Transformations in Remote Sensing

= Converting image bands into secondary channels

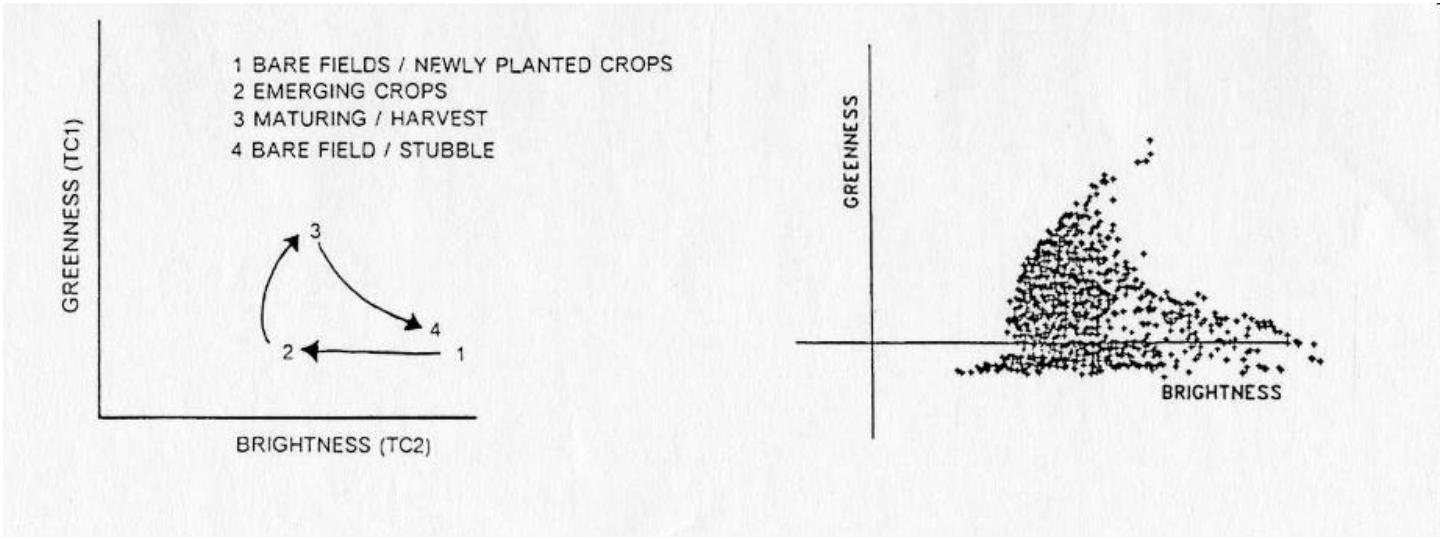
- **Ratios / image arithmetic and Indices**
- **Tassel Cap Analysis**
- **Principal Component Analysis (PCA)**
- **Pansharpening / image fusion**

Tasseled Cap transformation

ArcMap 10.3

The Tasseled Cap (Kauth-Thomas) transformation is designed to analyze and map vegetation and urban development changes detected by satellite sensors. It is known as the Tasseled Cap transformation due to the data shape.

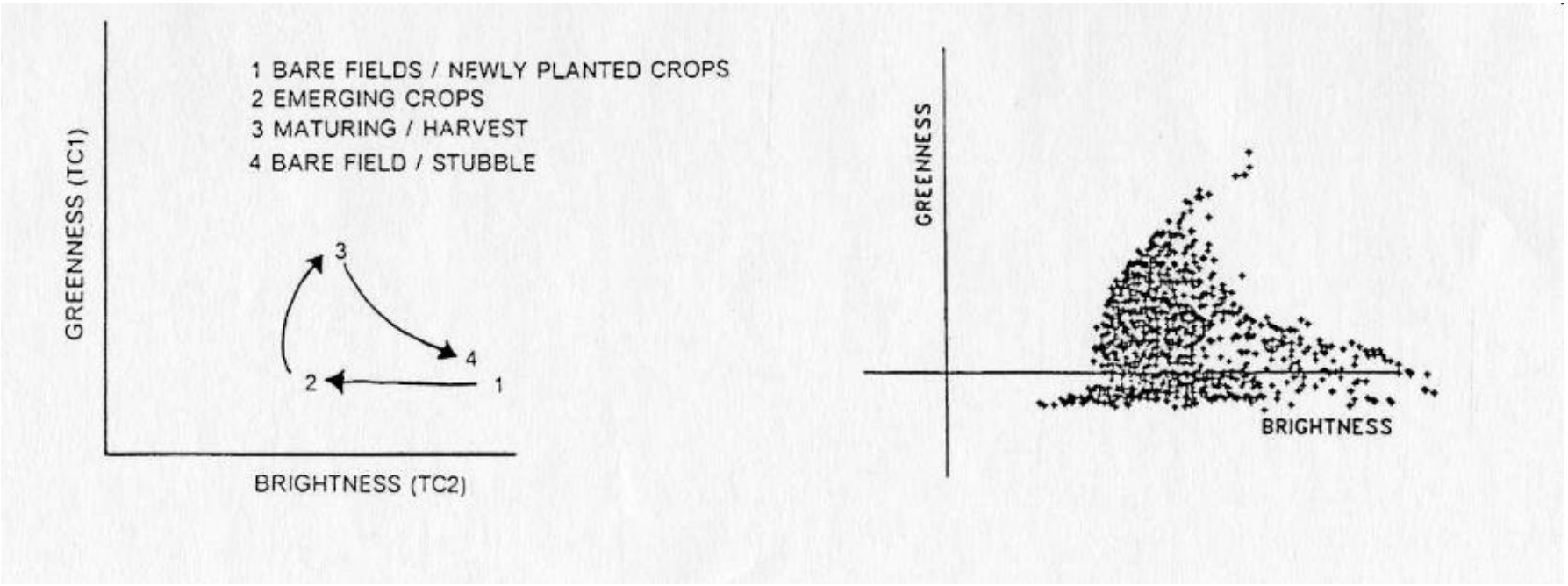
It was developed in 1976 by R.J. Kauth and G.S. Thomas of the Environmental Research Institute of Michigan (ERIM). The researchers found the patterns in Landsat MSS data of agricultural fields as a function of the life cycle of the crop. Essentially, as crops grow from seed to maturity, there is a net increase in near-infrared and decrease in red reflectance based on soil color



Kauth, R. J., & Thomas, G. S. (1976). The Tasselled-Cap—A Graphic Description of the Spectral-Temporal Development of Agricultural Crops as Seen by Landsat. . Proceedings, Symposium on Machine Processing of Remotely Sensed Data, Purdue University, West Lafayette, IN, 29 June-1 July 1976, 41-51.

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 transformation

For each pixel DN, the new channels weight the input bands, e.g.: Landsat MSS
Brightness channel = 0.433*Band4 + 0.632*Band5 +0.586*Band6 +0.264*Band7
etc.. 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 TM 4/3 ratio)
Yellowness = Green v Red
“Non-such” = difference between the 2 IR bands (noise)

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The Tasseled Cap Transformation in Remote Sensing

.. the conversion of the DNs 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 another the **yellowness** of vegetation, or perhaps the **wetness** of the soil.

Usually there are just **three** composite variables.

http://www.sjsu.edu/faculty/watkins/tassel.htm

Tasseled Cap Transformation

MSS data, the 4-band dataset creates channels:

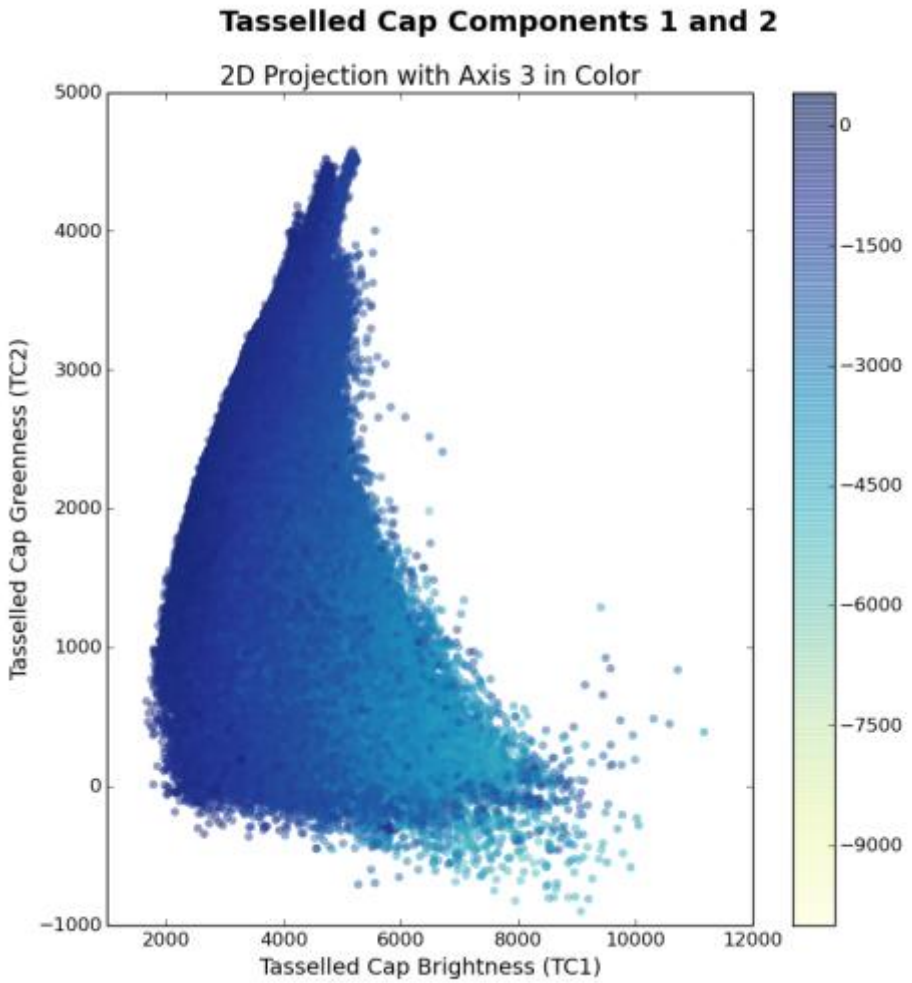
Brightness, Greenness, Yellowness

TM data, 6-band (no thermal)

Brightness

Greenness

Wetness (SWIR)



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

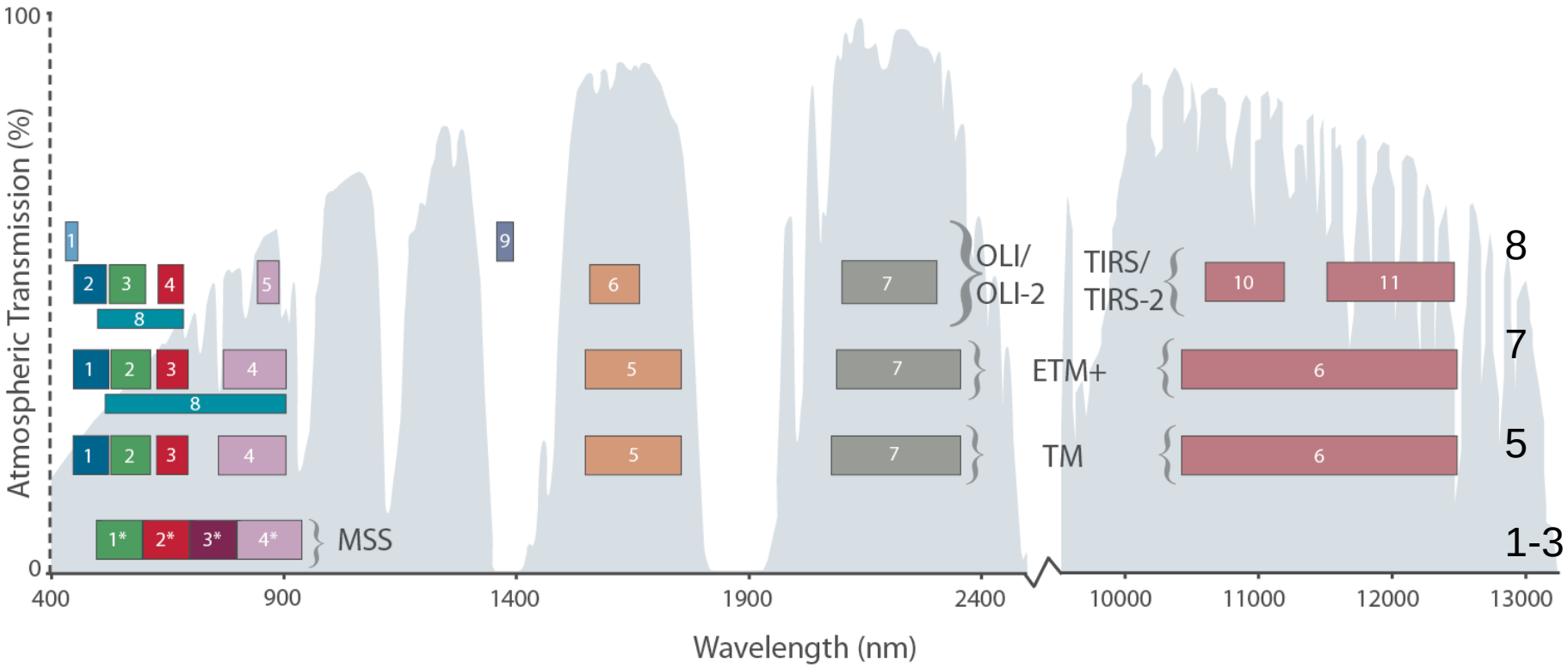
	Coastal Band 1	*Blue Band 2*	*Green Band 3*	*Red Band 4*	*NIR Band 5*	*Mid-IR1 Band 6*	*Mid-IR2 Band 7*
Brightness	0	0.3029	0.2786	0.4733	0.5599	0.5080	0.1872
Greenness	0	-0.2941	-0.2430	-0.5424	**0.7276**	0.0713	-0.1608
Wetness	0	0.1511	0.1973	0.3283	0.3407	**-0.7117**	**-0.4559**

You may have noticed these components on your TCA channels in the files listings

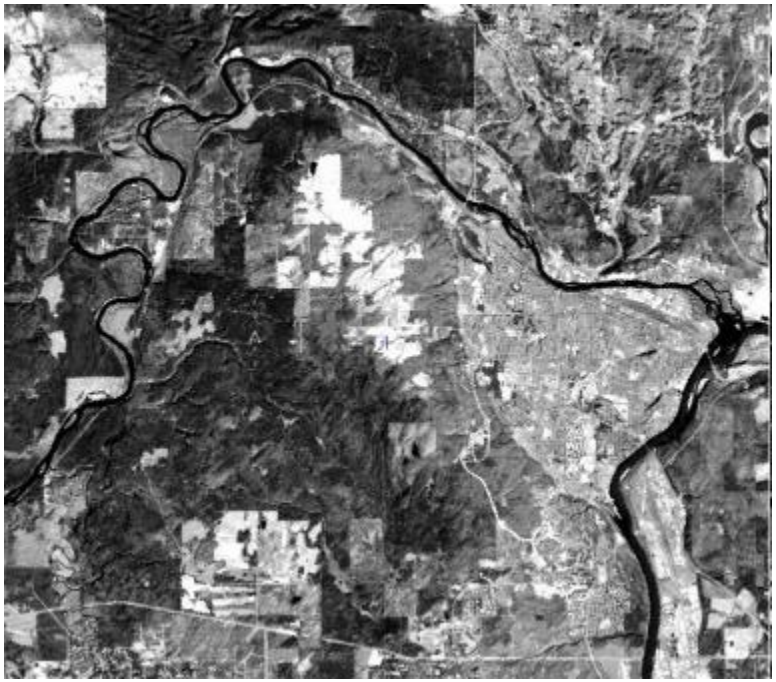
Why are they different at all – Landsat 5 TM vs ETM+ vs OLI ? ….

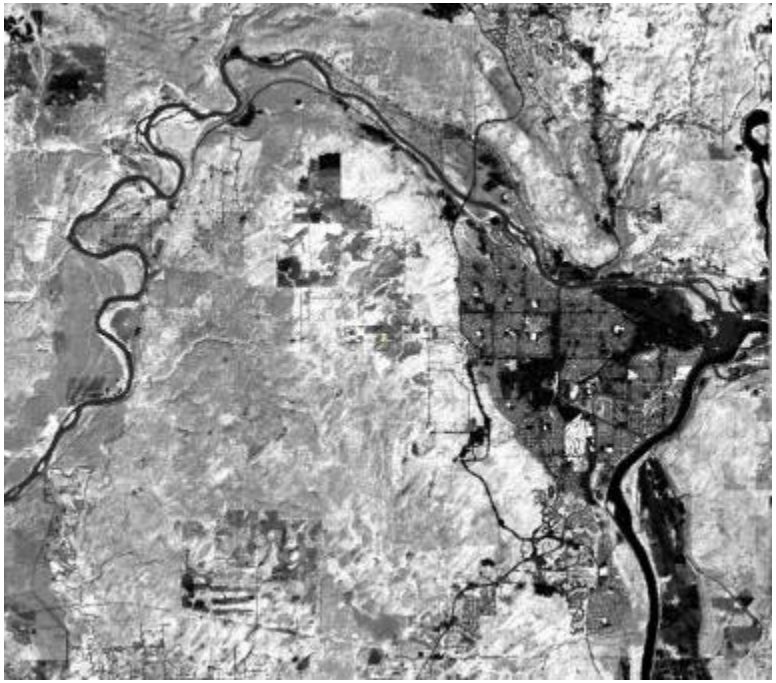
Landsat sensors and band wavelengths

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



Similar bands on Landsat TM / OLI are close but no cigar …





tasseled cap channels 1,2,3

a. **Brightness** – overall reflectance

b. **Greenness** – vegetation

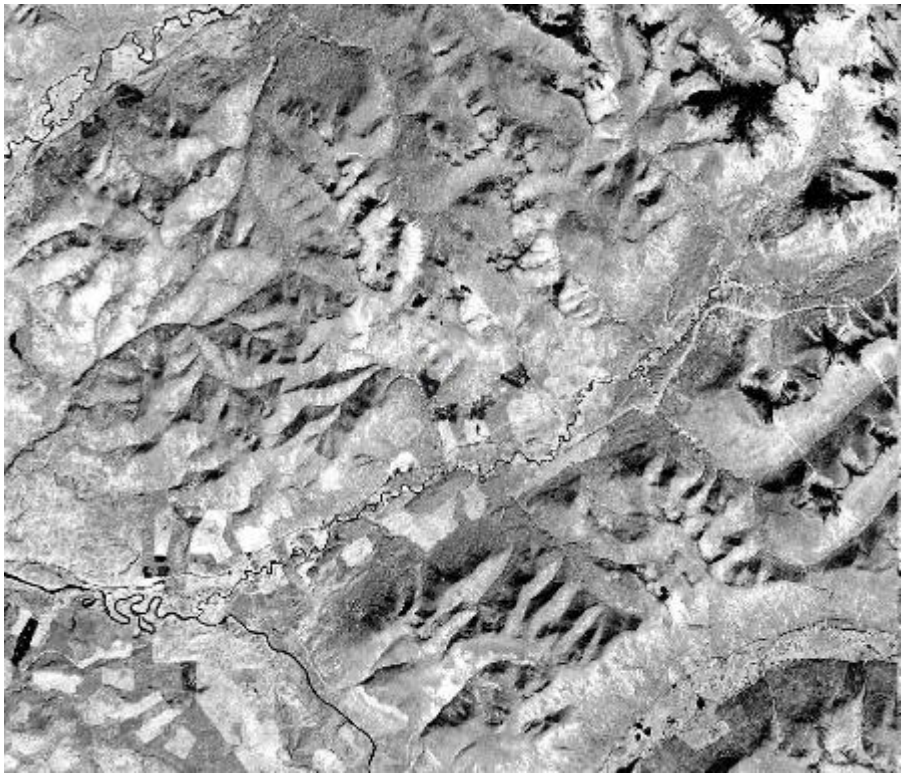
c. **Wetness** – soil / canopy moisture

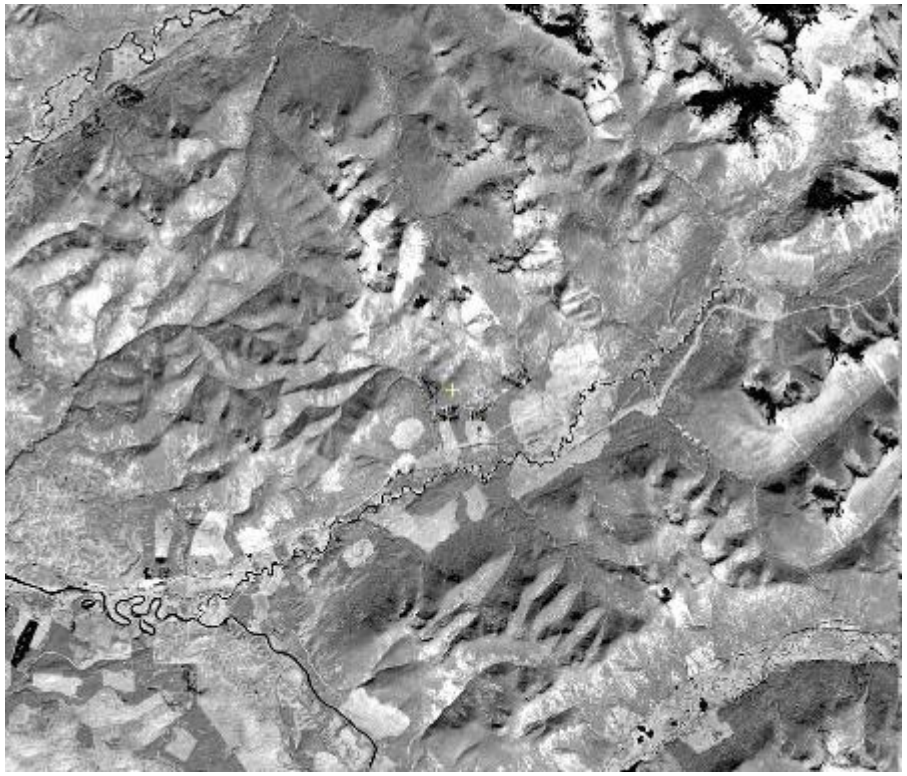
the 3 channels are uncorrelated

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

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.

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.

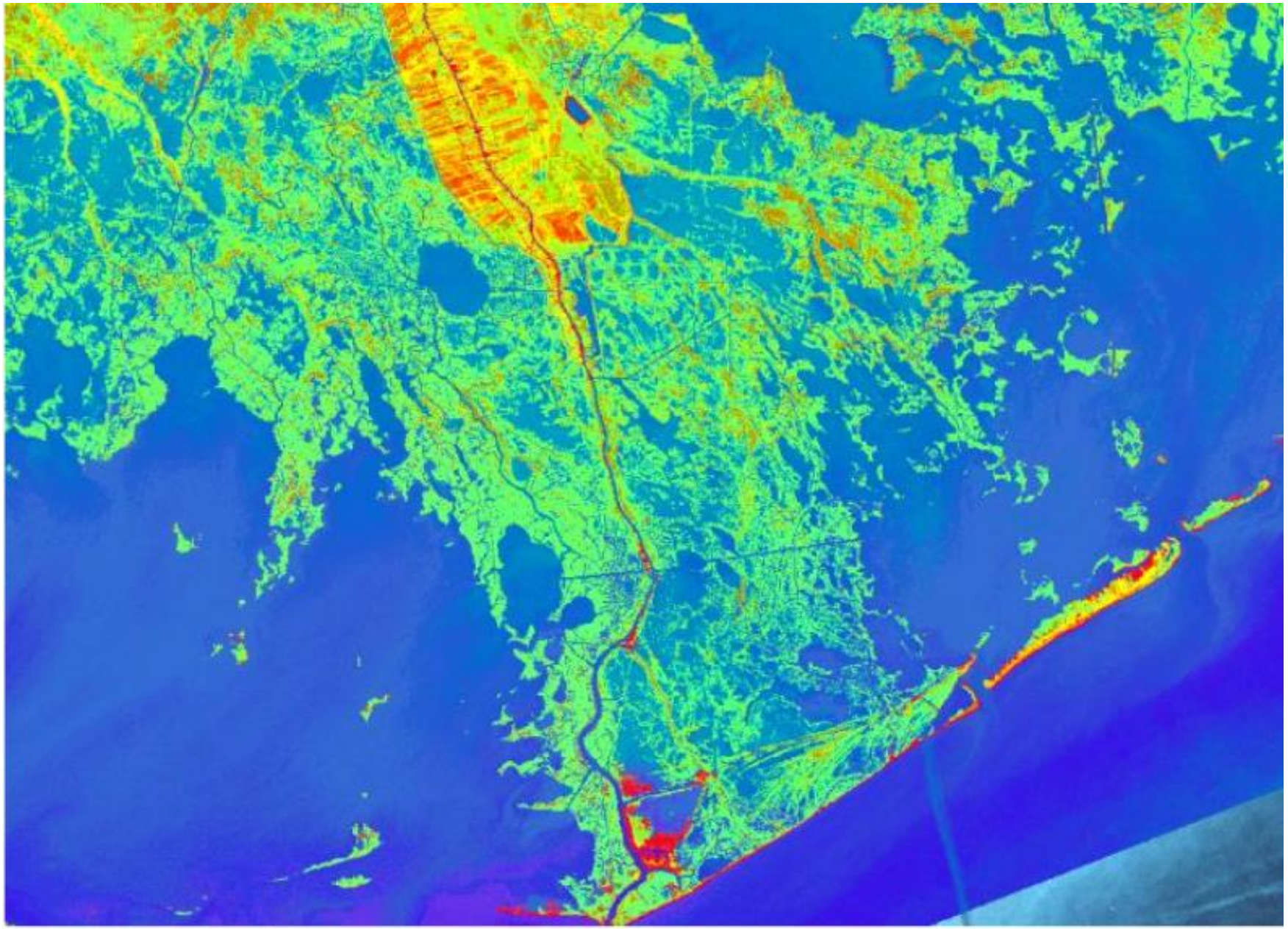


Figure 3. Three-band, 8-bit tasseled cap transformation image of the same Landsat 7 ET

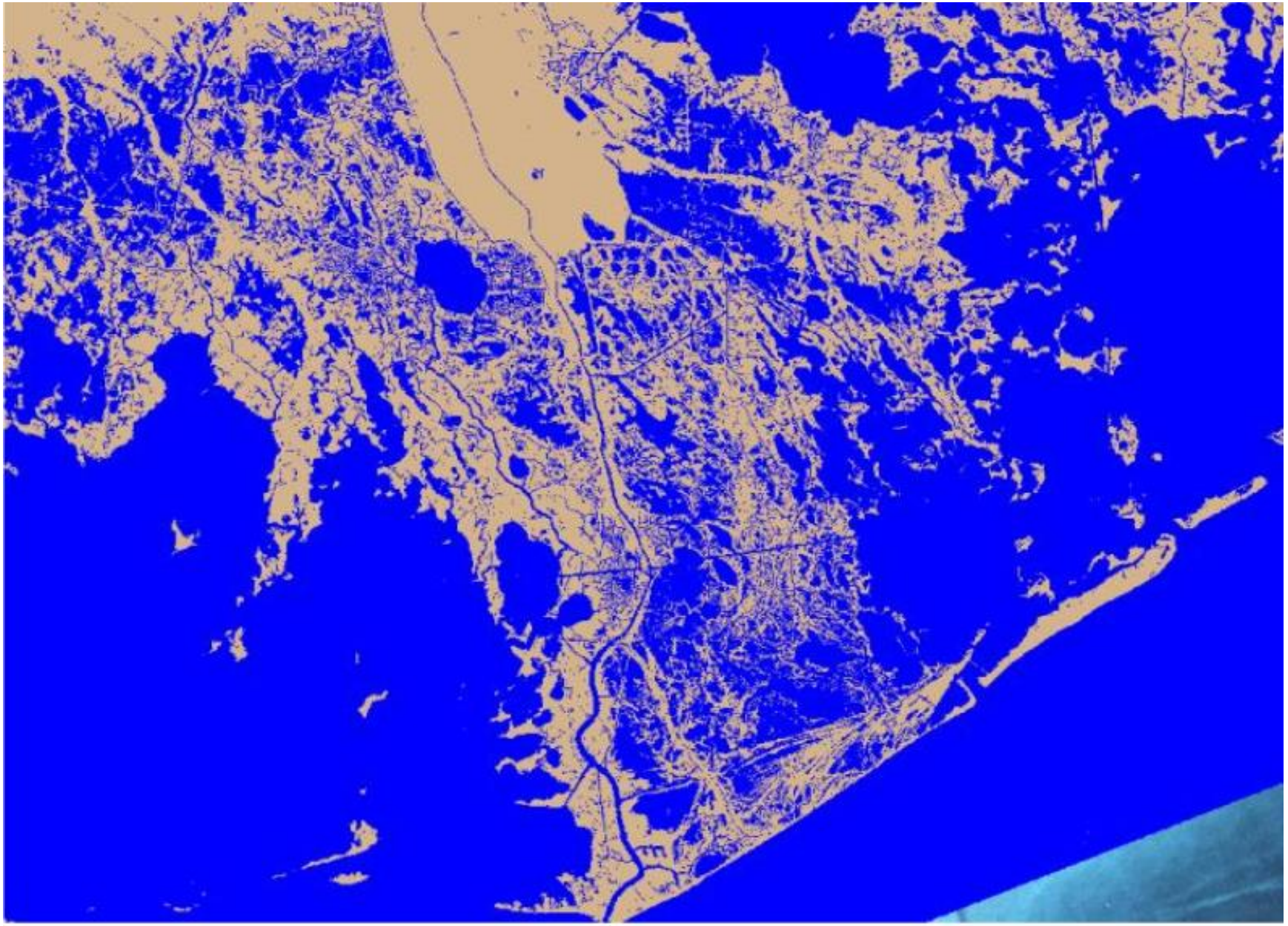


Figure 4. Two-bit raster file of the same Landsat 7 ETM scene showing pixel classificati
(brown) and water (blue).

Reasons to use Tassel Cap Analysis

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

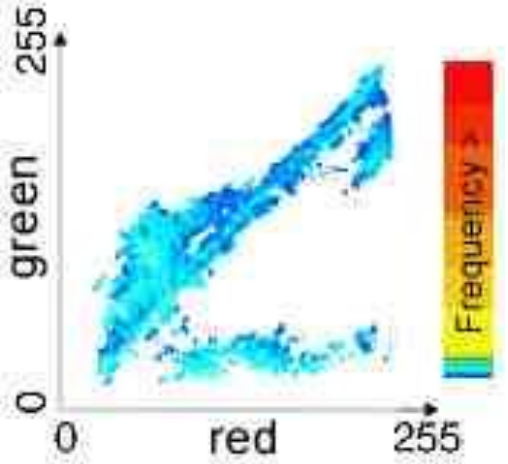
- **The 3 channels could be used in a classification**

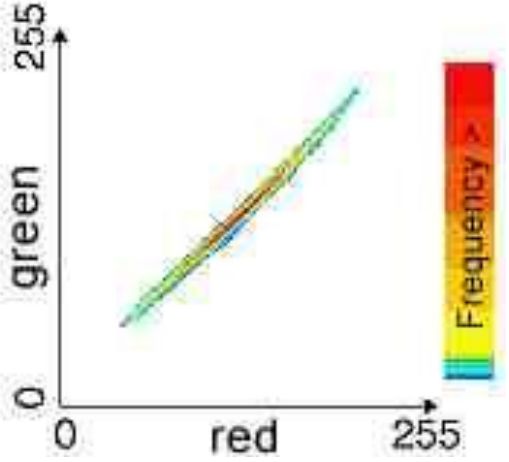
- **The coefficients are universal for each sensor scene e.g. the same for all Landsat 8 images, or the same for all Sentinel 2 images – but different between sensors**

PCI Catalyst can handle a range of sensor types (tool TASSEL)– initially only Landsat MSS and TM, and SPOT HRV

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

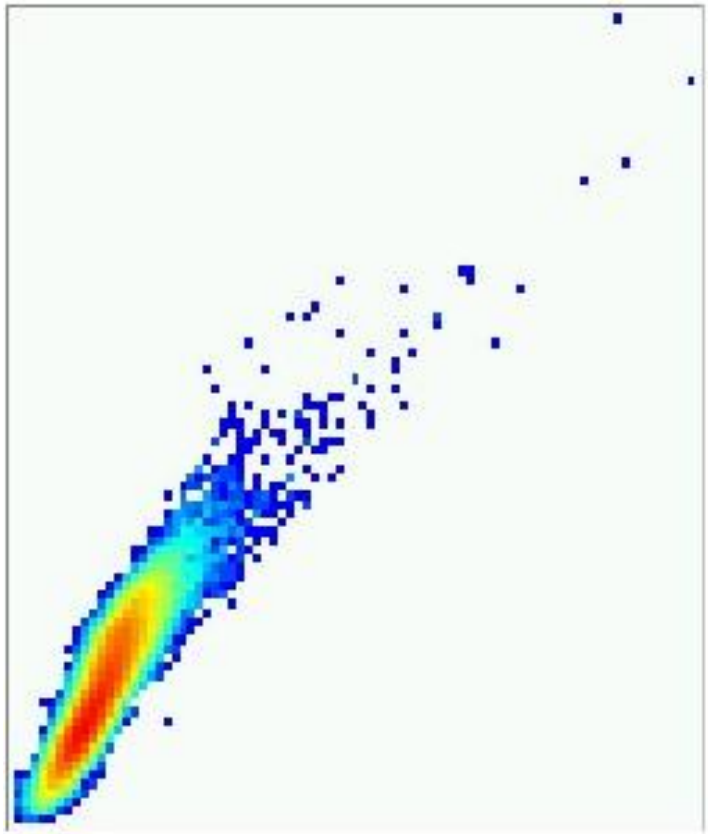


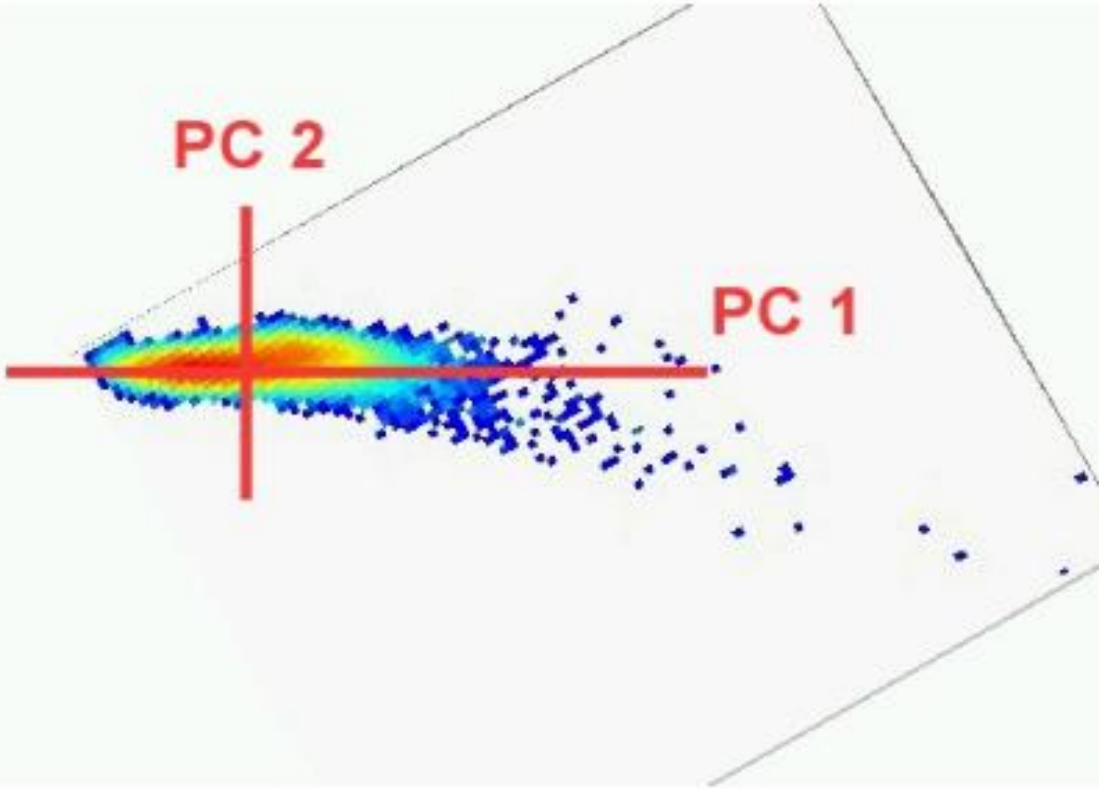


http://eoedu.belspo.be/en/guide/compprin.asp

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.

Principal Components Analysis (PCA)

('Hotelling'- Harold, 1933)

(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 as there are input **channels**

e.g. for Landsat TM, there could be 6-7 new component channels

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 explain 95-99% with PC3; the rest are 'noise'

PC1= what is explained in both bands (images)

PC2= what is different between them (similar to a band ratio)

PCA channels: PG 1996 scene example

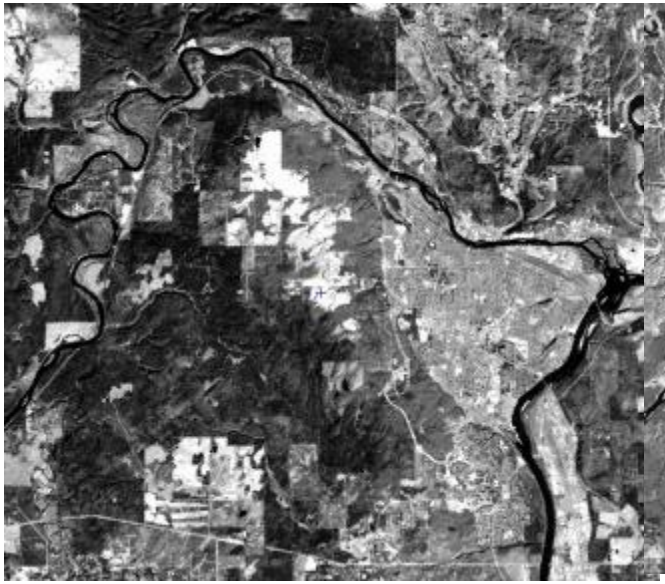
Eigenvectors of covariance matrix (arranged by rows):

	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

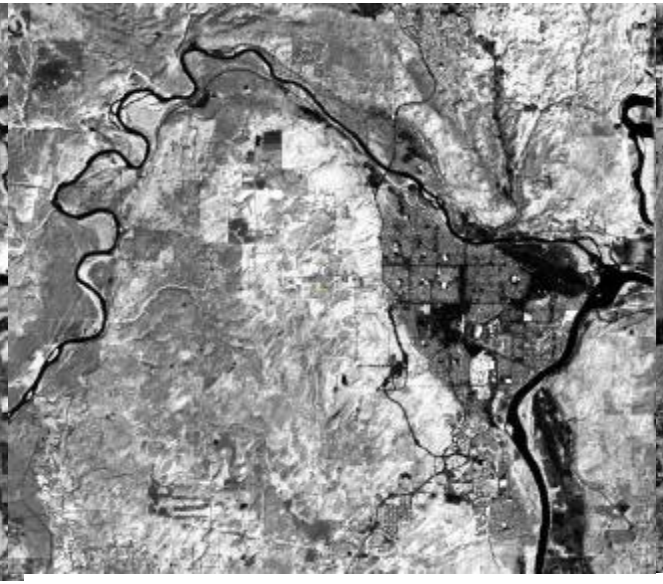
Component

71% Brightness
21% Greenness
3.8% Swirness / Wetness
2.3% Impact of TM6
1.6% Band 5 v 7 (MIR)
0.2% Band 1 v 3 (B v R)
0.1% Band 2 v 3 (Yellowness)

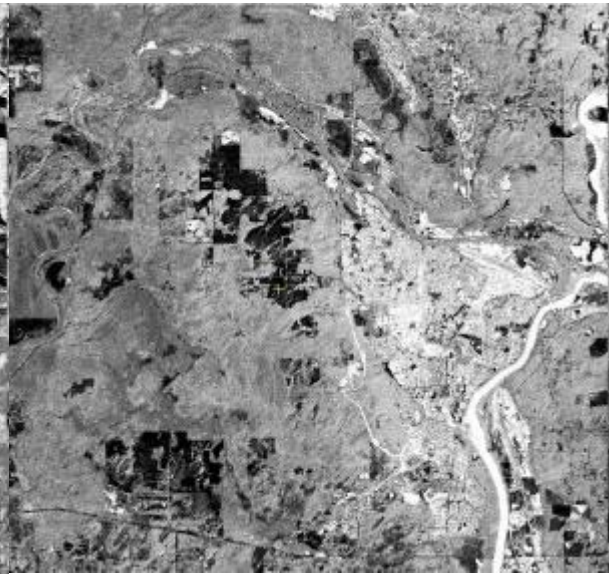
PC1: Brightness,



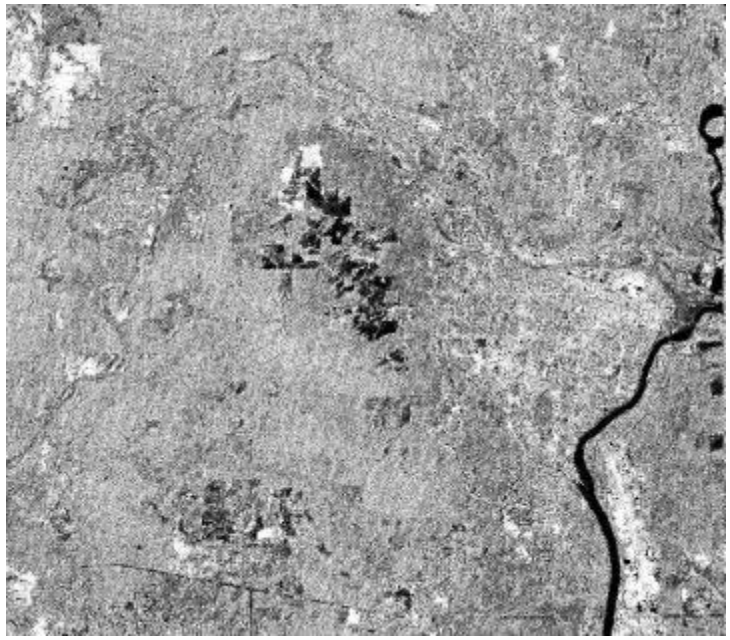
PC2: Greenness,

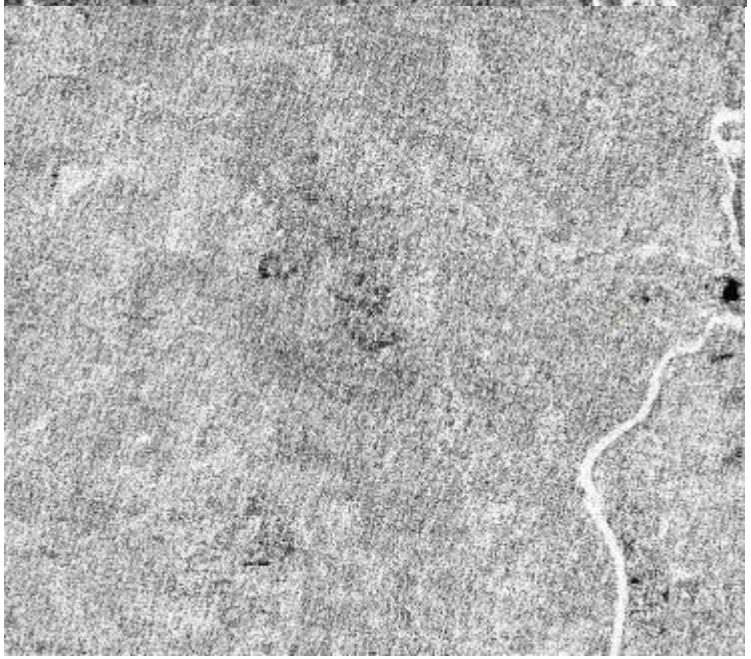


PC3: Swirness / Wetness



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 three new transformed **channels**

3. Can also load bands (channels) from multiple dates – 'time series'

Note there is a high correlation between all 'greenness' channels:
-As they all contrast near-IR and visible bands

- NDVI
- 4/3 ratio
- TCA greenness
- PCA component 2 (usually)

Face Recognition Using Principal Component Analysis ?





PC1: Human-ness (or lack of)

PC2: Gender

PC3: Hair (colour / volume / lack of)

PC4: Facial hair

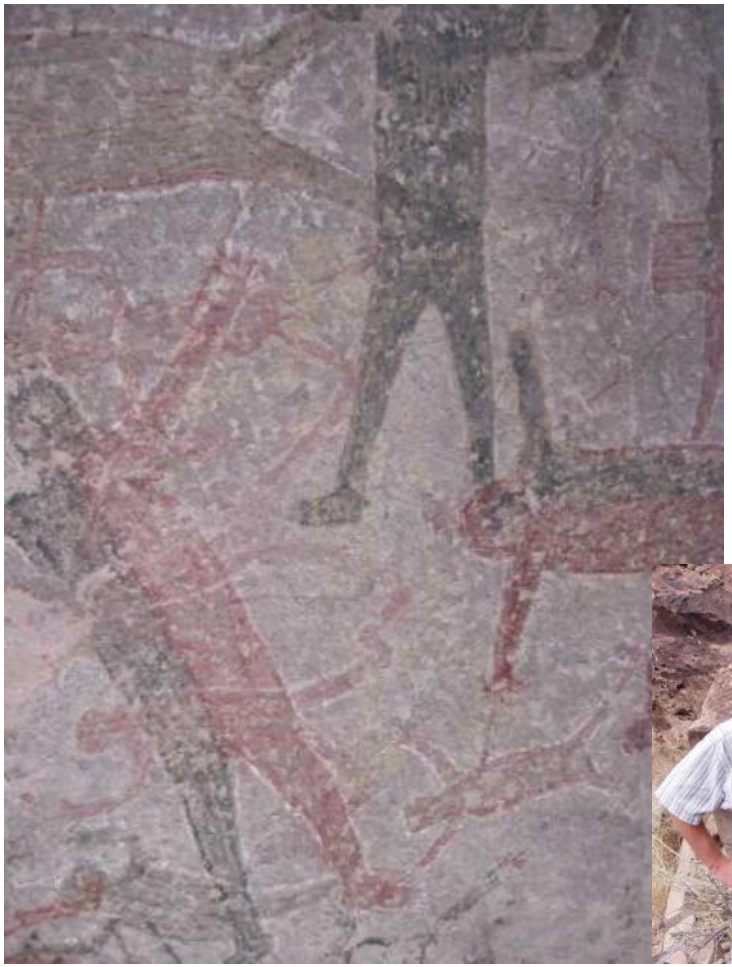
PC5: Mouth – Smile – Teeth - smirk

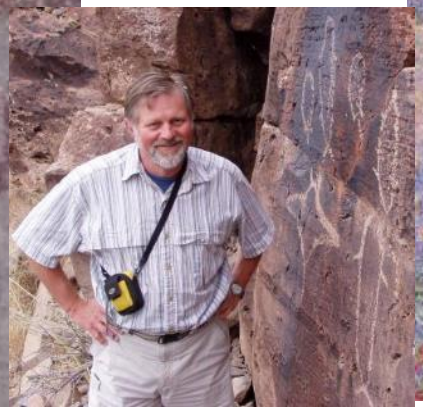
PC6-7: Eyes, Nose … ?

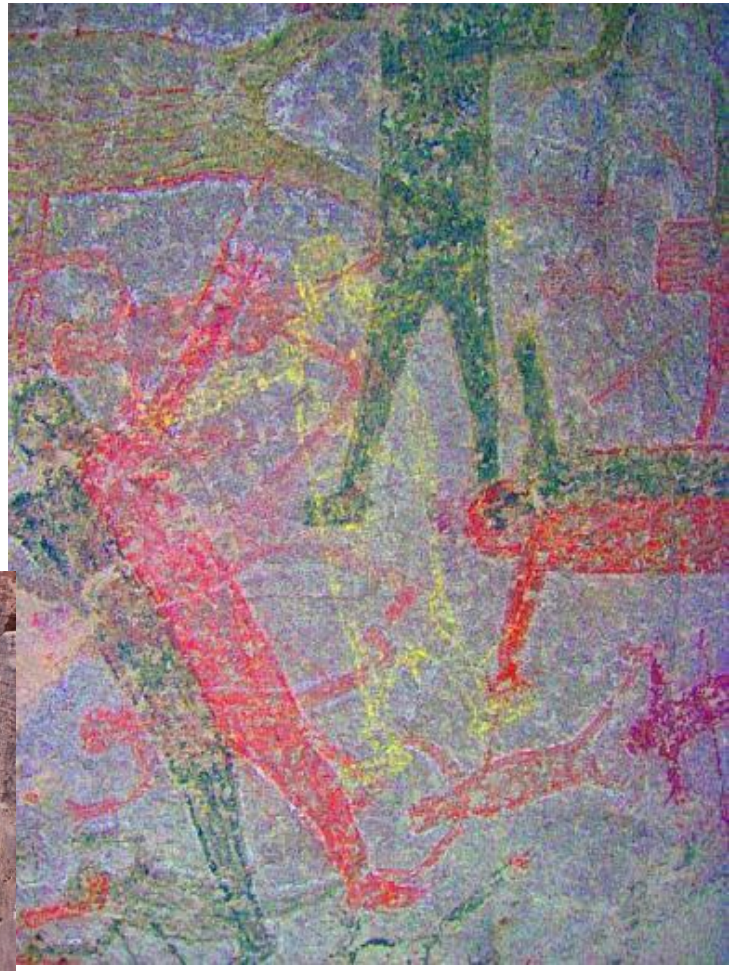

Slightly weird PCA analogy
Does this help at all ?

Decorrelation Stretch: Remote sensing technique to enhance images

- **Based on Principal Components Analysis (PCA) …. DECORR tool**
- **Can work on 2-256 image layers**
- **used to Enhance Rock Art Images** By Jon Harman https://www.dstretch.com http://rockartresearch.org/jon-harman.htm







Gillespie, A.R., A.B. Kahle, R.E. Walker, 1986. "*Color Enhancement of Highly Correlated Images. I. Decorrelation and HSI Contrast Stretches*". Remote Sensing of Environment, Vol.20, p.209-235.

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 more detail in visual display

With more and 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 1-3	1986	10m	20m
SPOT 4	1998	10m	20m
SPOT 5	2002	2.5/5m	10/20m

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

Ikonos	2000	1m	4m

[Not Sentinel 2 as VNIR are also 10m, although SWIR is only 20m]

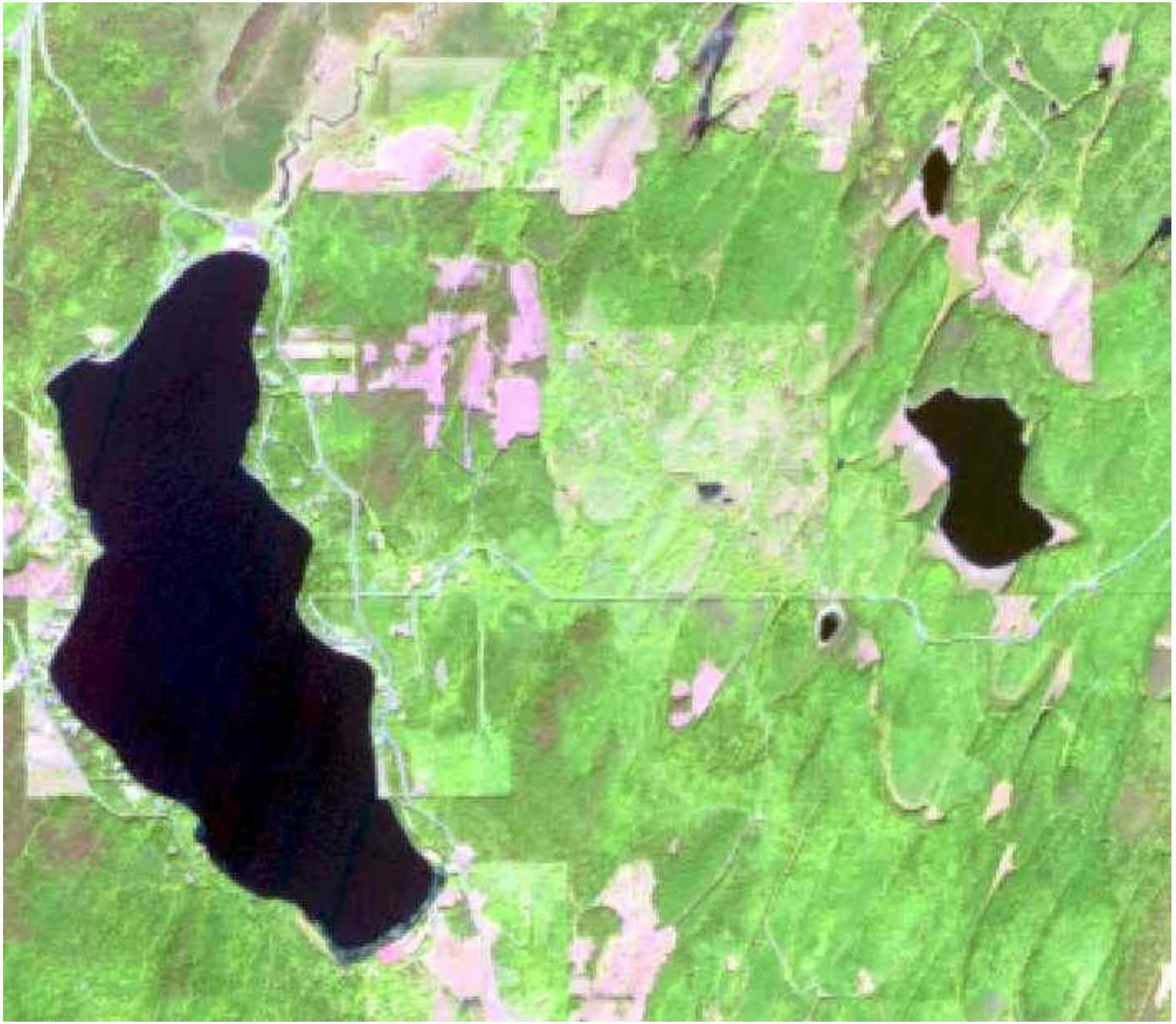
PCI/others recommend maximum ratio of 4 or 5 : 1 for pansharpening

Enhanced Thematic Mapper Plus (ETM+)	Landsat 7	Wavelength (micrometers)	Resolution (meters)
	Band 1	0.45-0.52	30
	Band 2	0.52-0.60	30
	Band 3	0.63-0.69	30
	Band 4	0.77-0.90	30
	Band 5	1.55-1.75	30
	Band 6	10.40-12.50	60 * (30)
	Band 7	2.09-2.35	30
	Band 8	.52-.90	15

Technically pansharpening should be used on bands within the same wavelengths

Landsat 8 Operational Land Imager (OLI) and Thermal Infrared Sensor (TIRS) Launched February 11, 2013	Bands	Wavelength (micrometers)	Resolution (meters)
	Band 1 - Coastal aerosol	0.43 - 0.45	30
	Band 2 - Blue	0.45 - 0.51	30
	Band 3 - Green	0.53 - 0.59	30
	Band 4 - Red	0.64 - 0.67	30
	Band 5 - Near Infrared (NIR)	0.85 - 0.88	30
	Band 6 - SWIR 1	1.57 - 1.65	30
	Band 7 - SWIR 2	2.11 - 2.29	30
	Band 8 - Panchromatic	0.50 - 0.68	15
	Band 9 - Cirrus	1.36 - 1.38	30
	Band 10 - Thermal Infrared (TIRS) 1	10.60 - 11.19	100
	Band 11 - Thermal Infrared (TIRS) 2	11.50 - 12.51	100

SPOT PAN – Tabor Lake 10m



SPOT 20m MS

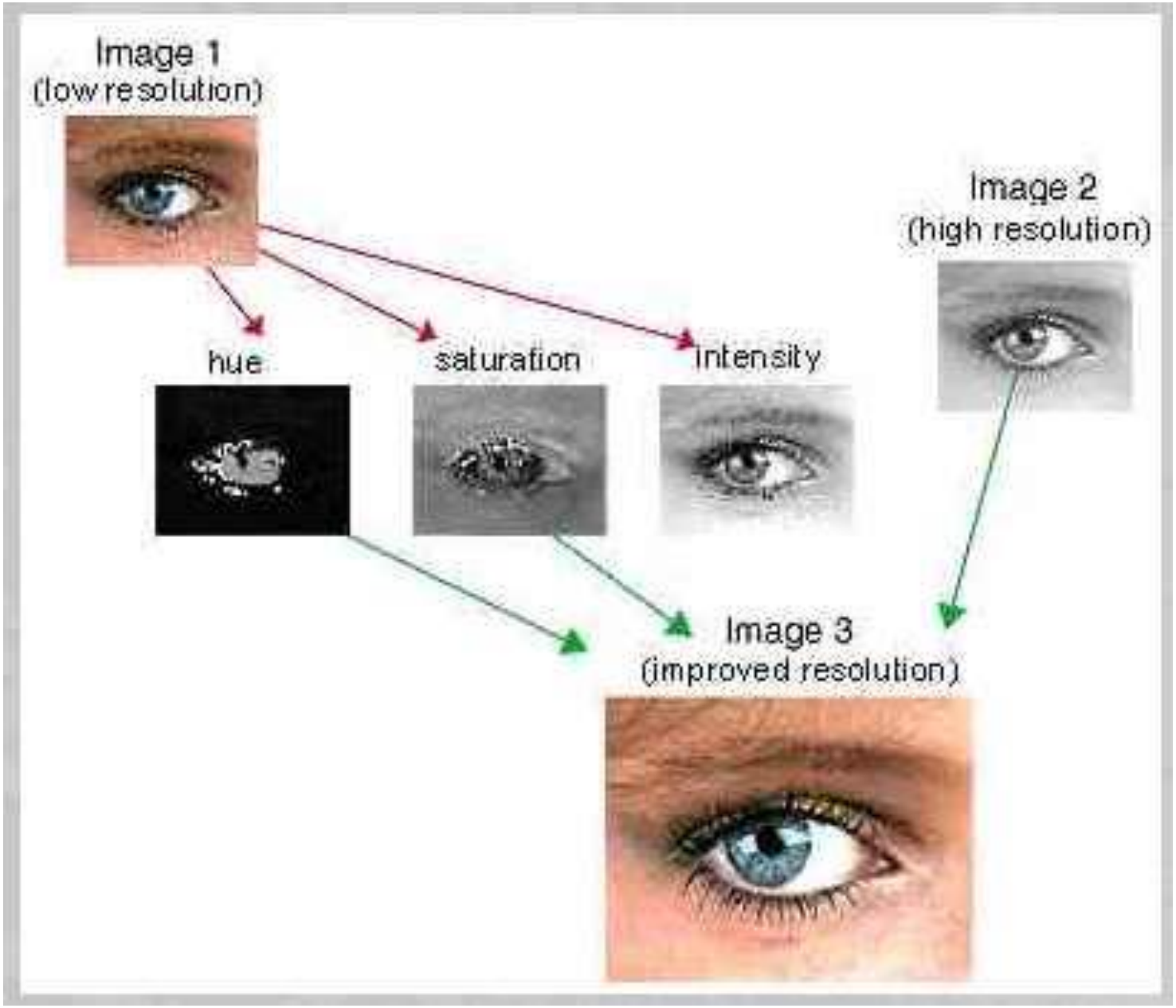
FUSE

Fusing Method

"IHS transformation"
RGB image -> HSI

Hue,Saturation, Intensity

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



http://eoedu.belspo.be/en/guide/fusion.asp?section=3.11.2

fusion of Sentinel 2 classified image plus high-res provincial LiDAR

Marcel Morin mashup, Lost Art Cartography

https://www.facebook.com/lostartcartography