GEOG 357

LECTURE 7

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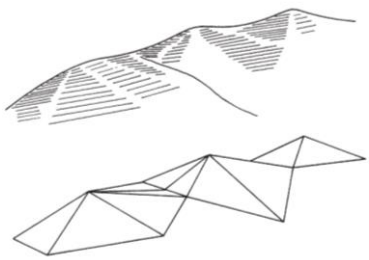
GEOG457: Advanced Remote Sensing

GEOG457 is offered every 2 Yrs. If you would like to take it, consider taking it during the next semester, otherwise it will be 2024.

To be taught by Dr. Roger Wheate

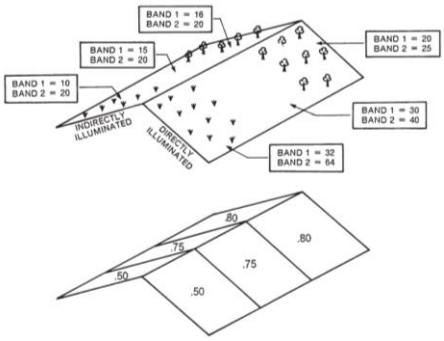
GEOG 457
Next Semester
(Jan 2022)



Band Ratios

- Brightnesses of surfaces depend on the orientation of the surface in relation to the direction of illumination.
- If these surfaces all have the same surface material their brightnesses are related to the angles at which they are oriented.
  - Lambert's Cosine Law

Image: Campbell and Wynne, 2011



Band Ratios

- Consider a topographic surface, parts of which are indirectly illumined.
  - Because of shadowing, separate surface materials cannot be clearly separated into their distinctive classes.
  - However, ratios of the two bands remove the topographic effects to show the distinct spectral classes.

Image: Campbell and Wynne, 2011

Presentation Title 5

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Band ratios

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

- 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

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Band ratios

- e.g. for a pixel if band a = 50 and band b = 25, then the ratio DN = 50/25 for that pixel
  - new DN = 2 (2.0)

- if a = 100 and band b = 40, then the band ratio
  - DN = 2.5 (or rounded to 3 if there are only integer DNs)

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Ratio DN values

- The DNs in a band ratio could hypothetically range from: 0-255
  (e.g. if 8-bit band data ranges from 0 to 255)

- But in practice they rarely exceed: 0-10

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Ratio DN values

- The result is 'naturally' decimal, and can be written to:
  - 32 bit 'real' channel (decimals) if 'real' DNs are needed
  - However, 8-bit (Integer) channel can also be used
    16-bit is unlikely as DNs won't exceed 255 (16 bit =0-65,535)

- A (scalar) multiplier can create values to fill the 8 -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

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Ratio DN values

- So we have 3 options:

- **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
- = less data storage (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 data range

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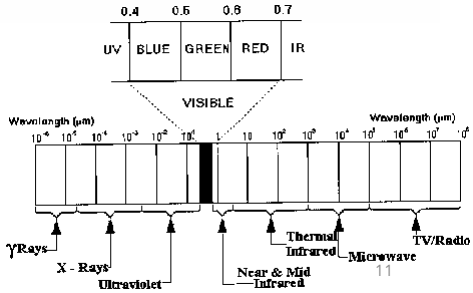
Commonly used Ratios for Landsat MSS

MSS Bands

Band # (L1-L2)	Band # (L3)	Band # (L4-L5)	µm	Resolution*	L4/L5 TM Band Equivalent
4	4	1	0.5-0.6	68 m X 83 m	~ 2 (0.52–0.60 µm)
5	5	2	0.6-0.7	68 m X 83 m	~ 3 (0.63–0.69 µm)
6	6	3	0.7-0.8	68 m X 83 m	~ 4 (0.76–0.90 µm)
7	7	4	0.8-1.1	68 m X 83 m	~ 4 (0.76–0.90 µm)
N/A	8	N/A	10.4-12.6	68 m X 83 m	~ 6 (10.41-12.5 µm)

https://landsat.gsfc.nasa.gov/multispectral-scanner-system



9/4/20XX

http://www.geo.mtu.edu/rs/back/spectrum/

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Landsat MSS bands 1-4 (also known as = 4-7 for L1-L3)

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

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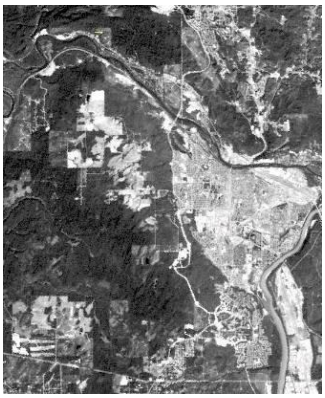
Why use band ratios ?



- 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 is the most common ratio)

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Band ratios

- TM4/3 ratio - no scalar (DNs 0-3)
  - Vegetation > 1; water < 1
    - 0: Water,
    - 1: Urban,
    - 2: treed,
    - 3: deciduous
- Scaled or 32-bit: DNs ~ 0-255 continuum of DNs

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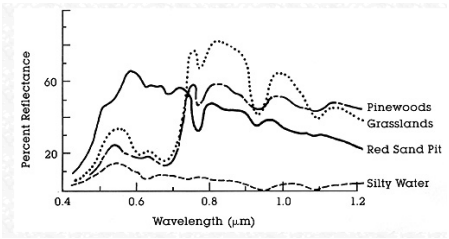
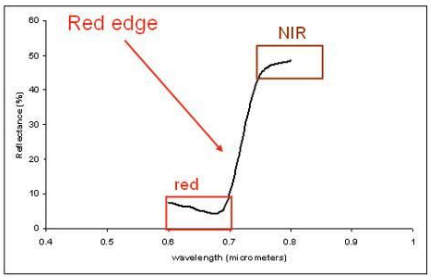
Role of ratios: a. Spectral slope enhancement

- band ratioing can emphasise the difference 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





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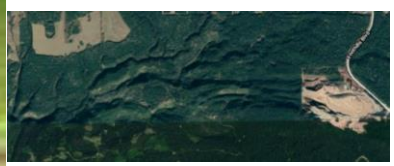
Role of ratios: b. reduce topographic effect (shadow)

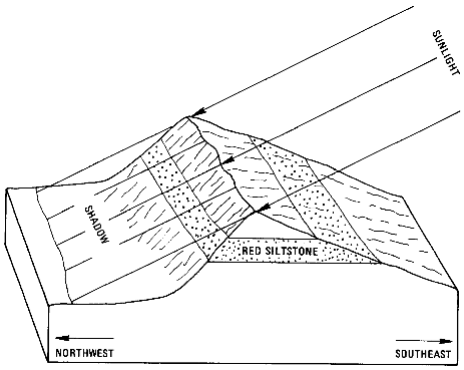
Digital Numbers may be a result of three elements:

a. **Atmospheric interference (e.g.haze)**

b. **Illumination (angle of reflection)**
c. **Albedo (response to surface cover)**

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





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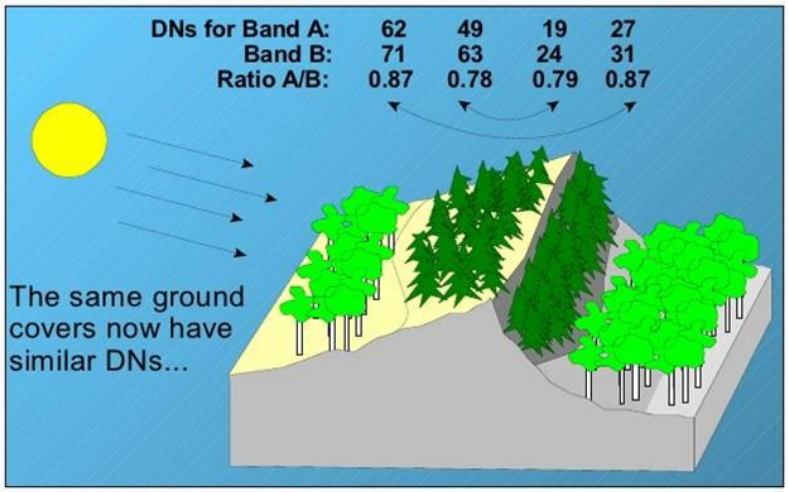
Ratio of Band A to Band B



USDA Forest Service, Remote Sensing Applications Center, http://fsweb.rsac.fs.fed.us and UAS ENVS403

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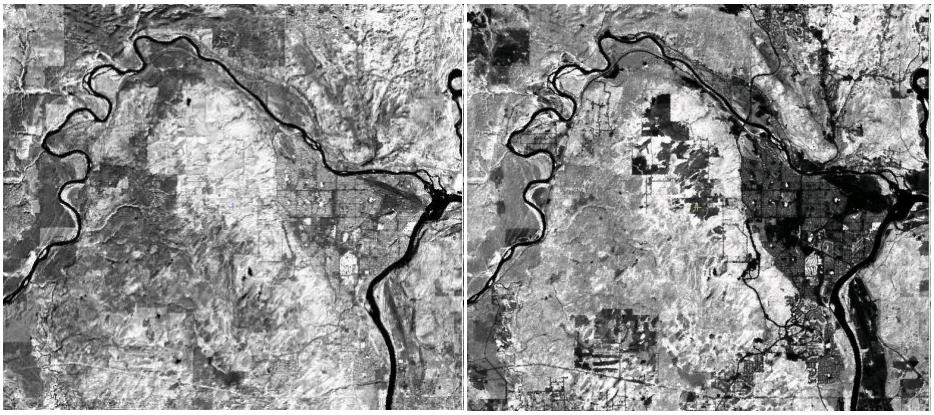
TM Band 4 **Band 4 / Band 3 ratio**

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



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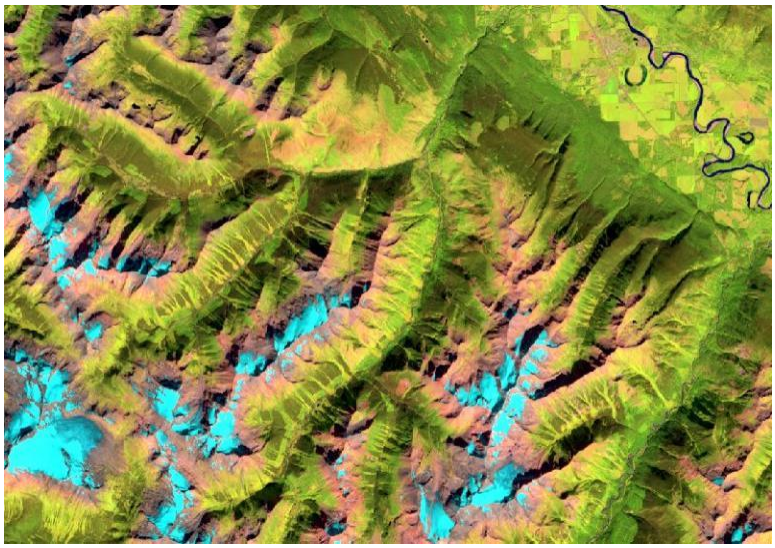
McBride 2014 Landsat 8 OLI



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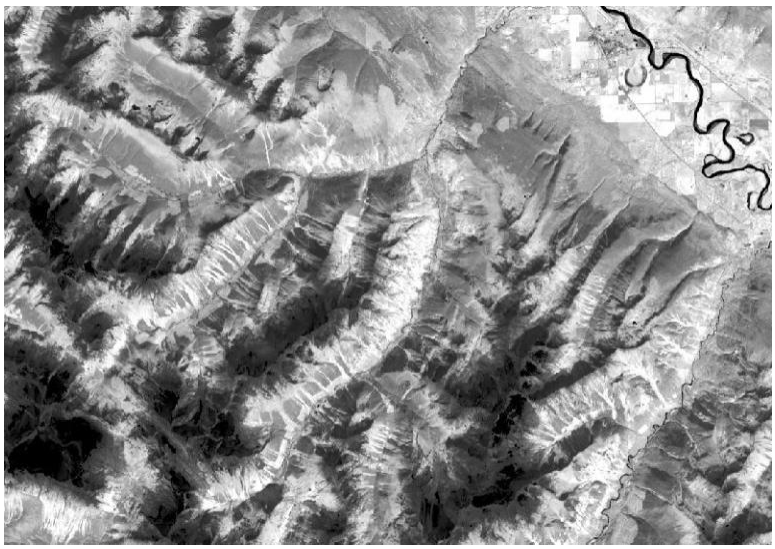
NIR/Red ratio = OLI 5/4 vegetation> 1.0



In mountain landscapes, a ratio only partly corrects for illumibation

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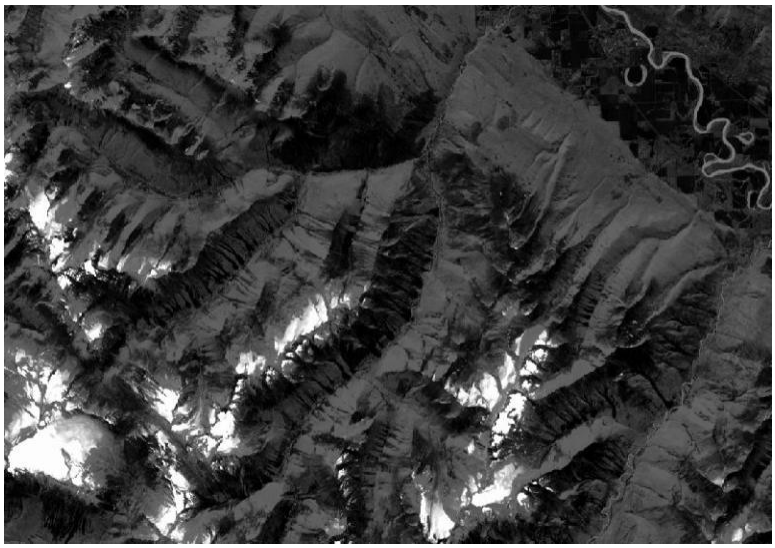
Red/MIR ratio = OLI 4/6 snow/ice>2.0 (or maybe 1.5)



More on this when we discuss glacier mapping

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Role of ratios: c. Include as input to classification

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

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

Check channel histograms and stats first

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Role of ratios:
d. New layers for analysis/display

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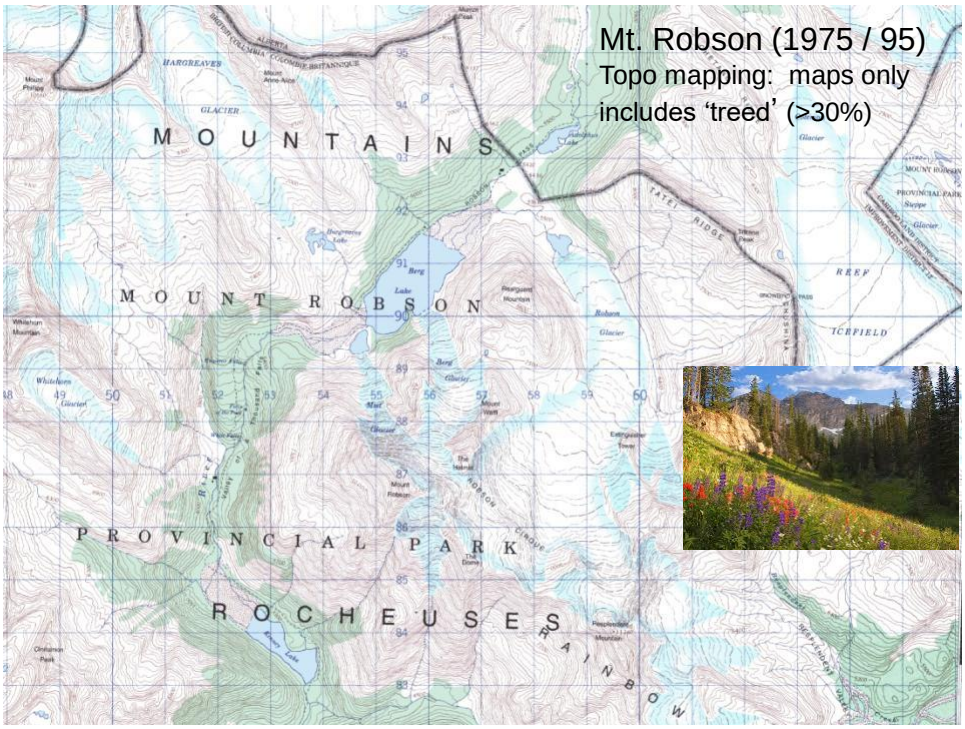

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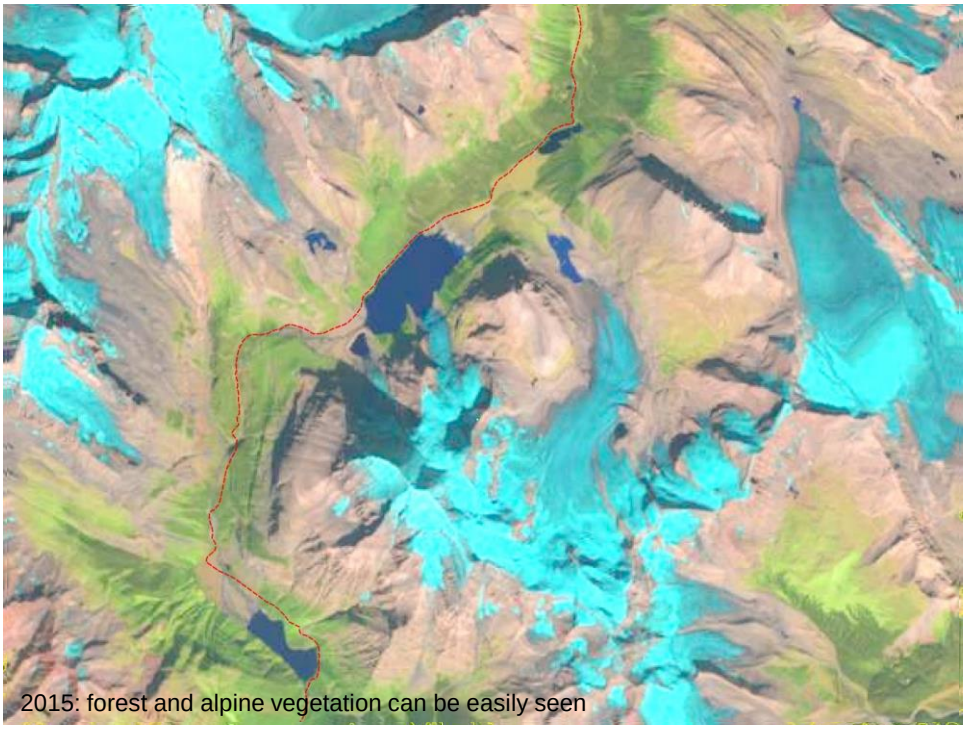
2015: forest and alpine vegetation can be easily seen

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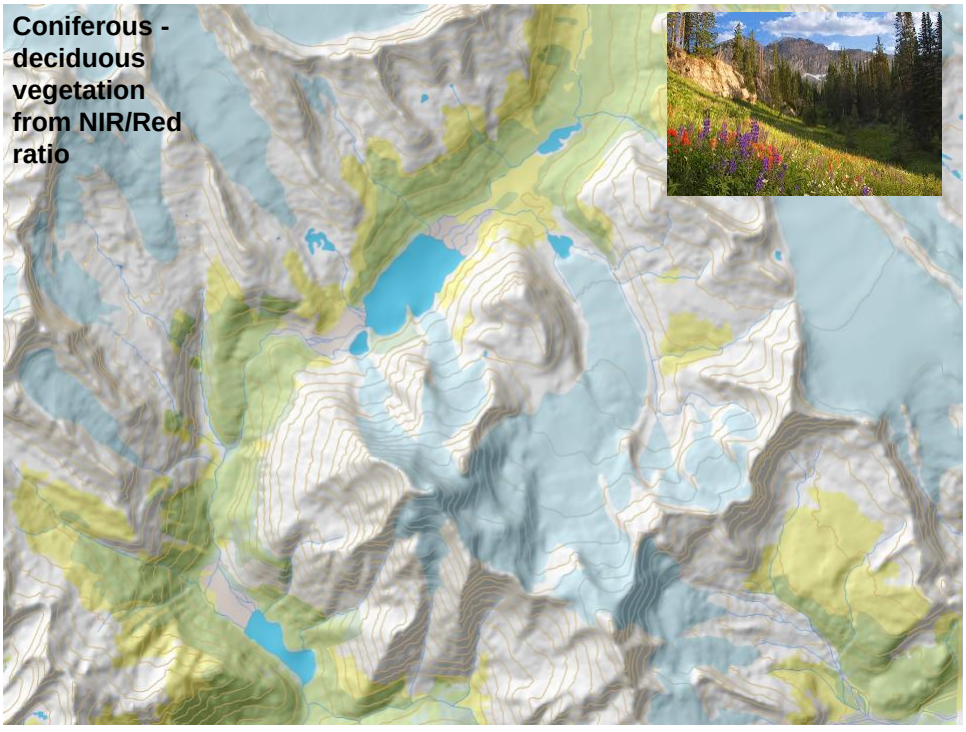
Coniferous - deciduous vegetation from NIR/Red ratio

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Which other ratios could be useful?

- How many ratio options in a multiband (n) dataset:
  - ***Ratios = n (n-1)***
    - e.g. with bands 1,2,3
    - Ratios = 1/2; 1/3; 2/3; 2/1; 3/1; 3/2 = 6

- 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***
  - = 15 (6 bands) for Landsat TM (excluding thermal)

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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)

  - TM 7/3 lithology 3/5 snow and ice 4/5 Moisture
  - OLI 7/4 4/6 5/7
- pairs of bands from <u>similar parts</u> of the EM spectrum may show more 'noise'

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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

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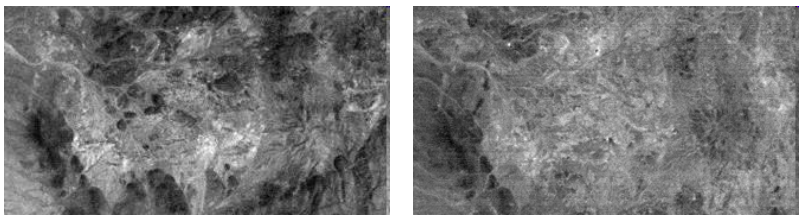
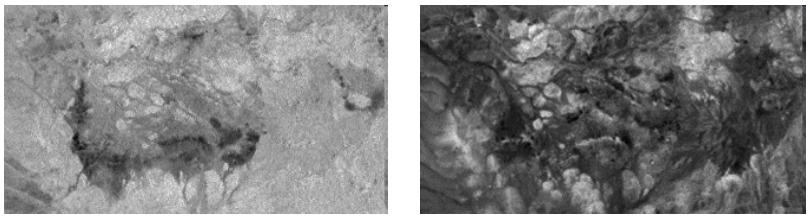
Thematic Mapper ratios, Utah (desert scene)

ratios 3/1 and 4/2



7/5 and 1/7 ratios



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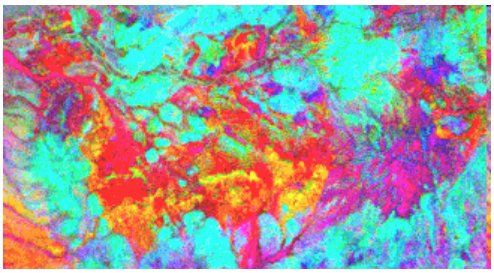
Ratios: e. Creating Colour Composites

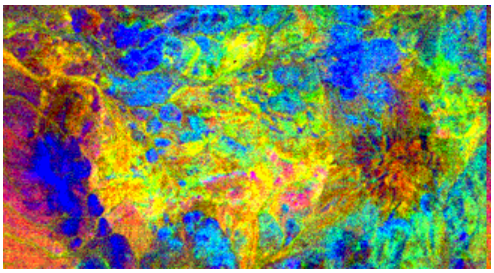
- use any 3 channels, not just bands



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 ?

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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

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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 DATAErik Borg, Bernd Fichtelmann

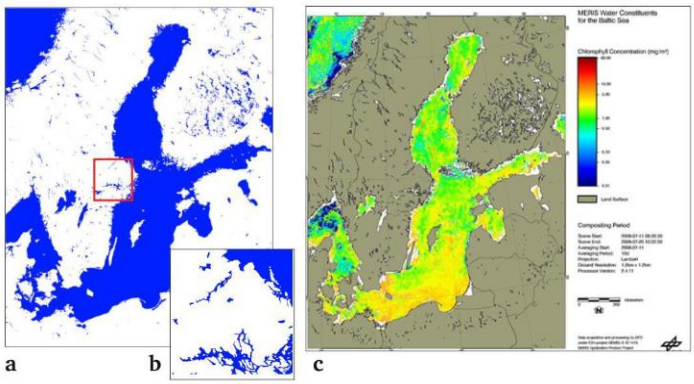

Figure 2: Land-water-mask of limited quality (a). The section shows details of the map around Stockholm (b). Quick-look product "Chlorophyll Concentration in the Baltic Sea" based on MOS data (c).

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

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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)

e.g. Normalised Difference Vegetation Index

NDVI = (NIR - R) / (NIR + R)

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