Transformations in Remote Sensing

= Converting image bands into secondary channels

	Raster Calculator
• **Ratios / image arithmetic & Indices**	**ARI / VEGINDEX**
• **Tasseled Cap Analysis**	**TASSEL**
• **Principal Component Analysis**	**PCA**
• **Pansharpening / image fusion**	**PANSHARP**

Tasseled Cap analysis / transformation

Goal: to reduce the high correlation between bands into new channels

For each pixel DN, the new channels **weight** the input bands as below, e.g.: Landsat MSS

Brightness channel = 0.433*Band4 + 0.632*Band5 + 0.586*Band6 + 0.264*Band7

etc.. and similarly for Greenness and Yellowness

WEIGHTS FOR TASSELED CAP TRANSFORMATION OF LANDSAT MSS DATA				
Component	**Channel 1**	**Channel 2**	**Channel 3**	**Channel 4**
Brightness	0.433	0.632	0.586	0.264
Greenness	-0.290	-0.562	0.600	0.491
Yellowness	-0.829	0.522	-0.039	0.194
"Non-such"	0.223	0.012	-0.543	0.810

4:Green 5:Red 6:NIR1 7:NIR2

Brightness = a weighted average of all bands
Greenness = visible versus Near-IR bands (like a NIR/Red ratio) - vegetation
Yellowness = Green v Red (soils)
“Non-such” = difference between the two IR bands

Tasseled Cap TM data, 6-band (no thermal): Brightness, Greenness, Wetness

WEIGHTS FOR TASSELED CAP TRANSFORMATION OF THEMATIC MAPPER DATA						
Component	**Channel 1**	**Channel 2**	**Channel 3**	**Channel 4**	**Channel 5**	**Channel 7**
Brightness	0.3037	0.2793	0.4343	0.5585	0.5082	0.1863
Greenness	-0.2848	-0.2435	-0.5436	0.7243	0.0840	-0.1800
Wetness	0.1509	0.1793	0.3299	0.3406	-0.7112	-0.4572

= New channels

Landsat 8 OLI coefficients

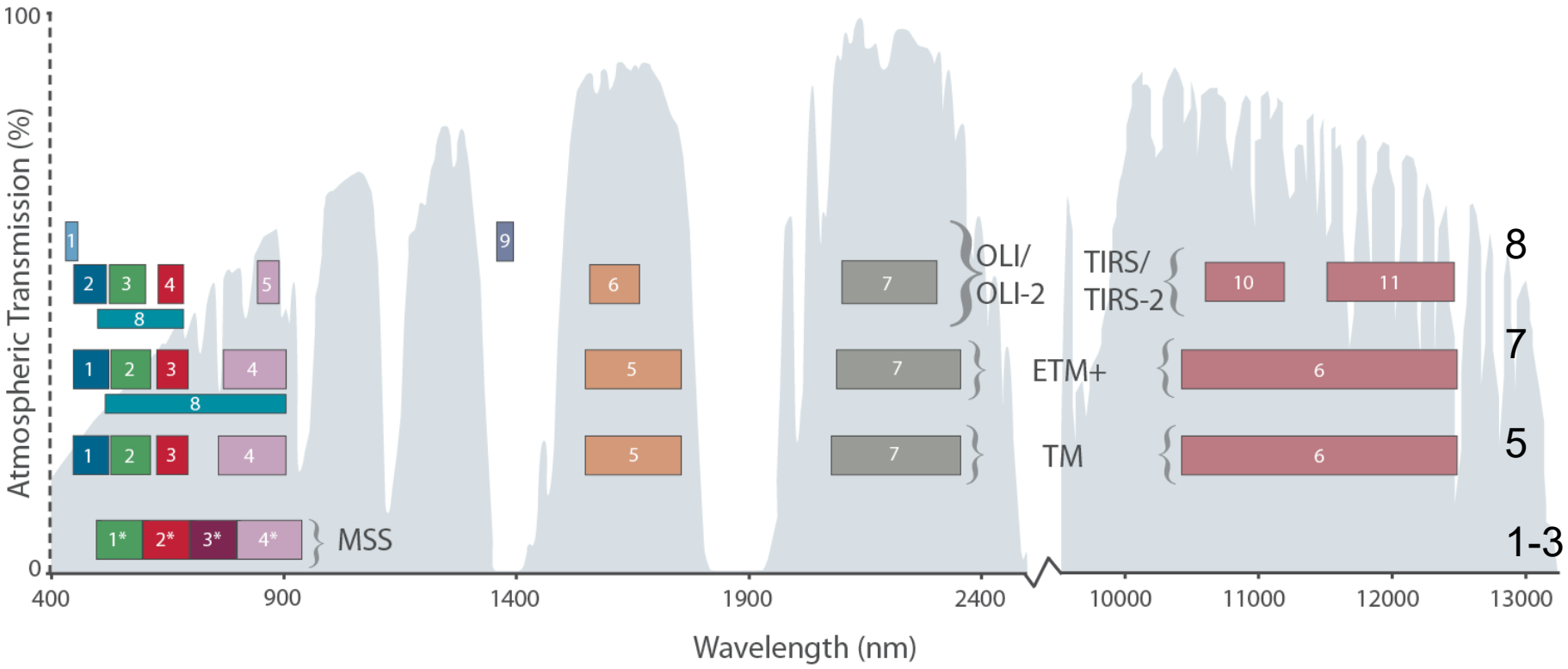
	Coastal Band 1	*Blue Band 2*	*Green Band 3*	*Red Band 4*	*NIR Band 5*	*Mid-IR1 Band 6*	*Mid-IR2 Band 7*
Brightness	0	0.3029	0.2786	0.4733	0.5599	0.5080	0.1872
Greenness	0	-0.2941	-0.2430	-0.5424	**0.7276**	0.0713	-0.1608
Wetness	0	0.1511	0.1973	0.3283	0.3407	**-0.7117**	**-0.4559**

These weights vary for different sensors – but almost the same for TM vs OLI (why?)

Why are they different at all ? …. Spectral resolution of bands

Landsat sensors and band wavelengths

Landsat 1-3, 4-5, 7 and 8



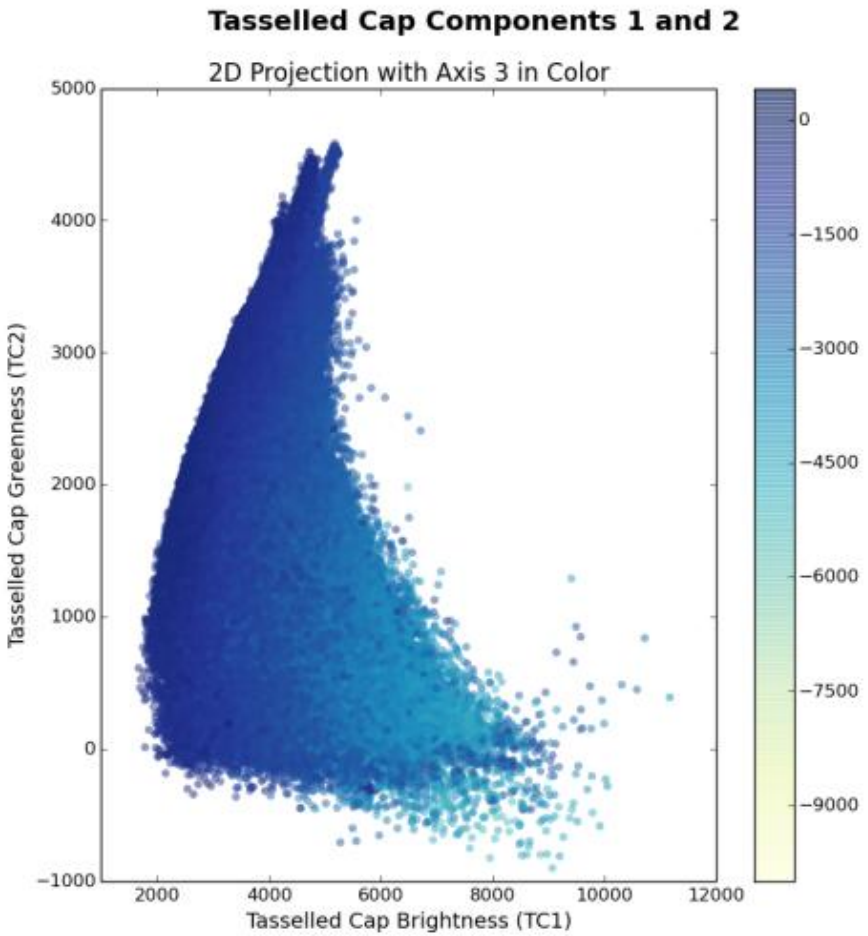
Similar bands on Landsat TM / OLI are close but not exact

Tasseled Cap Transformation

TM data, 6-band (no thermal)

.. the conversion of the DN readings in a set of bands into weighted sums of **separate channels**. One measures the **brightness** of each pixel in the scene.

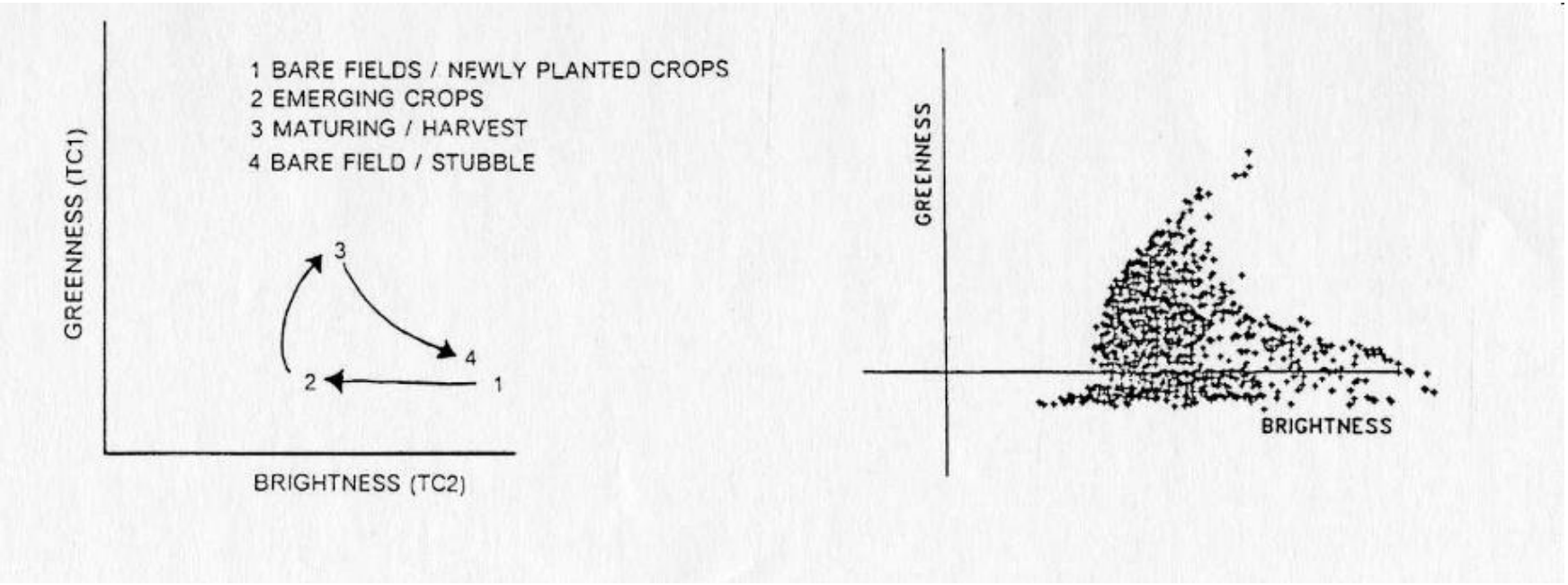
The other composite values are linear combinations of the values of the separate channels, but some of the weights are negative and others positive. One of these represents the degree of **greenness** of the pixels and one the **yellowness** of soil / vegetation (MSS), or the **wetness** of the soil (TM/OLI). Usually there are just **three** composite variables.

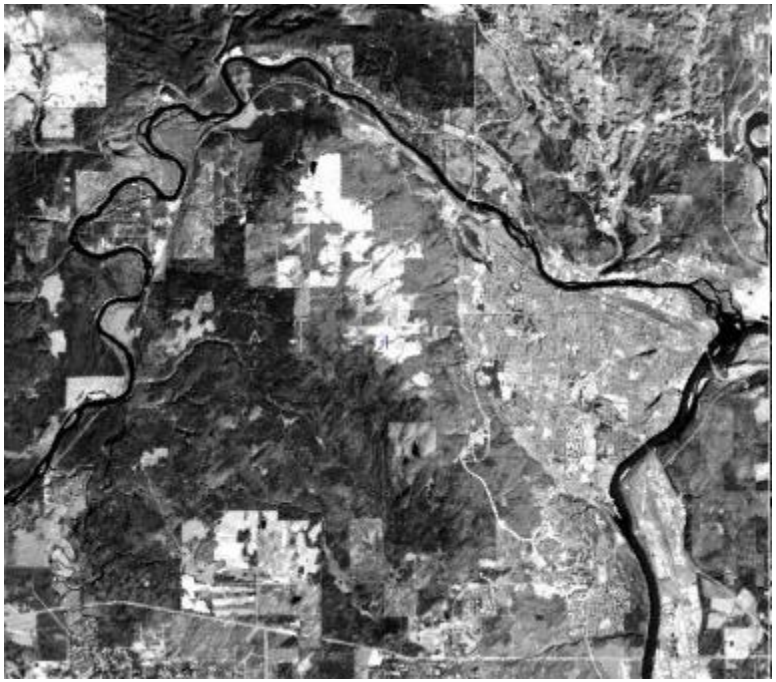


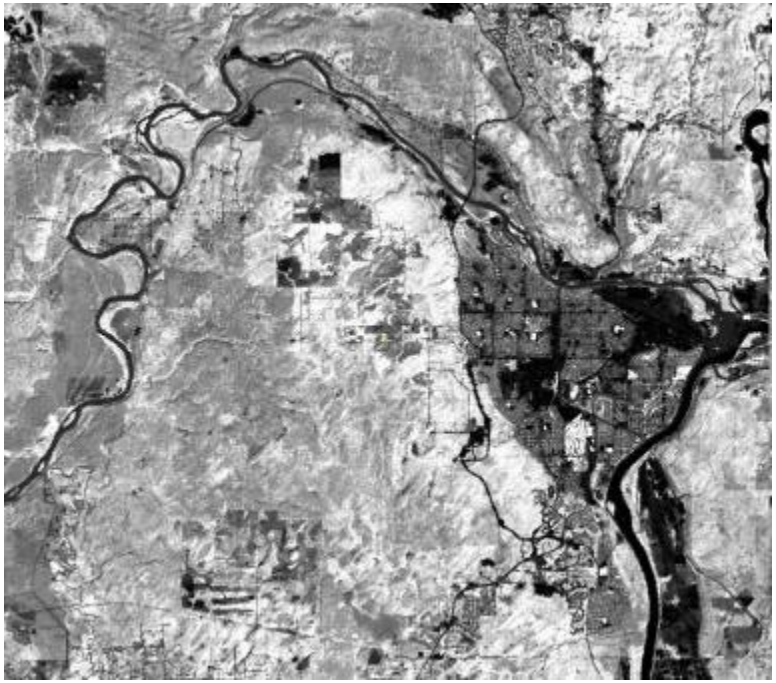
Named ‘Tasseled Cap’ from the shape of the scatterplot of Brightness vs Greenness

The **Tasseled Cap transformation** was initially designed to analyze and map vegetation and urban development changes detected by satellite sensors. It was developed in 1976 by R.J. Kauth and G.S. Thomas of the Environmental Research Institute of Michigan (ERIM). The technique was named after the pattern of spectral change of agricultural crops during senescence, plotting brightness (visible) against greenness (NIR). As crops grow from seed to maturity, there is a net increase in near-infrared and decrease in red reflectance based on soil color

1. Bare fields / newly planted crops - high brightness, low greenness (spring)
2. Plant Growth - <-<- brightness (early summer)
3. Maturity: -> -> greenness (late summer)
4. Senescence (harvest) - bare field/stubble: <-<-greenness, ->-> brightness (Fall)







Tasseled cap channels 1, 2, 3

a. Brightness – overall reflectance

b. Greenness – vegetation

c. Wetness – soil / canopy moisture

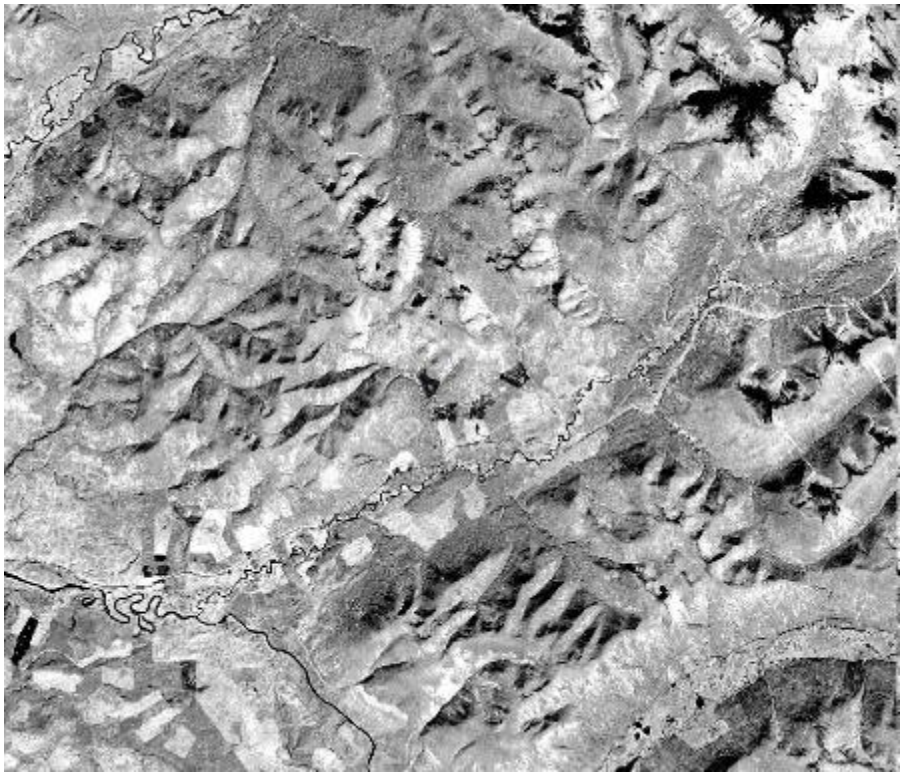
the 3 channels are mostly uncorrelated

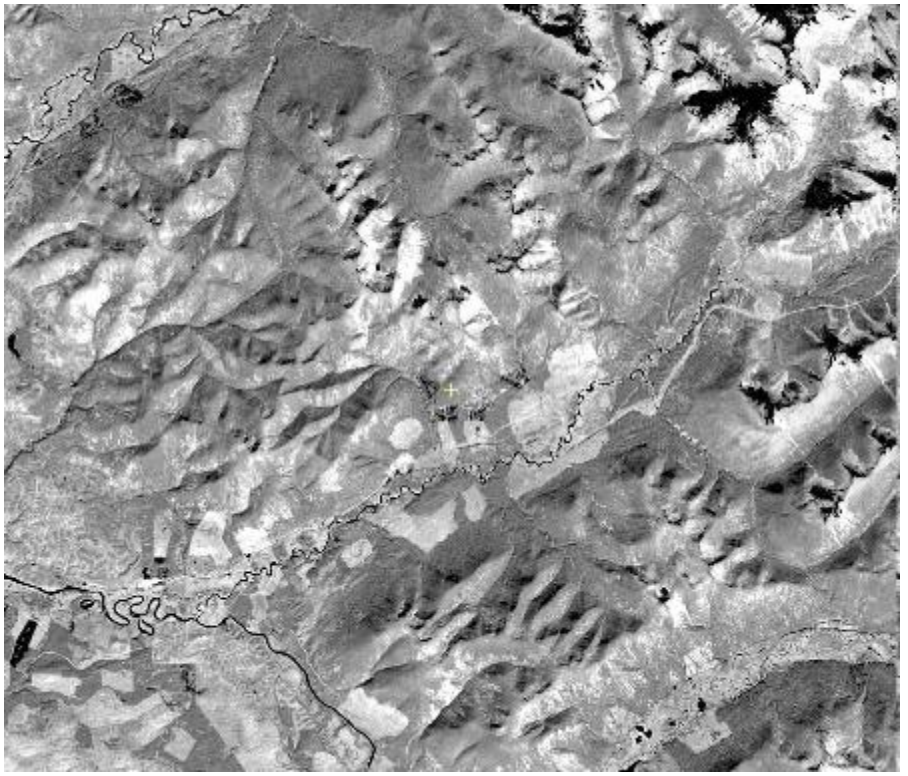
These yield a higher contrast composite but with unfamiliar colours and include maximum information

This reduces the info from 6 bands to 3 channels

NDVI v Tasseled Cap greenness

both contrast NIR versus visible reflectance





TCA Greenness is similar to NDVI, with subtle differences and is used in habitat studies.
TCA seems to reduce shadows more and gives better details in riparian zones

Figure : John Paczkowski MSc thesis – **remote sensing and grizzly bear habitat**
Wildlife ecologist, Kananaskis Country, Canmore, AB

Figure 2. The north-central part of the original true-color Landsat 7 ETM scene P22 R40.

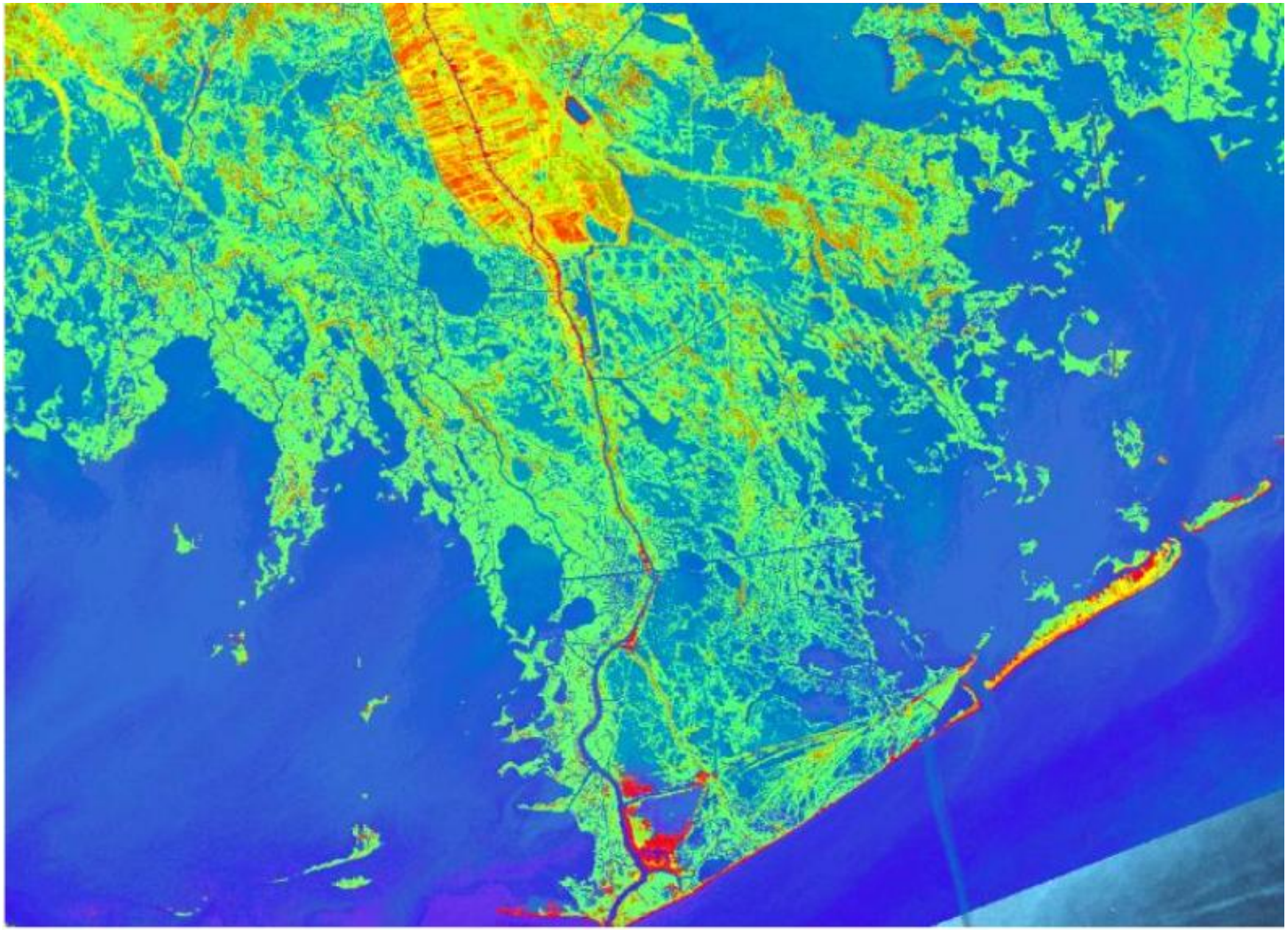


Figure 3. Three-band, 8-bit tasseled cap transformation image of the same Landsat 7 ETM+

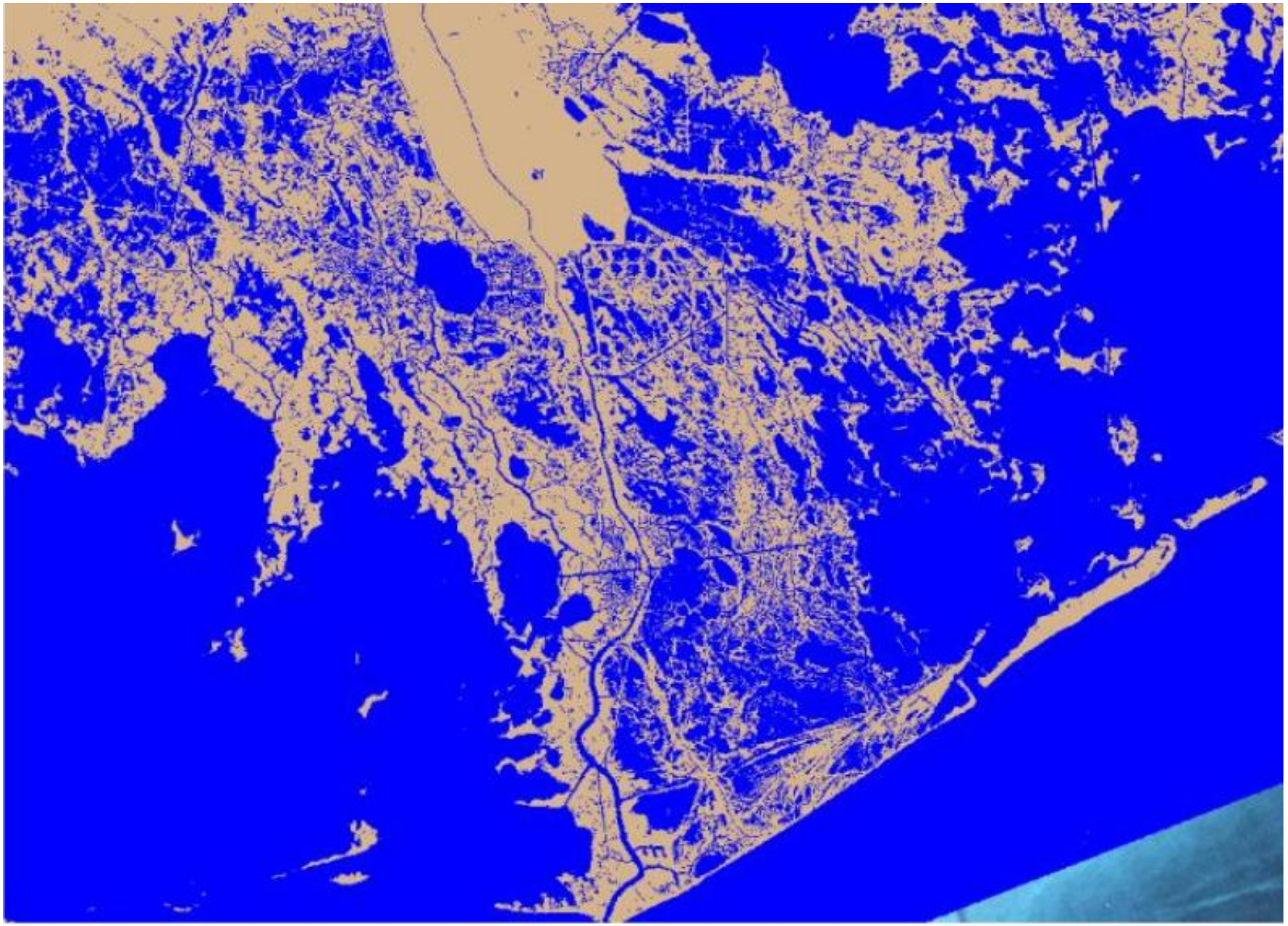


Figure 4. Two-bit raster file of the same Landsat 7 ETM scene showing pixel classificati
(brown) and water (blue).

An example of 'feature extraction' (next lecture)

Reasons to use Tassel Cap Analysis

- It reduces a multi-band dataset (4-6) to 3 channels –
  Brightness, Greenness, Wetness – each might be useful

- The 3 channels could be used in a classification – combined they provide more total information than any 3 bands

- The coefficients are universal for each sensor scene
  e.g. the same for all Landsat 8 images, or the same for all Sentinel 2 images – but different between sensors

PCI Catalyst can handle a range of sensor types – initially only Landsat MSS / TM, and SPOT HRV – now~25 examples

Principal Components Analysis (PCA)

('Hotelling'- Harold, 1933)
Statistical example: influential factors on life expectancy
Family history, affluence, lifestyle, diet, environment

(Like TCA) PCA is a mathematical transformation that converts original data into new data channels that are uncorrelated and minimise data redundancy.

Differences with TCA :

1. PCA transformation is scene specific – while TCA coefficients are 'global'

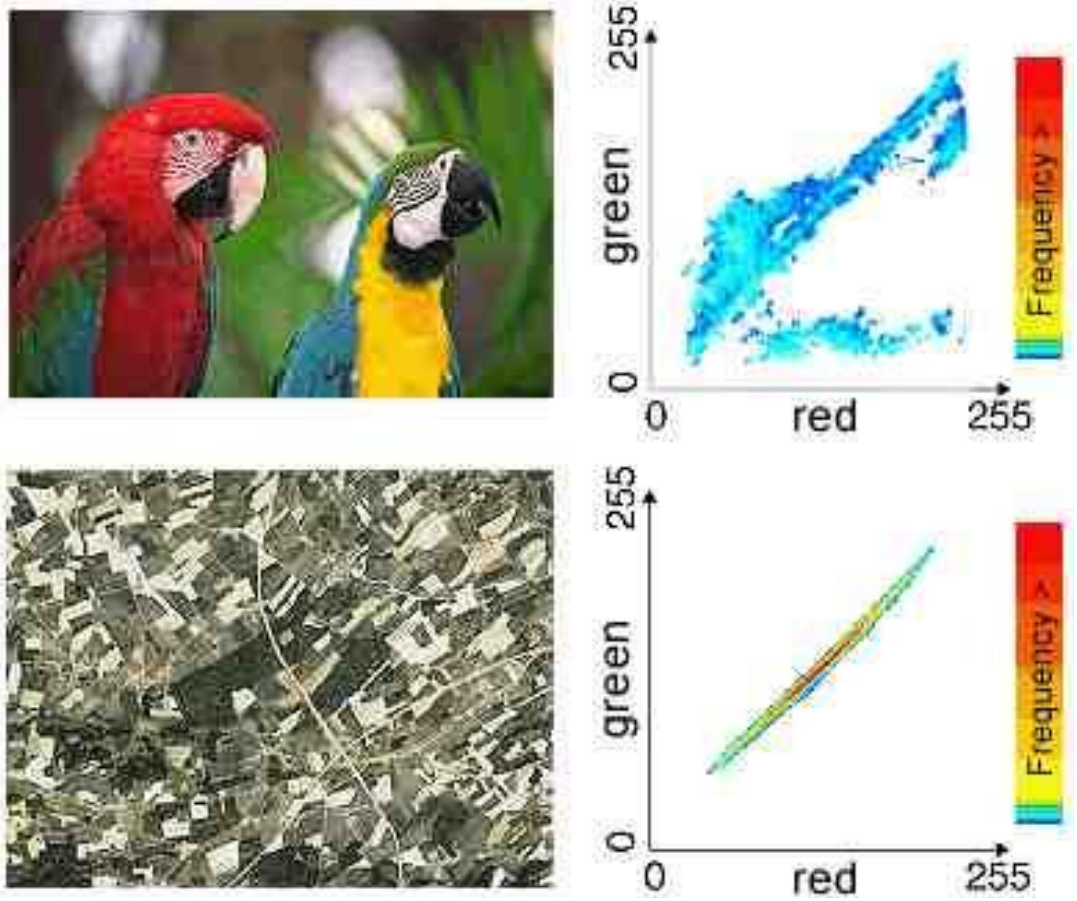
2. TCA creates three new transformed **channels,**
- PCA generates as many new ones as there are input **channels**
  e.g. for Landsat TM, there could be 6-7 new component channels

Principal: (adjective) Most important or influential

Principle: (noun) a rule, guideline, or fact

Principal Components Analysis (PCA)

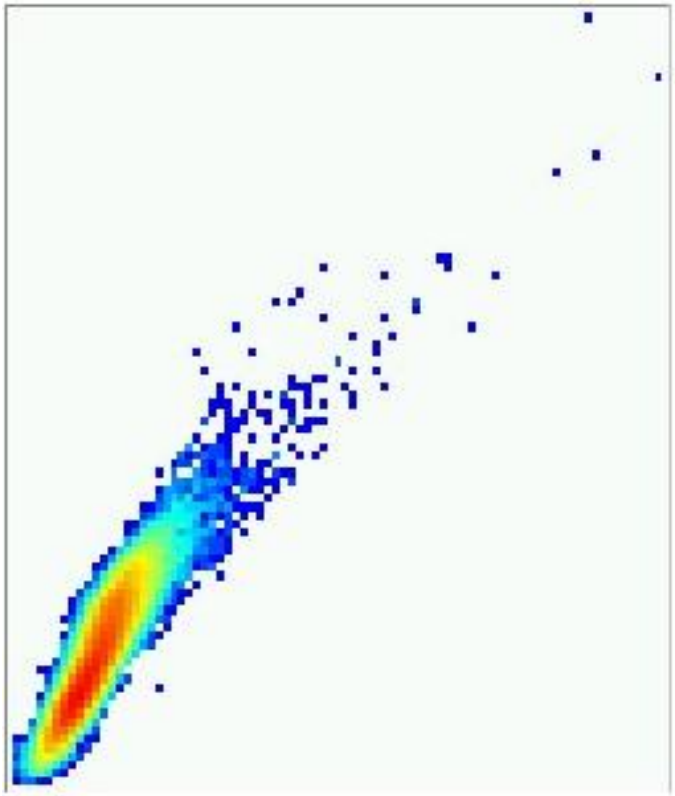
PCA is a mathematical transformation that converts original data into new data channels that are uncorrelated and minimise data redundancy.
Like TCA, it can also: reduce shadows and spectral correlation between bands

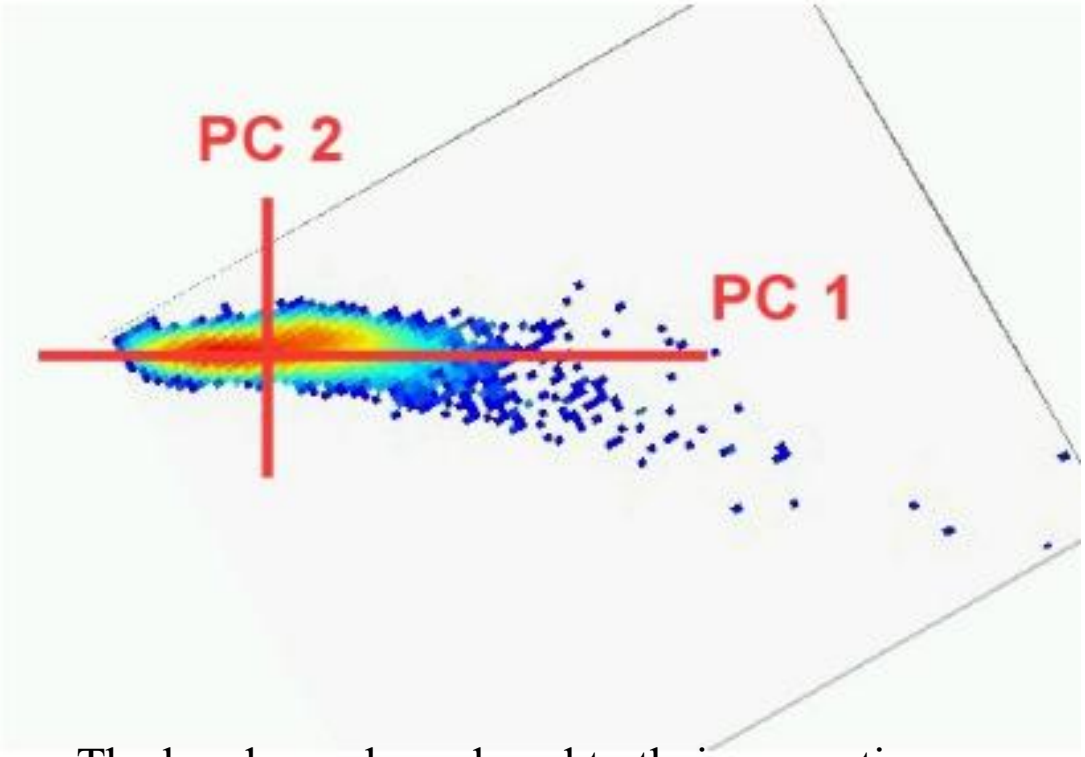


https://eo.belspo.be/en/principal-component-analysis

The main axis through the points is a 'component'; if all points were on it, correlation=1, the first component (PC1) would 'explain' all the variation.

The 2nd component (PC2) is normal to PC1, uncorrelated and hence two bands are converted to two components, but most variation is explained by the first (the 2nd is always smaller)

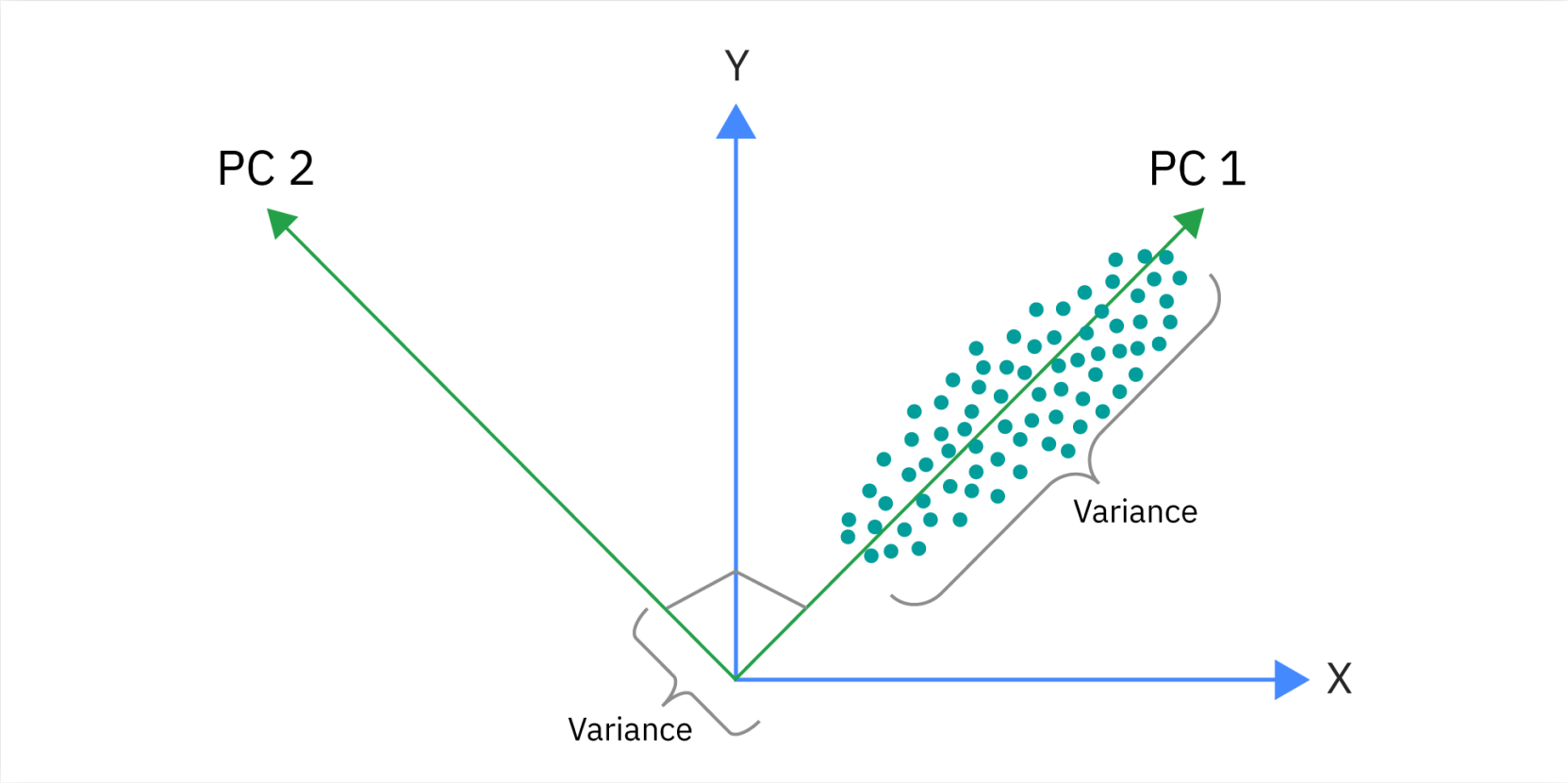




The bands can be reduced to their respective 'components', by an 'axial rotation'

Now ! imagine this in 3d, or in 7 dimensions, which includes all of the bands.

A simpler graphic showing most of the variation occurring along the axis of PC 1



Principal Components Analysis (PCA)

The new channels are defined by eigenvectors / eigenvalues.

In the ‘matrix’:

Eigenvectors: define the **contribution** of each band

Eigenvalues: ‘explain’ the **% variance** of each PCA channel

PC1 and PC2 usually explain 95-99% along with PC3; the rest are ‘noise’

PC1= what is explained in all bands (images)

PC2= what is the first difference between them (similar to a band ratio)

PC3= what is the second difference

PCA channels: PG 1996 scene example

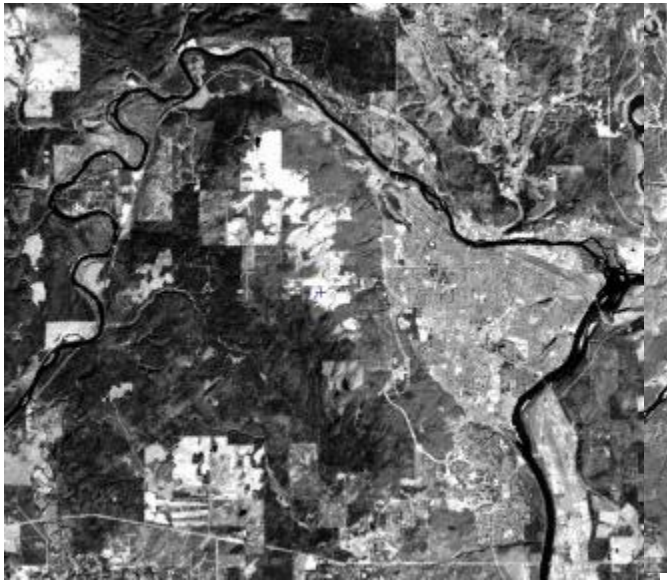
Eigenvectors of covariance matrix (arranged by rows):

	TM1	2	3	4	5	6	7
PC1	0.22	0.15	0.29	0.16	0.75	0.33	0.40
PC2	-0.28	-0.14	-0.29	**0.82**	0.23	-0.25	-0.16
PC3	**0.51**	**0.31**	**0.43**	**0.49**	-0.46	-0.05	-0.00
PC4	-0.09	-0.09	-0.19	0.19	-0.23	**0.91**	-0.18
PC5	0.31	0.13	0.05	-0.12	**0.35**	-0.00	-0.86
PC6	**0.69**	-0.16	-0.68	-0.01	0.01	-0.04	0.19
PC7	-0.19	**0.90**	-0.39	-0.04	0.00	0.00	0.06

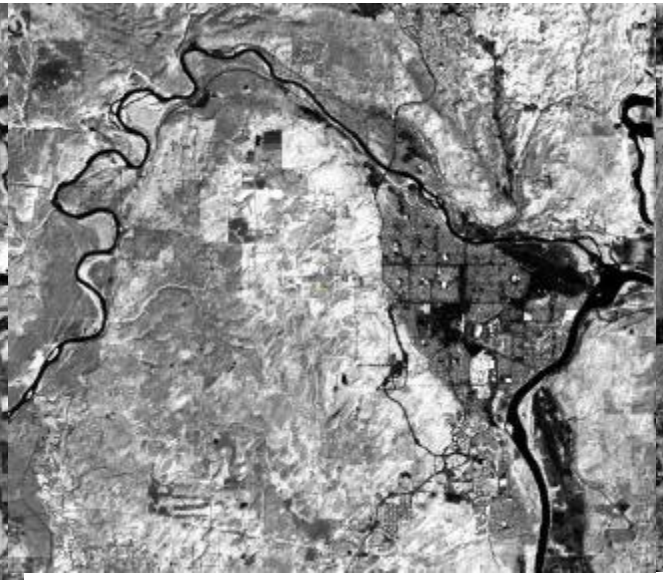
Component - eigenvalues

71% Brightness
21% Greenness
3.8% Swirness / Wetness
2.3% Impact of Thermal band
1.6% Band 5 v 7 (SWIR1 v 2)
0.2% Band 1 v 3 (B v R)
0.1% Band 2 v 3 (Yellowness)

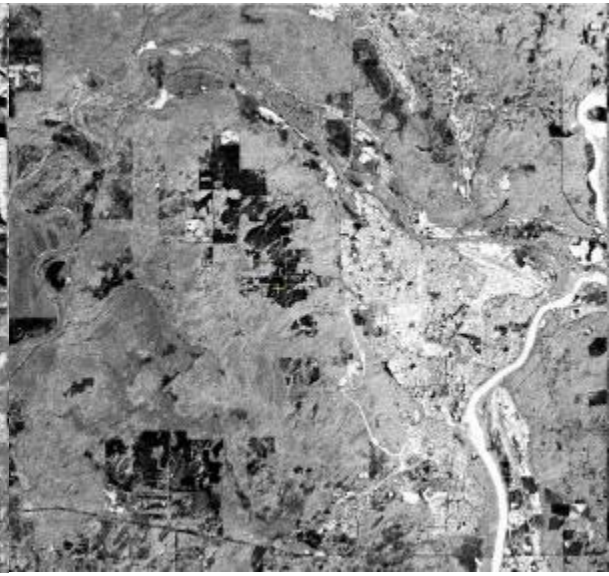
PC1: Brightness



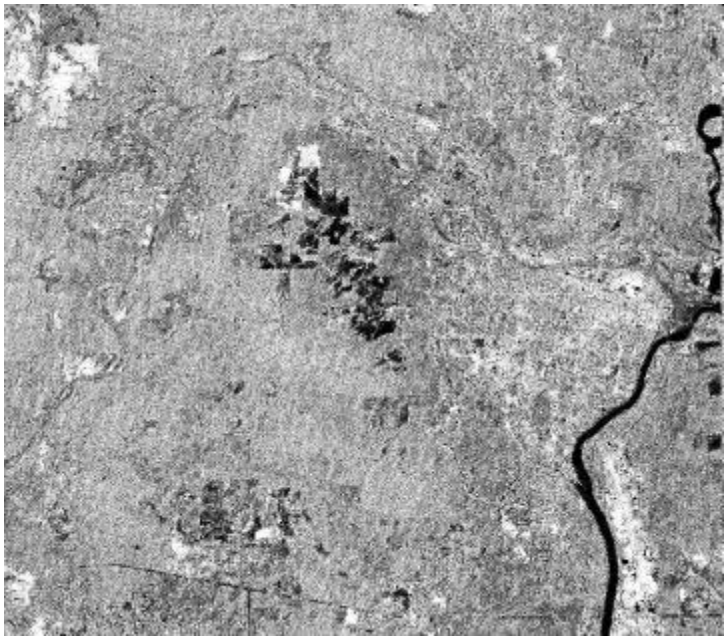
PC2: Greenness

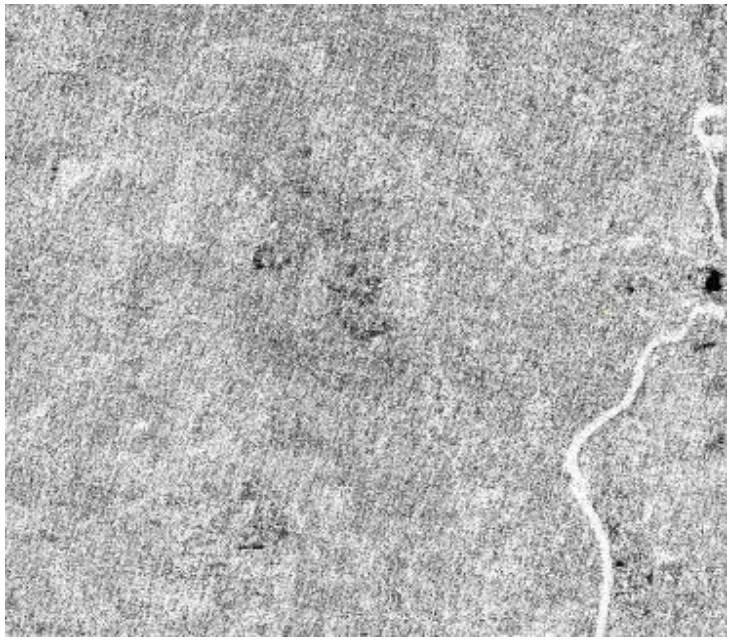


PC3: Swirness / Wetness



PC components PC4: TM6, PC5: TM5/7, PC6: TM1/3, PC7: TM2/3





Differences with Tasseled Cap (TCA) :

1. PCA transformation is scene specific -TCA coefficients are 'global‘

2. PCA generates as many components as there are input **channels**

   e.g. for Landsat TM, there could be 7 new component channels

   … while TCA creates just three new transformed **channels**

3. Can also load bands (channels) from multiple dates –> ‘time series’

TCA is only applied to one multispectral image dataset

Note: There is a high correlation between all ‘greenness’ channel types:

NDVI, NIR/Red ratio, TCA greenness, PCA component 2 (usually)

Image fusion / **Pansharpening**

Goal: Combine higher spatial information in one band with higher spectral information in another dataset to create 'synthetic' higher resolution multispectral datasets and images- for detail in display

MS bands should have similar wavelength to the PAN band e.g. visible

Fusion is a broader term involving merging of any two datasets with different resolutions

Lower resolution RGB (4m) Higher resolution PAN (1m) Pansharpened colour

https://satpalda.co/pan-sharpening

A common feature now in GIS software for image backgrounds / interpretation

With more sensors having a higher resolution PAN band, Pansharp has become a common software tool / option

Sensors with higher resolution Panchromatic band (some)

Platform/Sensor	**date**	**PAN**	**MS (m)**
Landsat ETM+	1999	15	30
Landsat OLI 8/9	2013	15	30
SPOT 1-4	1986	10	20
SPOT 5	2002	2.5/5	10/20

[Not Sentinel 2 as VNIR are 10m, no Pan band

Most high resolution sensors (<1m pixels) post-2000 e.g.

Ikonos	(2000)	1	4

PCI / others recommend maximum ratio of 4 or 5 : 1 for pansharpening

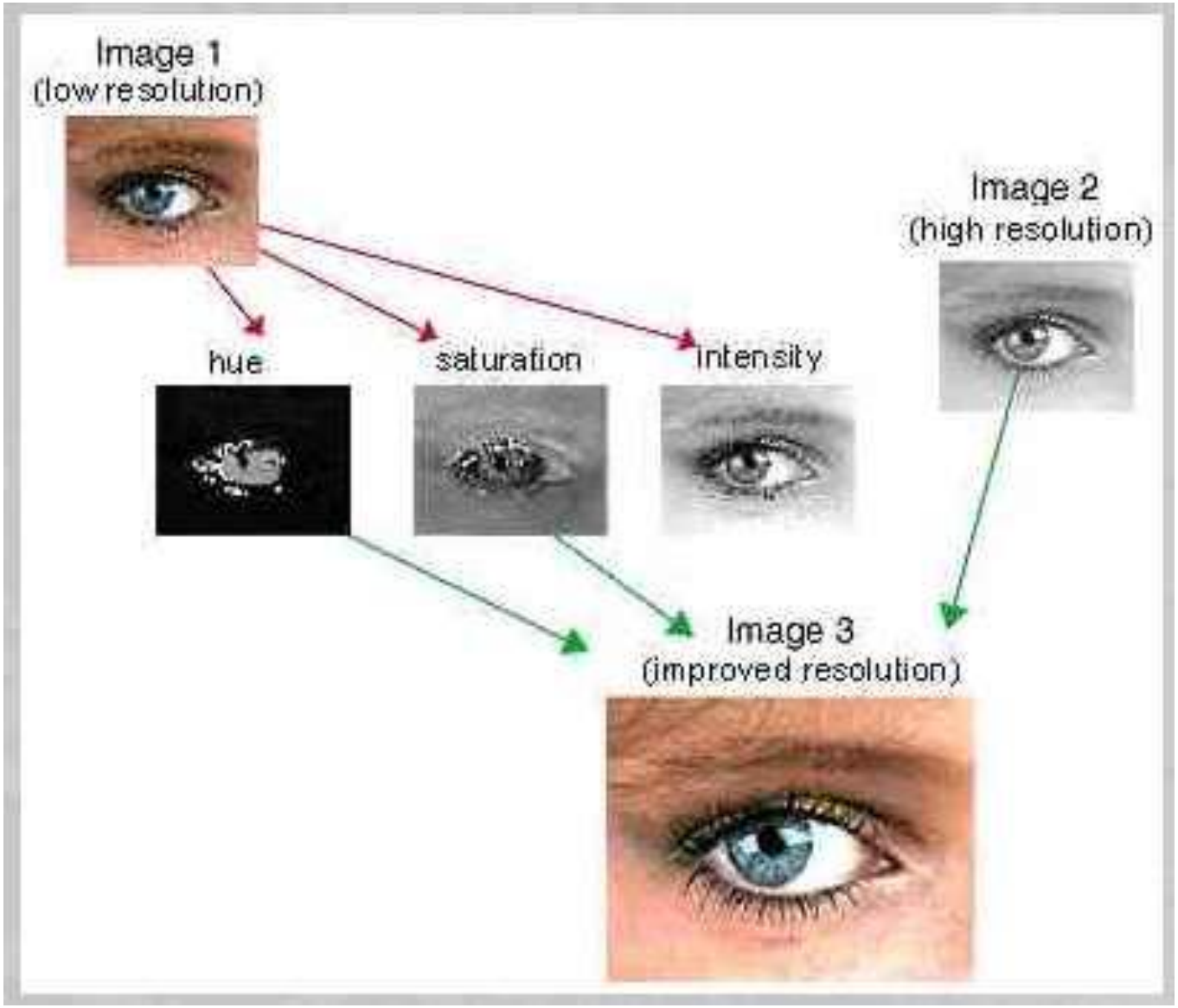
Fusing / Pansharp
How it works …

"IHS transformation"
RGB image -> HSI

Hue, Saturation, Intensity

https://www.rapidtables.com/web/color/RGB_Color.html

The intensity channel is replaced by the high res. (PAN) channel and the transformation is reversed: HIS -> RGB



https://eo.belspo.be/en/iv31-pan-sharpening

Decorrelation Stretch: Remote sensing technique to enhance images

- based on Principal Components Analysis (PCA) …. DECORR tool
- used to Enhance Rock Art Images by Jon Harman
- for (highly correlated) qualitative analysis of visible colour images