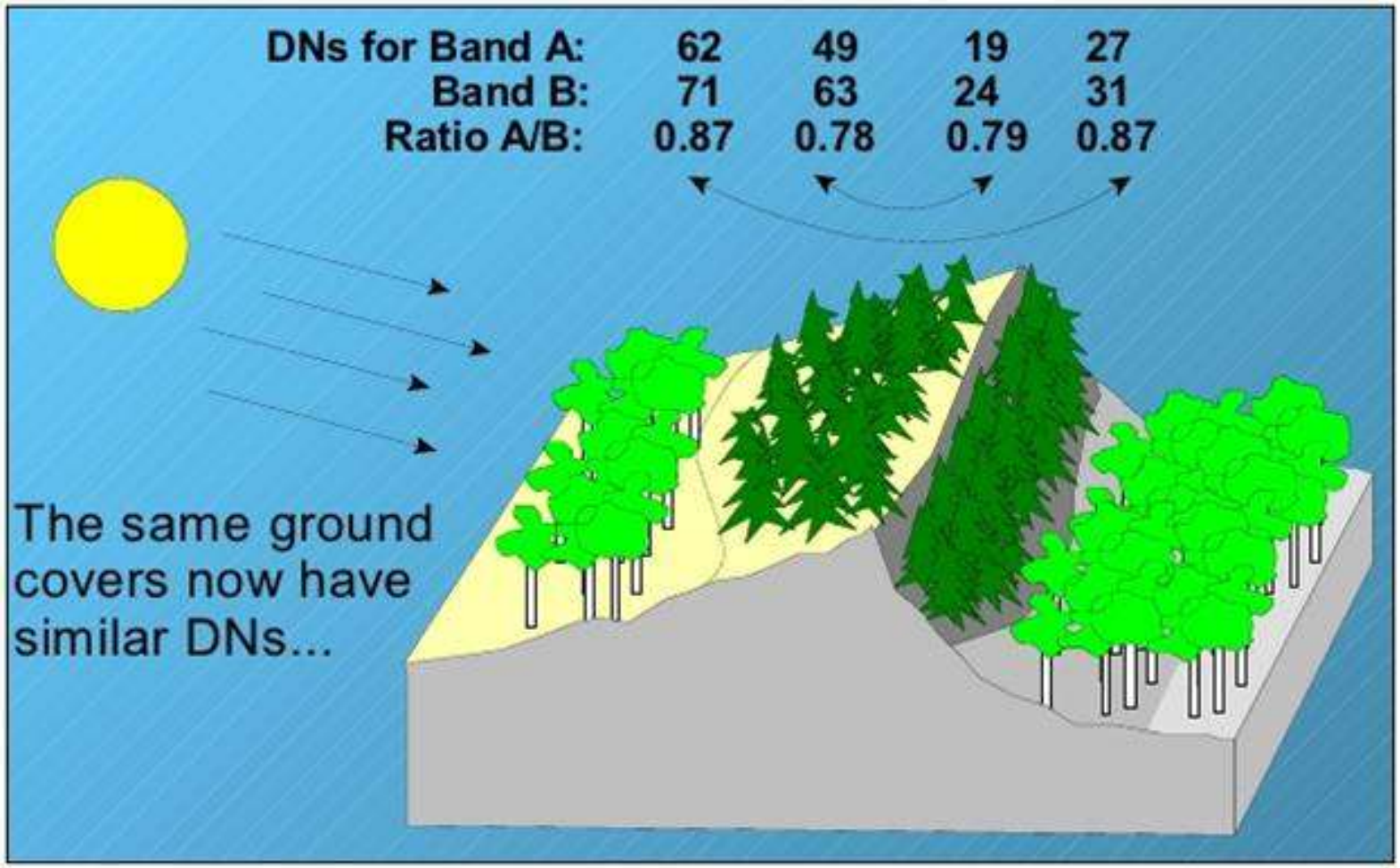
b. Illumination (angle of reflection)

c. Albedo (response to surface cover)

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

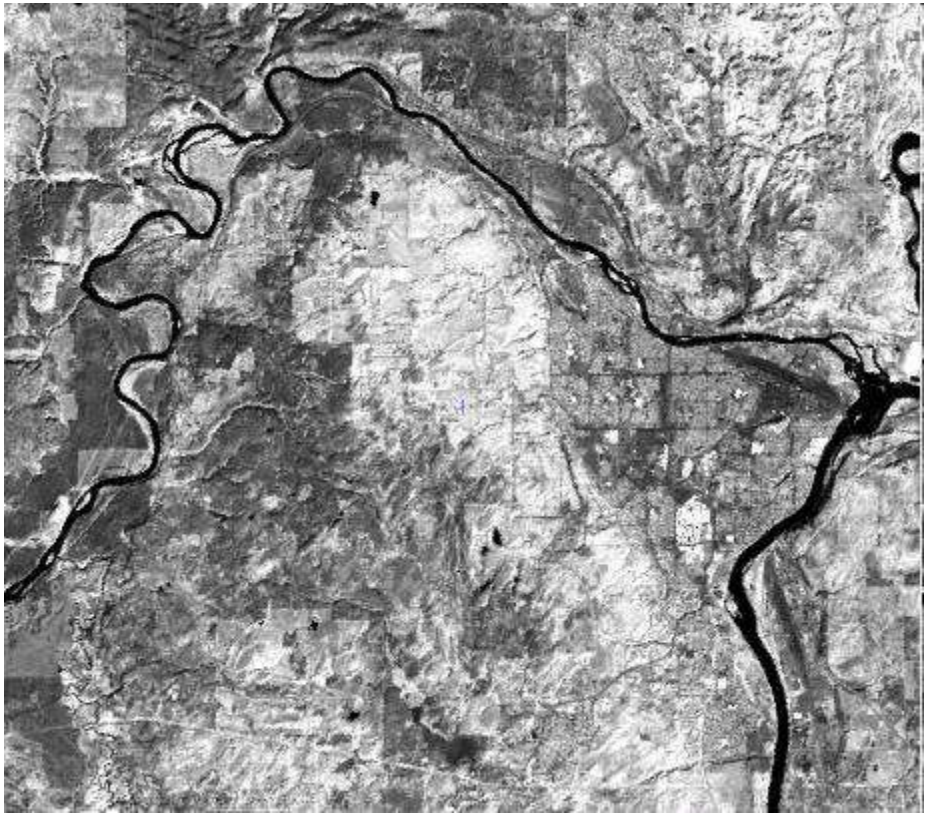


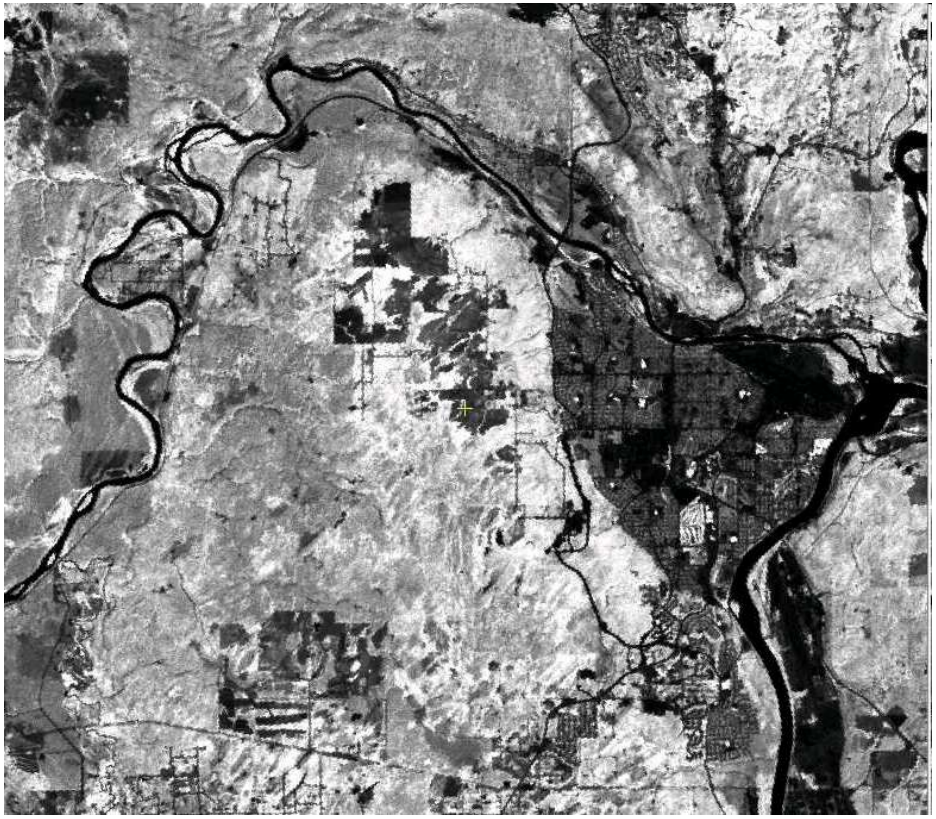
Ratio of Band A to Band B



TM Band 4 **TM 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 in one channel… (lab next week)

Use of ratios:
c. Threshold for a feature type

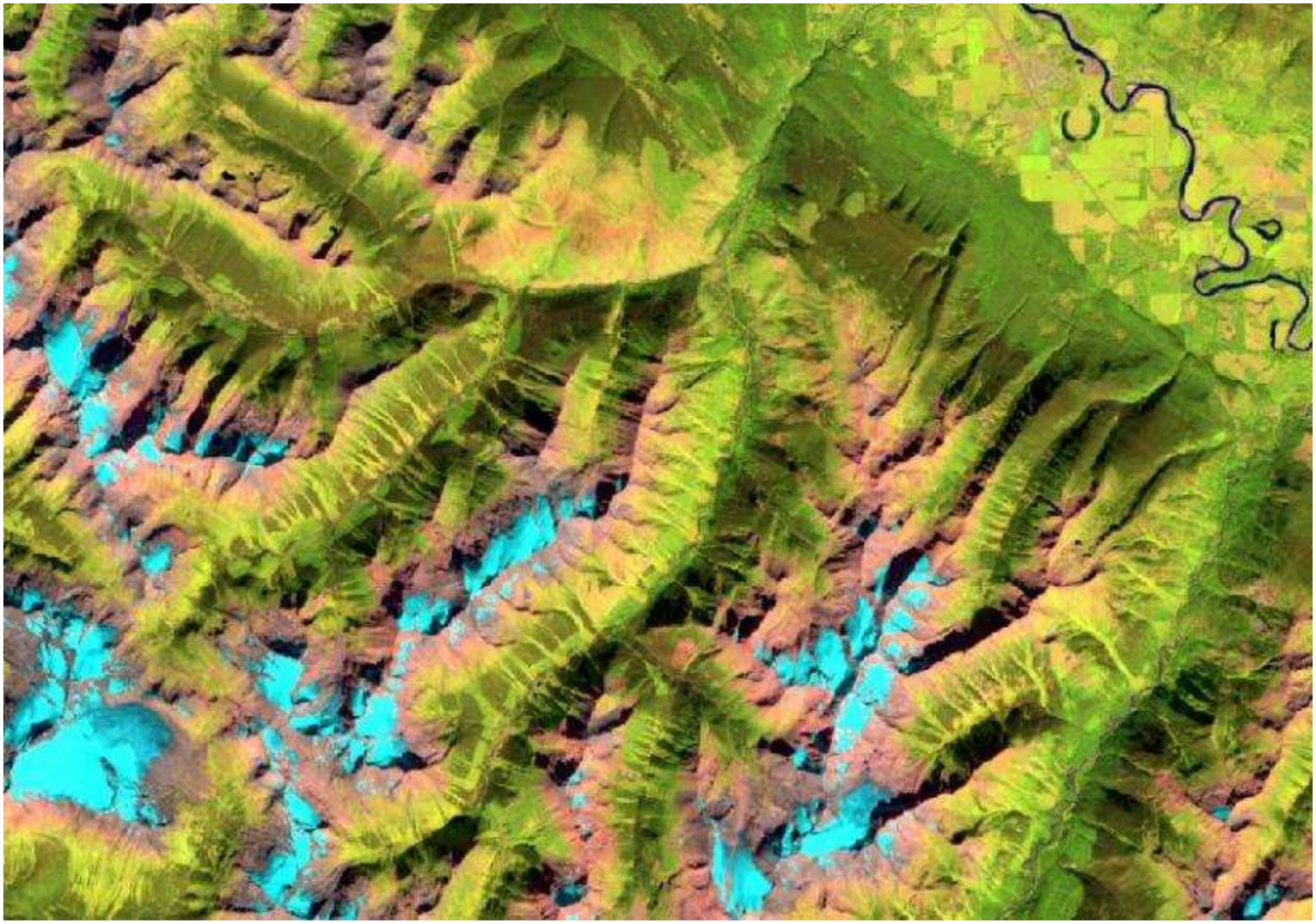
…. or include as input channel to classification (see lab 4)

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

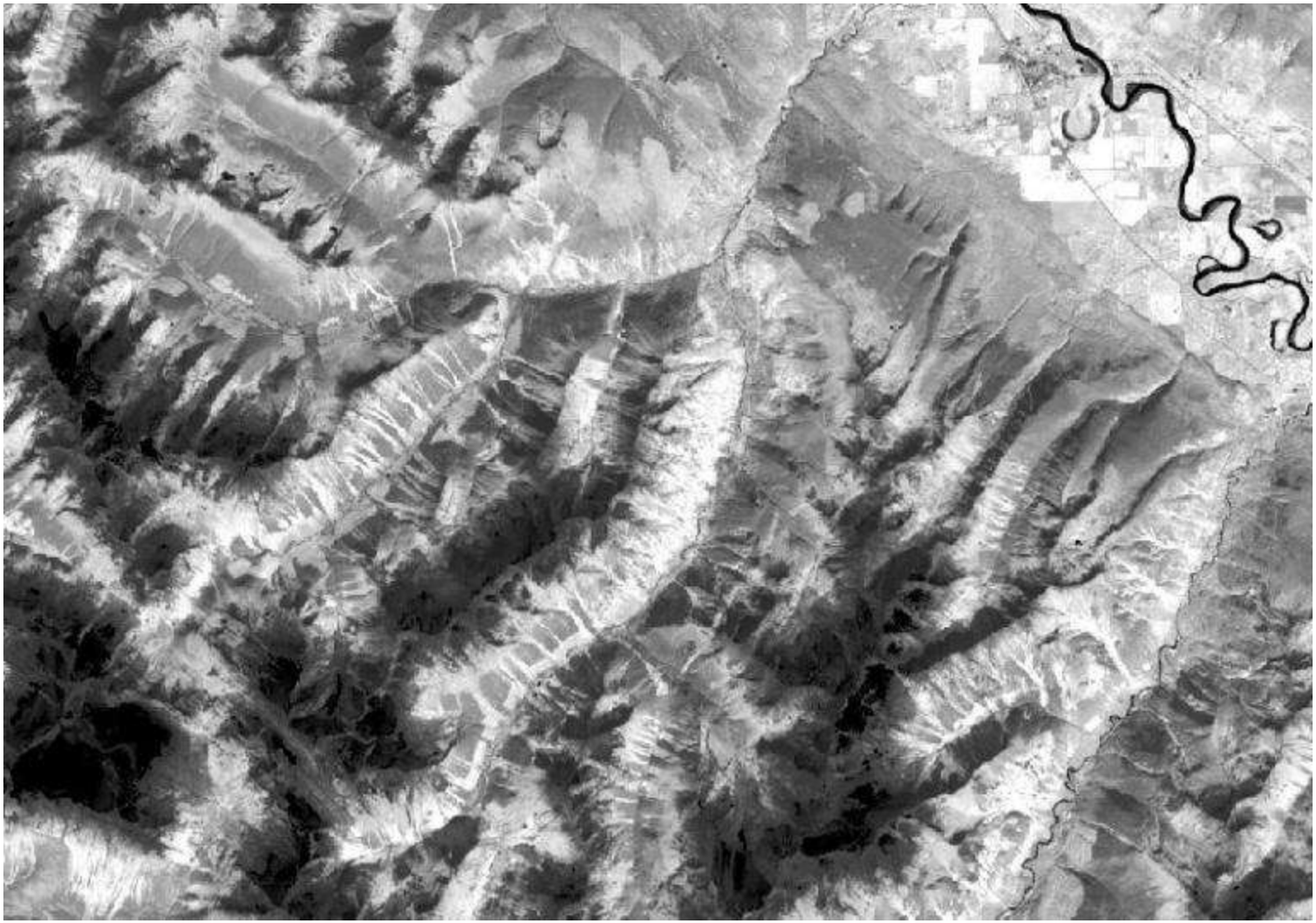
- **Landsat 5 TM: 8-bit 0-255**
- **Use scalar multiplier ~ 50-100**
- **Landsat 8 OLI: 16-bit 0-63,354**
- **Use scalar multiplier ~10,000**

Check channel histograms and stats first

McBride 2014 Landsat 8 OLI

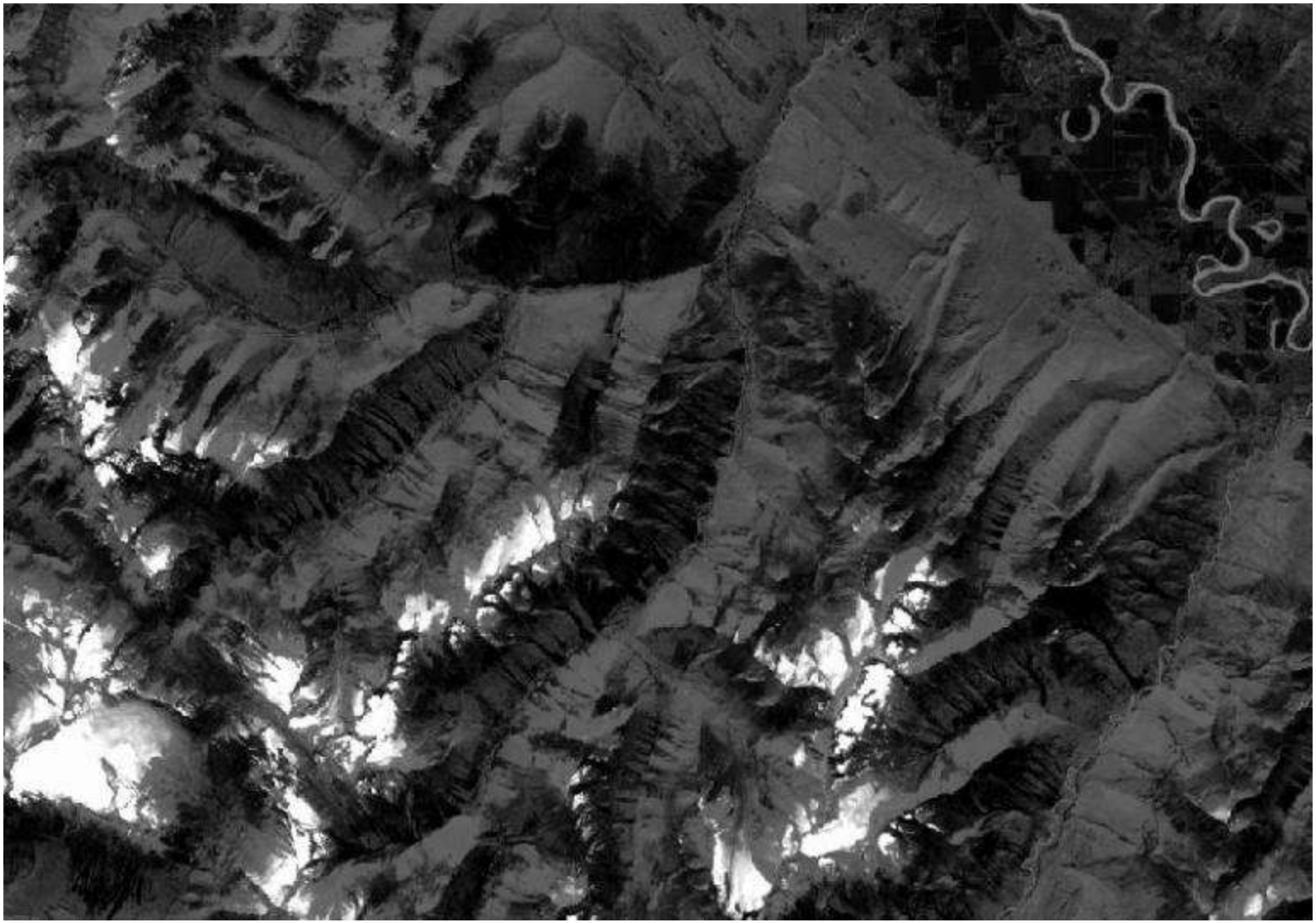


NIR/Red ratio = OLI 5/4 vegetation > 1.0 ??



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

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

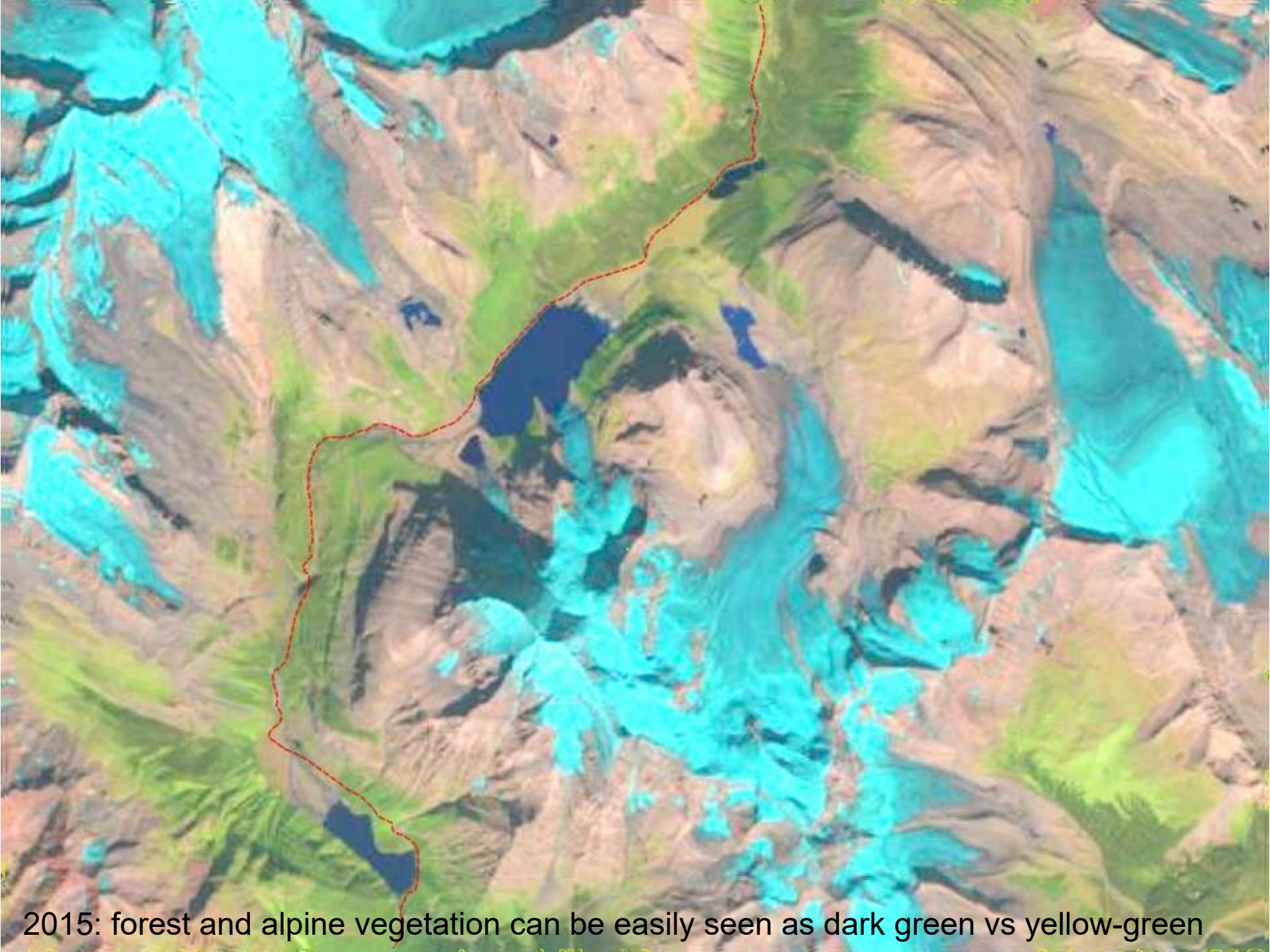


More on this when we discuss glacier mapping (Lab 6)

Mt. Robson (1975 / 95)

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

d. New layers for analysis/display (an extension of c.)



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 (beyond NIR/Visible) **might be useful?**

Consider the bands and their place in the spectrum:

	Visible	**/ NIR**	**/ SWIR**
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

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

Which other ratios could be useful?

But there are some applications using two bands in the same region,
e.g. in geology (iron oxide and mineral exploration)

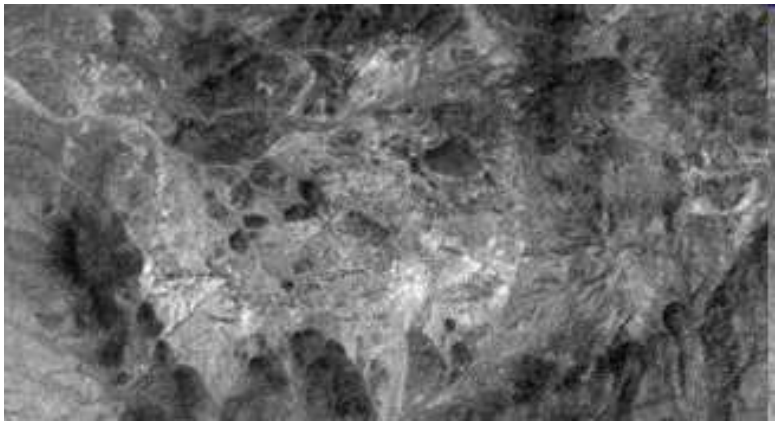
MSS: 5/4, 7/6 (4=green, 5=red, 6,7 =NIR)

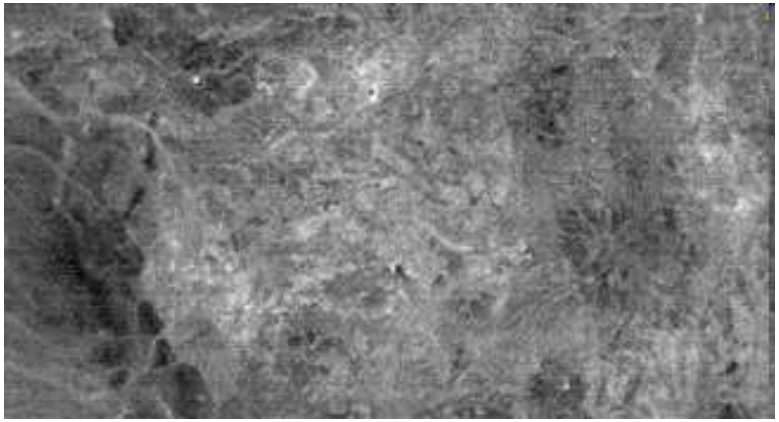
TM: 3/2, 3/1, 5/7 :
mineral enhancement (hydrothermally altered rocks)

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

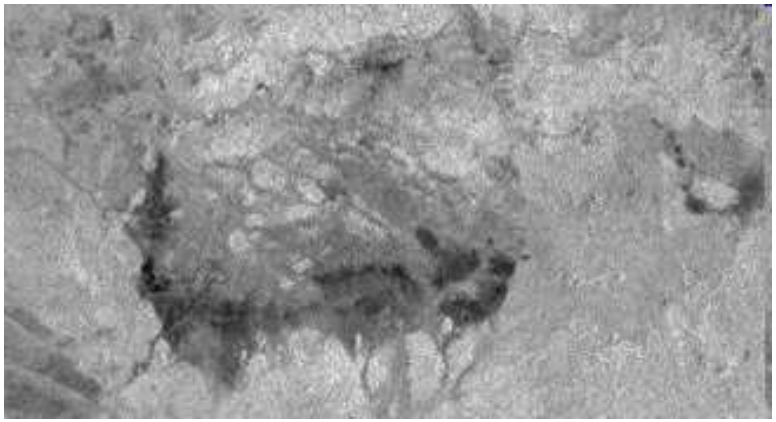
Thematic Mapper ratios, Utah (desert scene)

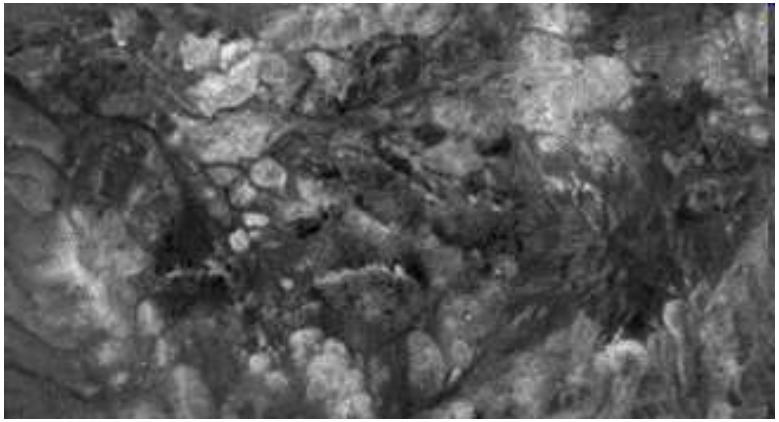
ratios 3/1 and 4/2





7/5 and 1/7 ratios

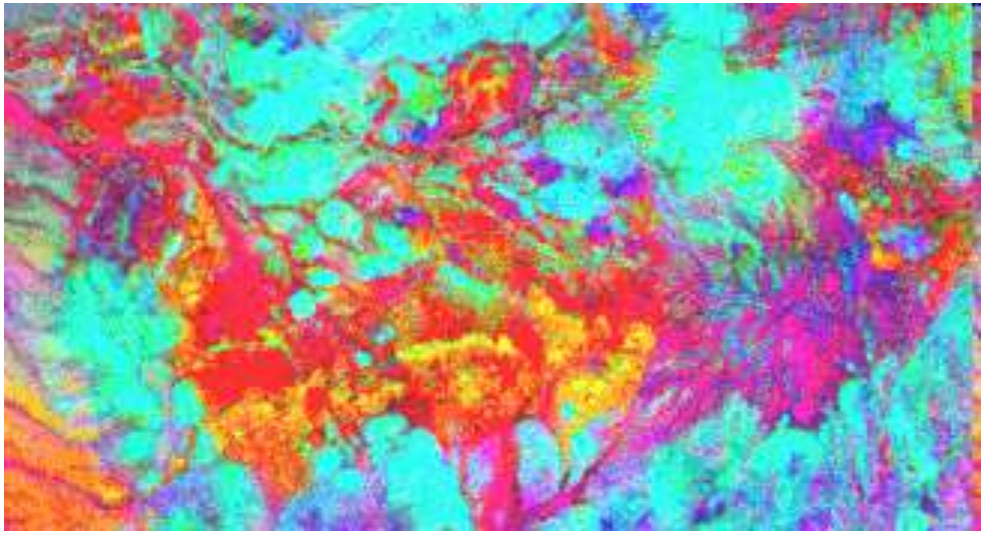




Geologists love these for classification when there is no vegetation in the way ….

Ratios: e. Creating Colour Composites

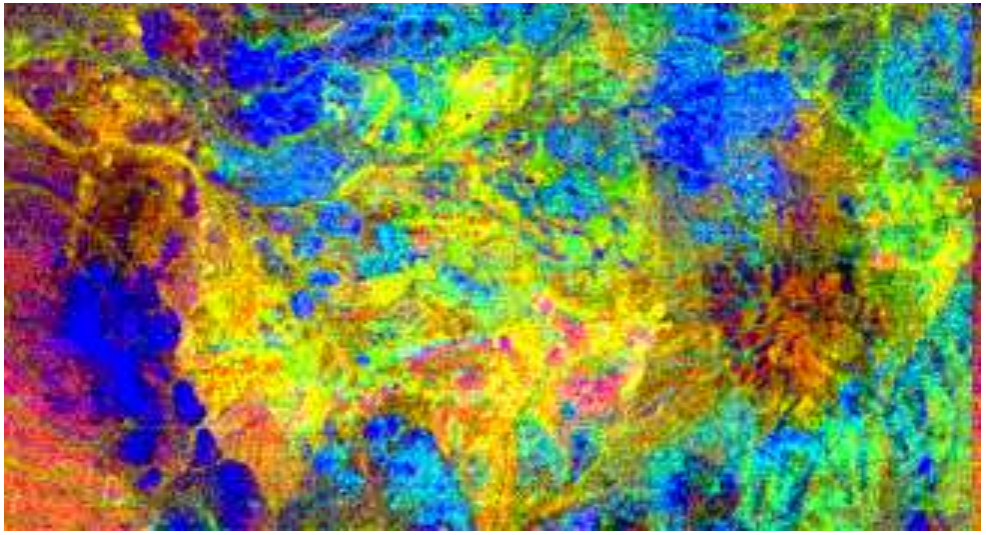
- use any 3 channels, not just bands



7/5 in Blue

1/7 in Green

3/1 in Red



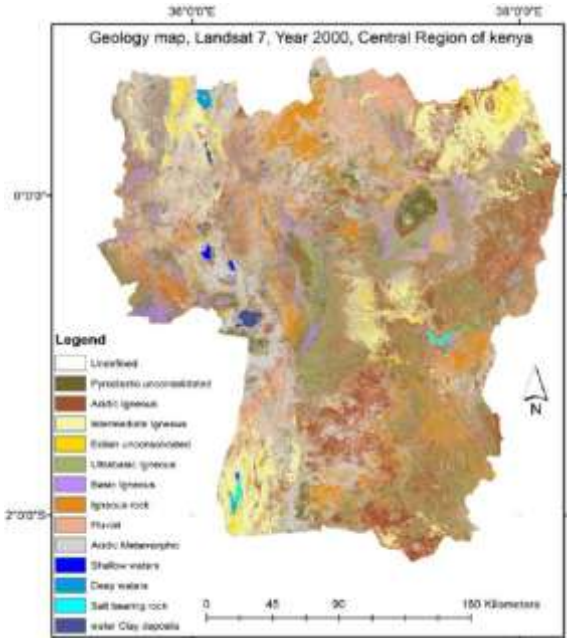
1/7 in Blue

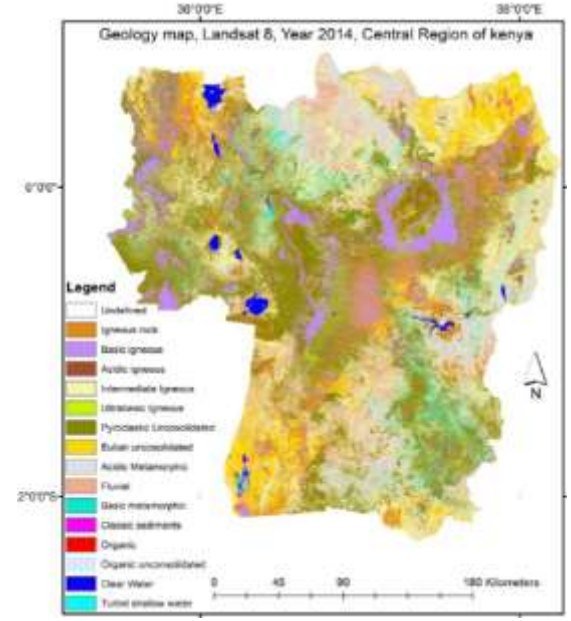
4/2 in Green

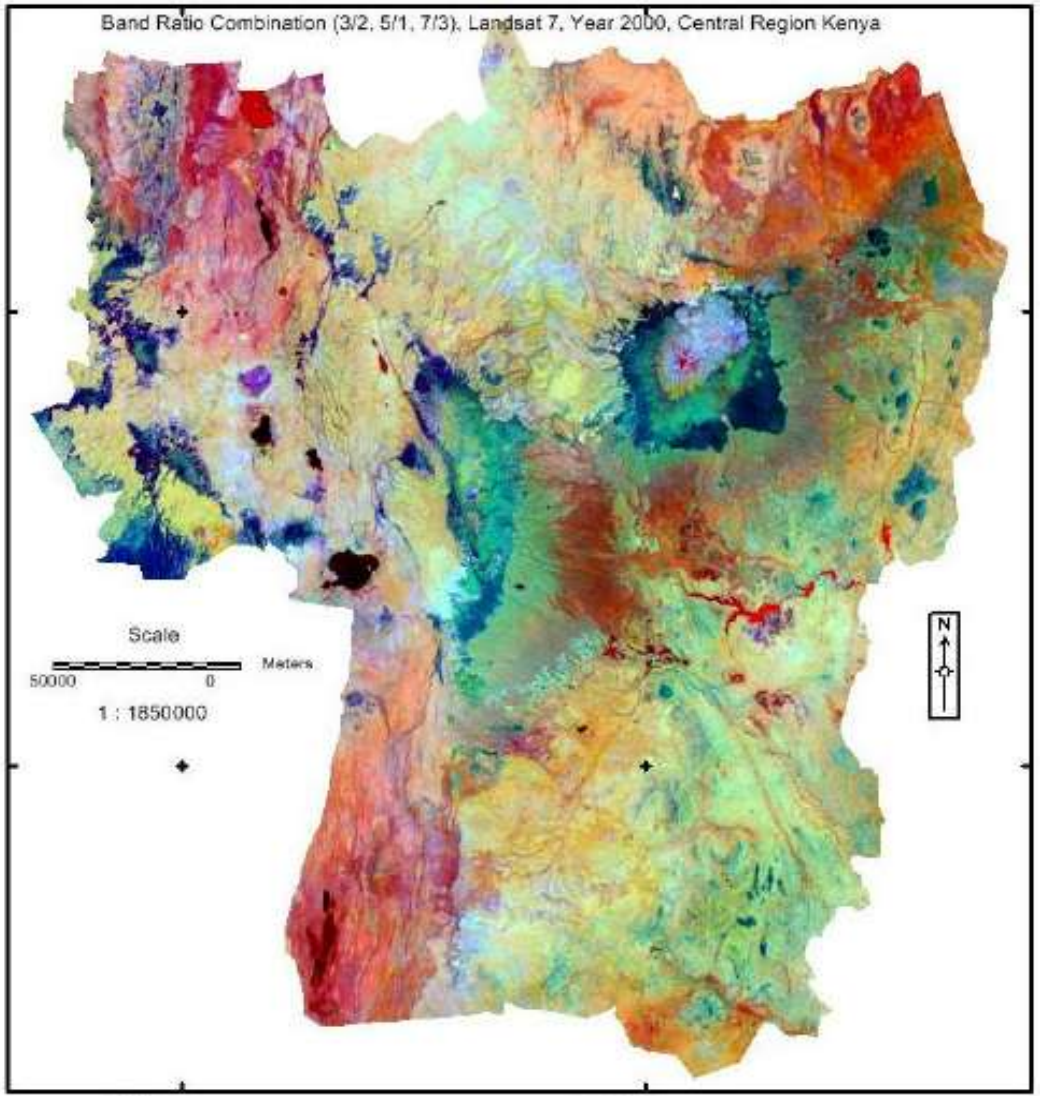
3/1 in Red

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
Geology mapping: Kenya

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

Sentinel-2 ratios and colour composites

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/

It doesn't end there – one could do ratios of ratios (15 x 14 options)

e.g. $3/2 \div 5/1$ or even ratios of ratios of ratios: $3/2 \div 5/1 \div 7/3$

Endless options, but what would they show ??

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 changes through time with two image dates.

- More on this when we discuss change detection

c. 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

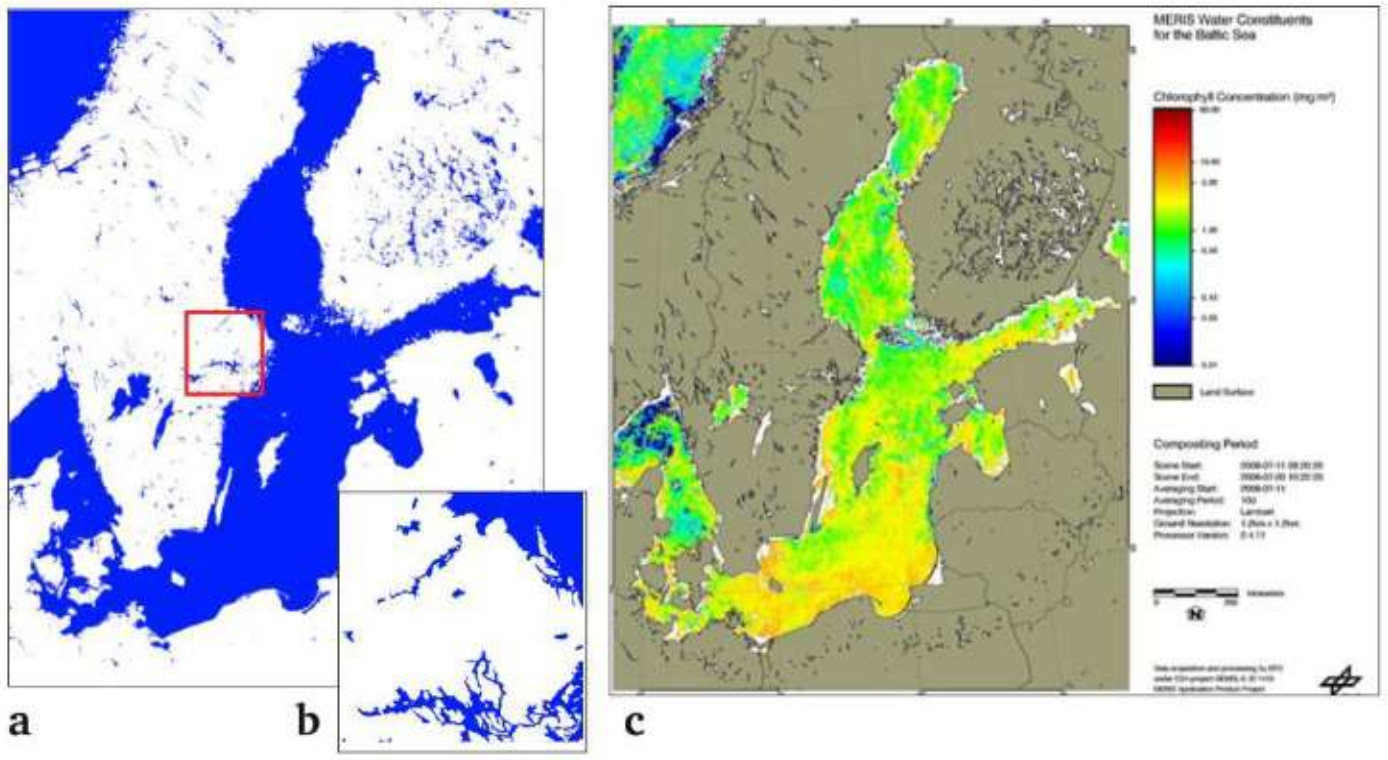


Figure 2: Land-water-mask of limited quality (a). The section shows details of the map around Stockholm (b). Quick-look product "Chlorophyll Concentration in the Baltic Sea" based on MOS data (c).

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

Other Image Arithmetic

d. Band (image) addition +

Used to create an overall or average image channel from 2 or more input bands

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

Sentinel-2 (2015 -> including 3 'Red Edge' bands)

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

Red-Edge Simple Ratio **(SRre) = NIR / RedEdge**

band 8 / 5 or band 8 / (band 5 + Band 6 + band 7) = NIR / red edge bands

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