GEOG357, Fall 2022 – sample midterm questions (Oct 11)

A. Multiple Choice (5%)

Which of these (EM spectrum) sections below has the shortest wavelengths ?

a. Near infra-red (NIR)
b. Mid/shortwave-infrared (SWIR)
c. Red
d. Thermal infra-red
e. Green

B. Briefly explain the difference between the two terms listed (5%)

- Supervised versus unsupervised classification

C. Remote sensing terms and concepts (5%)

Which two developments were responsible for the start of the new discipline of 'remote sensing' in the 1960s ?

Transformations in Remote Sensing

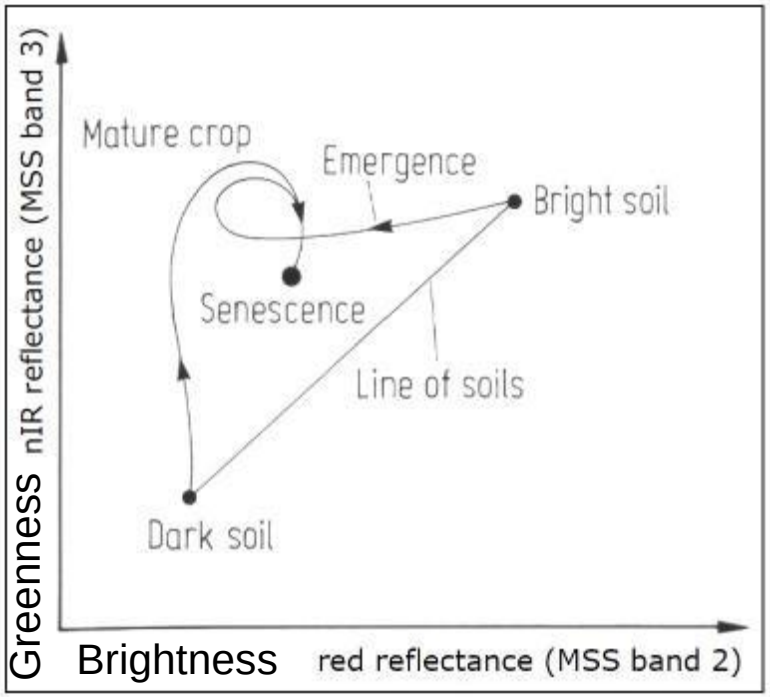
= Converting image bands into secondary channels

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

Tasseled Cap transformation

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 (Kauth and Thomas, 1976)

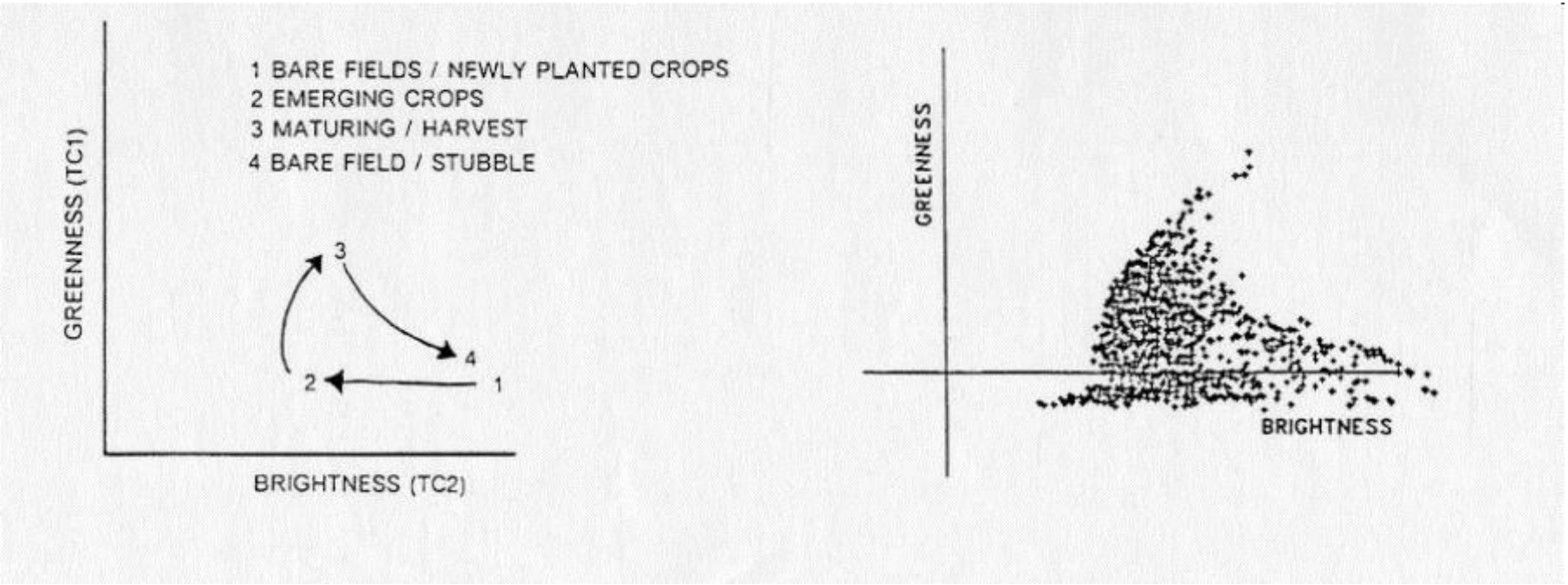
The Tasseled Cap transformation is designed to analyze and map vegetation and urban development changes detected by satellite sensors. (ArcGIS)



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.

Annual sequence of crop variation

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



Tasseled Cap transformation

For each pixel DN, the new channels are weighted by the input bands, e.g.: for 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 NIR / Red ratio)
Yellowness = Green v Red
(“Non-such” = the difference between the 2 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

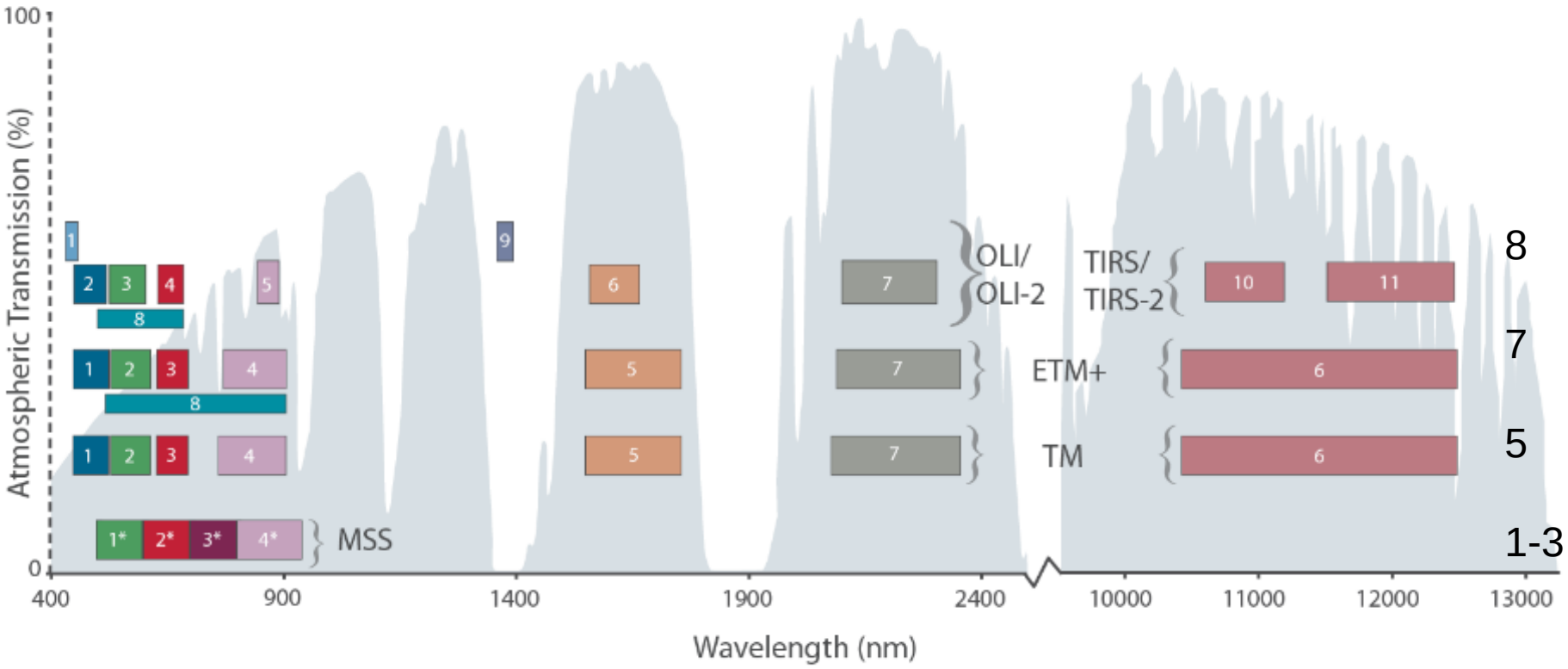
Landsat 8 OLI coefficients

	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**

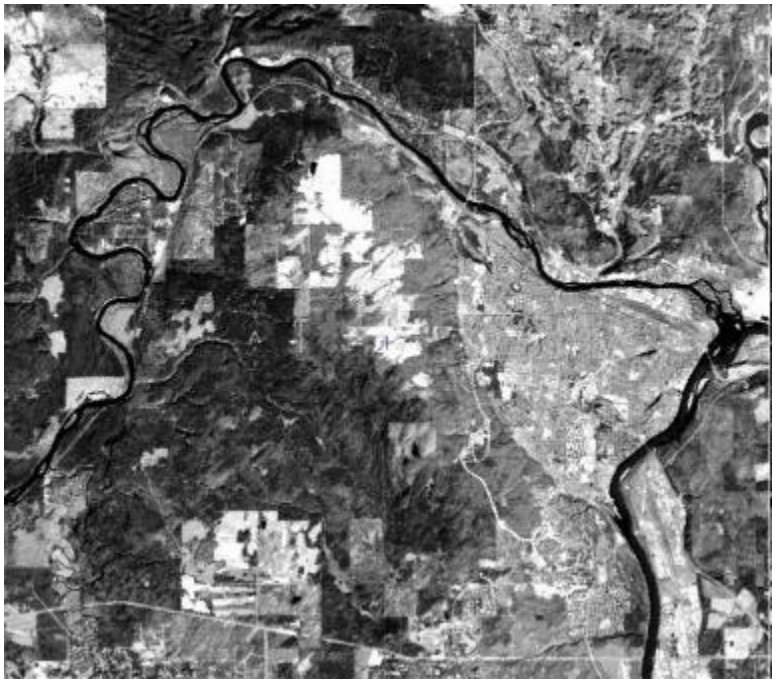
Why are they different at all ? Great exam question ? …. it's too hard – see next

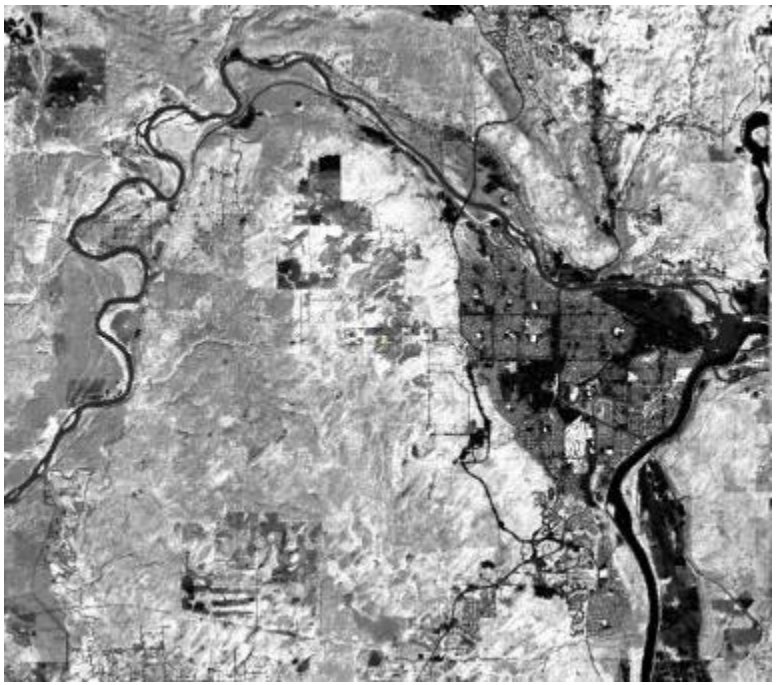
Landsat sensors and band wavelengths

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

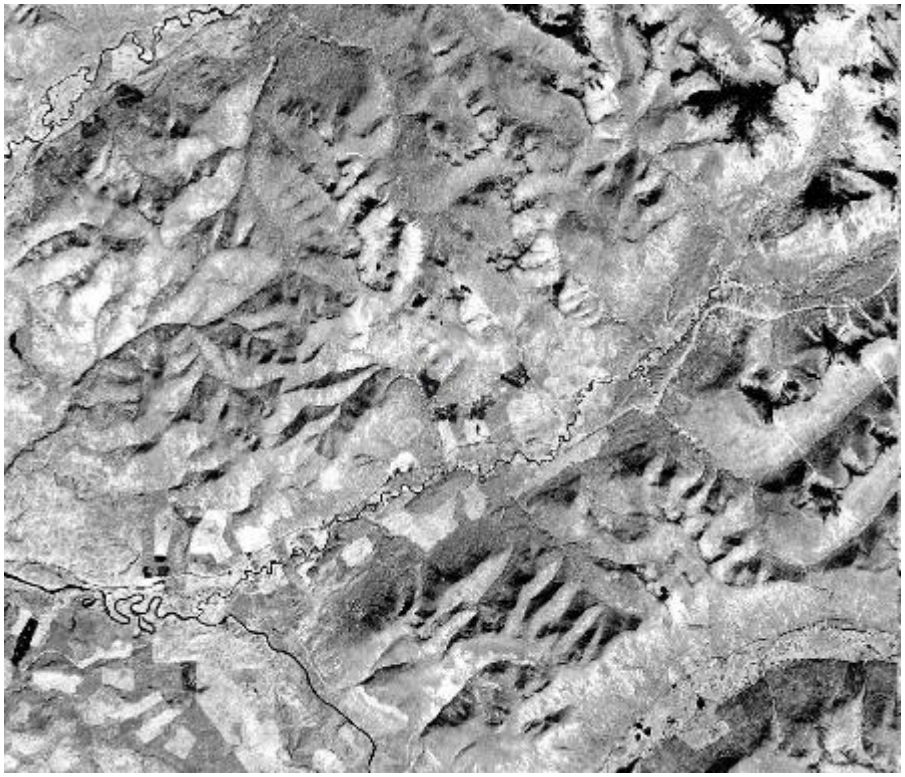
c. **Wetness** – soil / canopy moisture

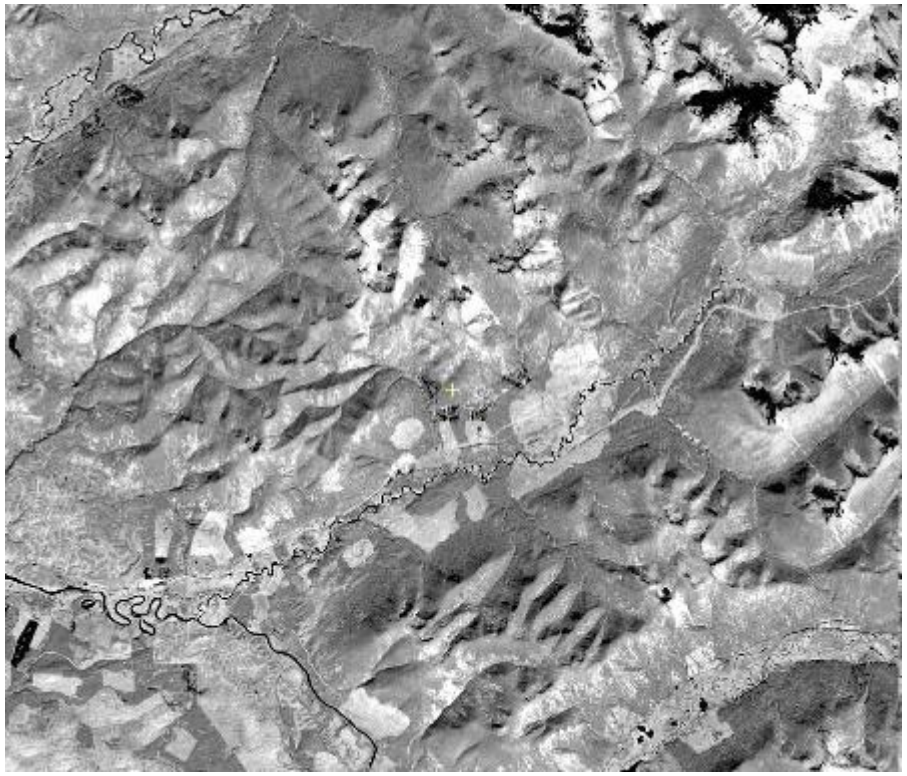
the 3 channels are uncorrelated

These would yield a higher contrast composite but with unfamiliar colours

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.

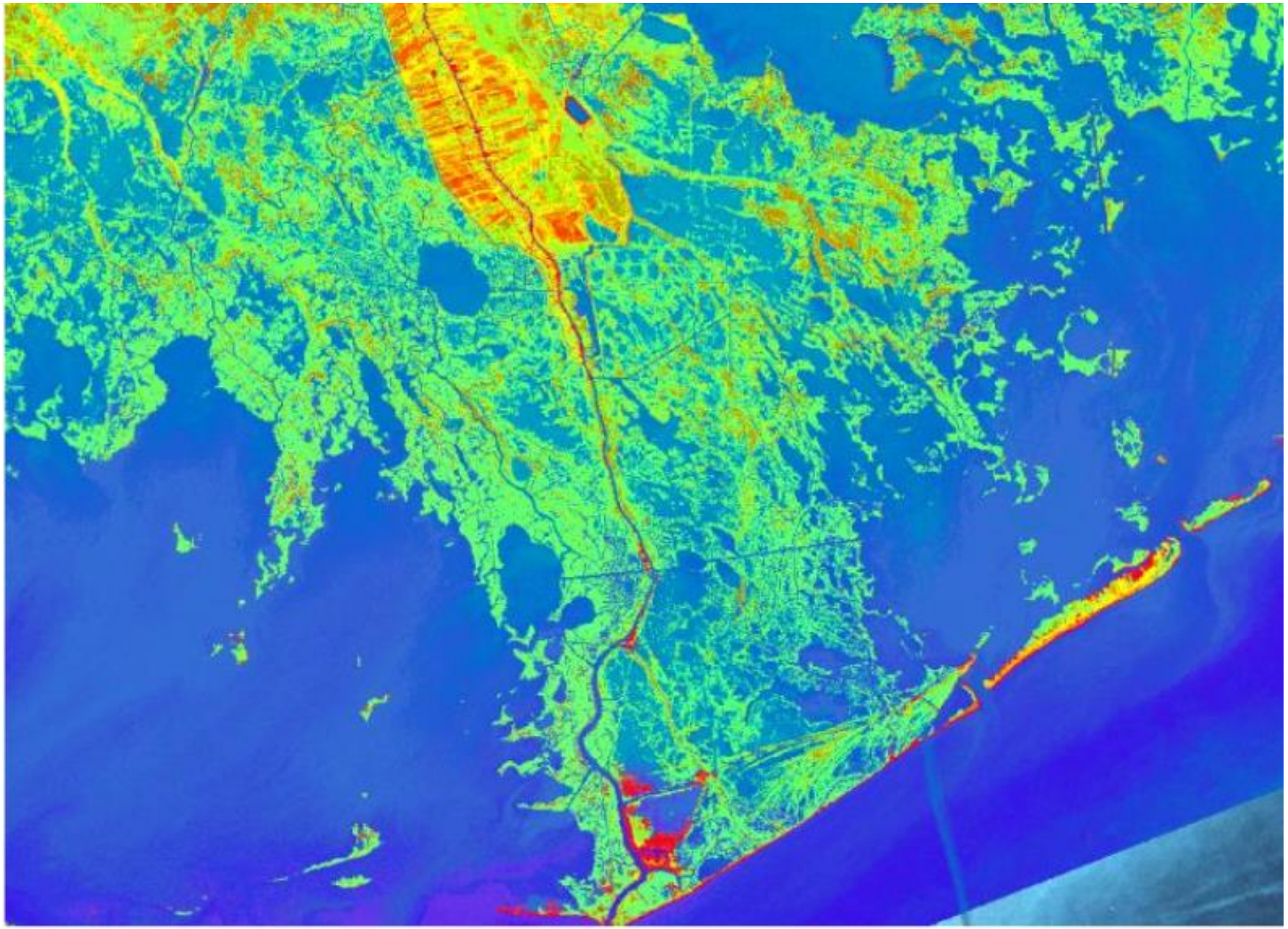


Figure 3. Three-band, 8-bit tasseled cap transformation image of the same Landsat 7 ET

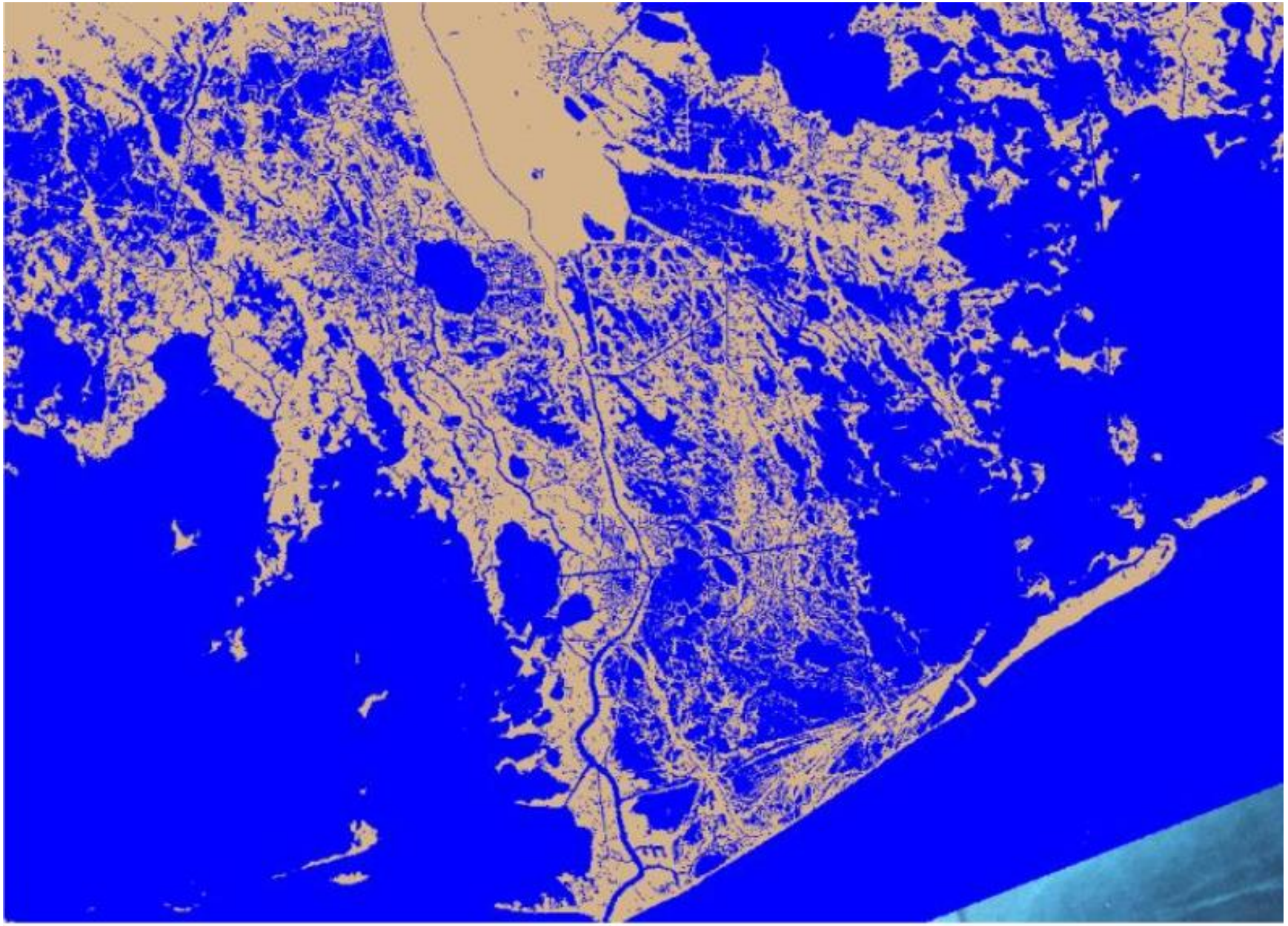


Figure 4. Two-bit raster file of the same Landsat 7 ETM scene showing pixel classificati
(brown) and water (blue).

Reasons to use Tasseled 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**

Principal Components Analysis (PCA)

('Hotelling'- Harold, 1933)

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

Differences with TCA :

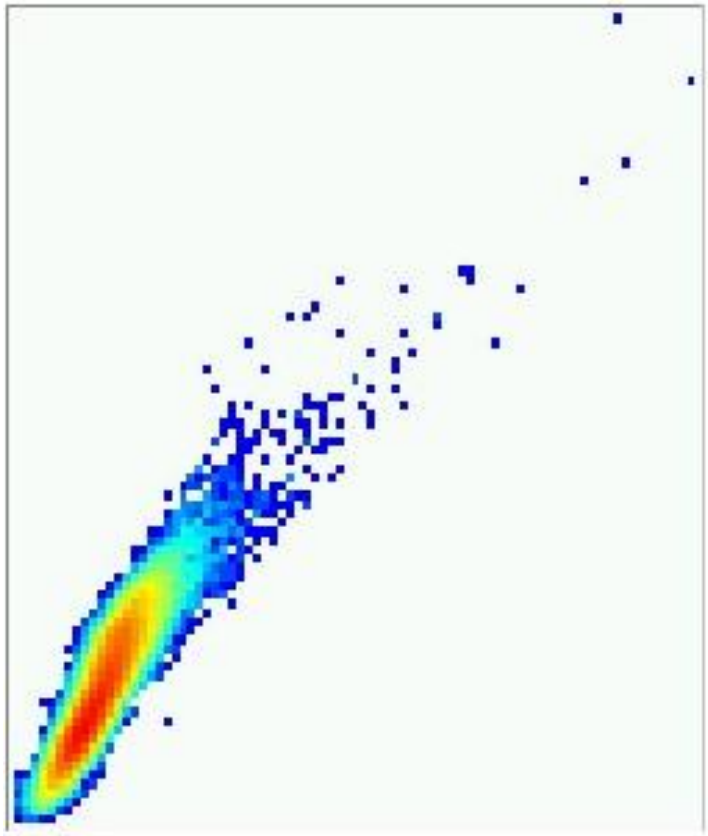
1. PCA transformation is scene specific – while TCA coefficients are 'global'

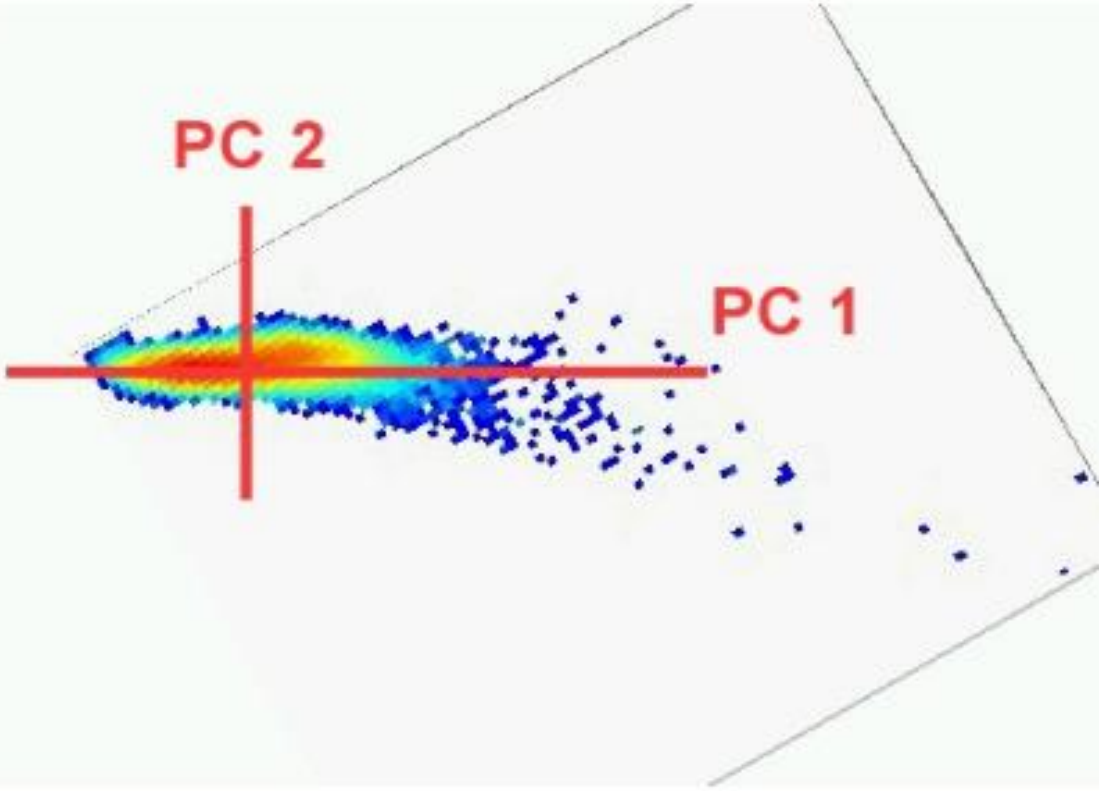
2. TCA creates three new transformed **channels,**
- PCA generates as many as there are input **channels**

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

Note: There is a high correlation between all 'greenness' channel types:
NDVI, 4/3 ratio, TCA greenness, PCA component 2 (usually)

If we plot the pixels of two bands, 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.

PC1= what is explained in both bands (images)
PC2= what is different between them (similar to a band ratio)

PCA consists of :

- **eigenvectors:** the 'loadings' for each band to create new components
- **eigenvalues:** how much variance is explained by each component

Usually the first 3-4 components 'explain' > 95% of all variance

each successive component contains less information / variance

PCA channels (PG 1996 scene)

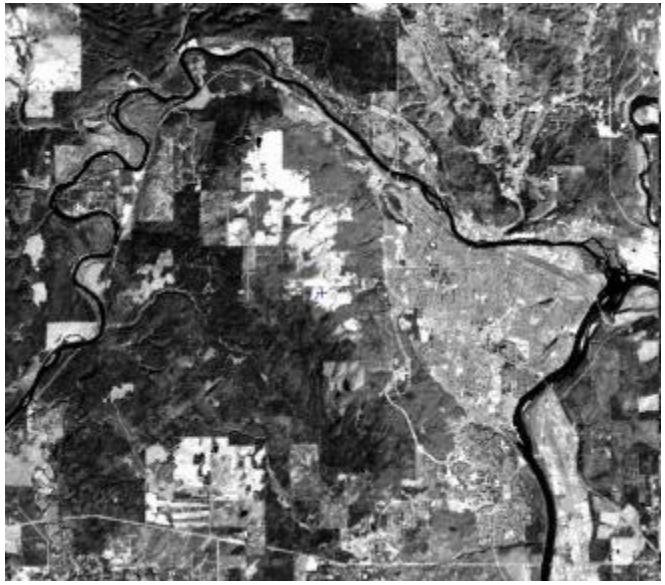
Eigenvectors of covariance matrix (arranged by rows):

	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

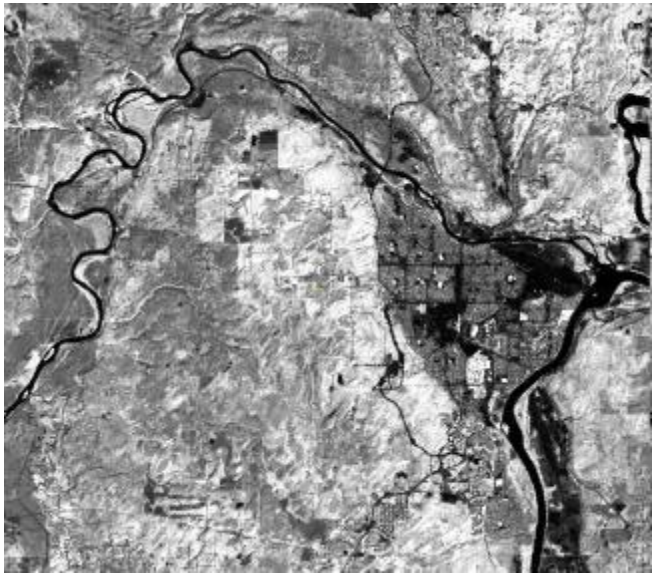
Component
Brightness
Greenness
Swirness / Wetness
Impact of TM6
Band 5 v 7 (SWIR)
Band 1 v 3 (B v R)
Band 2 v 3 (Yellowness)

PCA channels (PG 1996 scene)

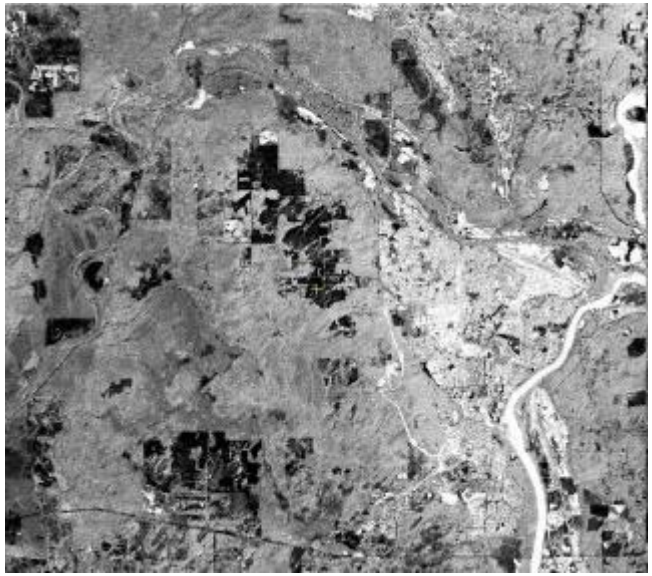
PC1: Brightness



PC2: Greenness



PC3: Swirness / Wetness



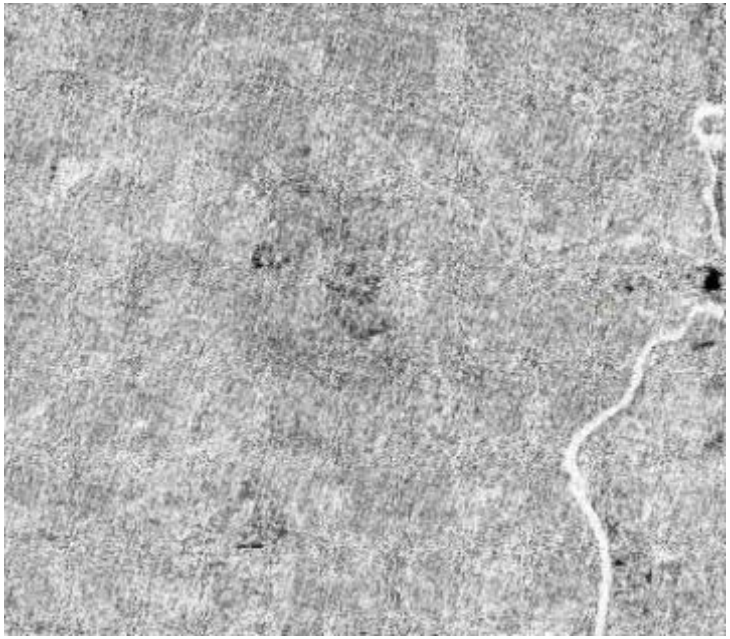
PC components (for PG scene) PC4: TM6, PC5: 5v7, PC6: 1v3, PC7: 2v3

PC4:
TM6
<-

PC5:
5v7
->

PC6:
1v3
<-

PC7:
2v3
->



Principal Components Analysis ('Hotelling'- Harold, 1933)

Why Use PCA ? (reduces multiband dataset) -more than Tassel.. and scene-specific - but are they useful ?

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

PC1 = what is common between images (no change)

PC2 = what is different – between most different sets

PC3 .... = what is another difference … and so on …

PCA – Time series analysis

36 monthly AVHRR NDVI images – for 3 years

= 36 potential components

PC1: average NDVI

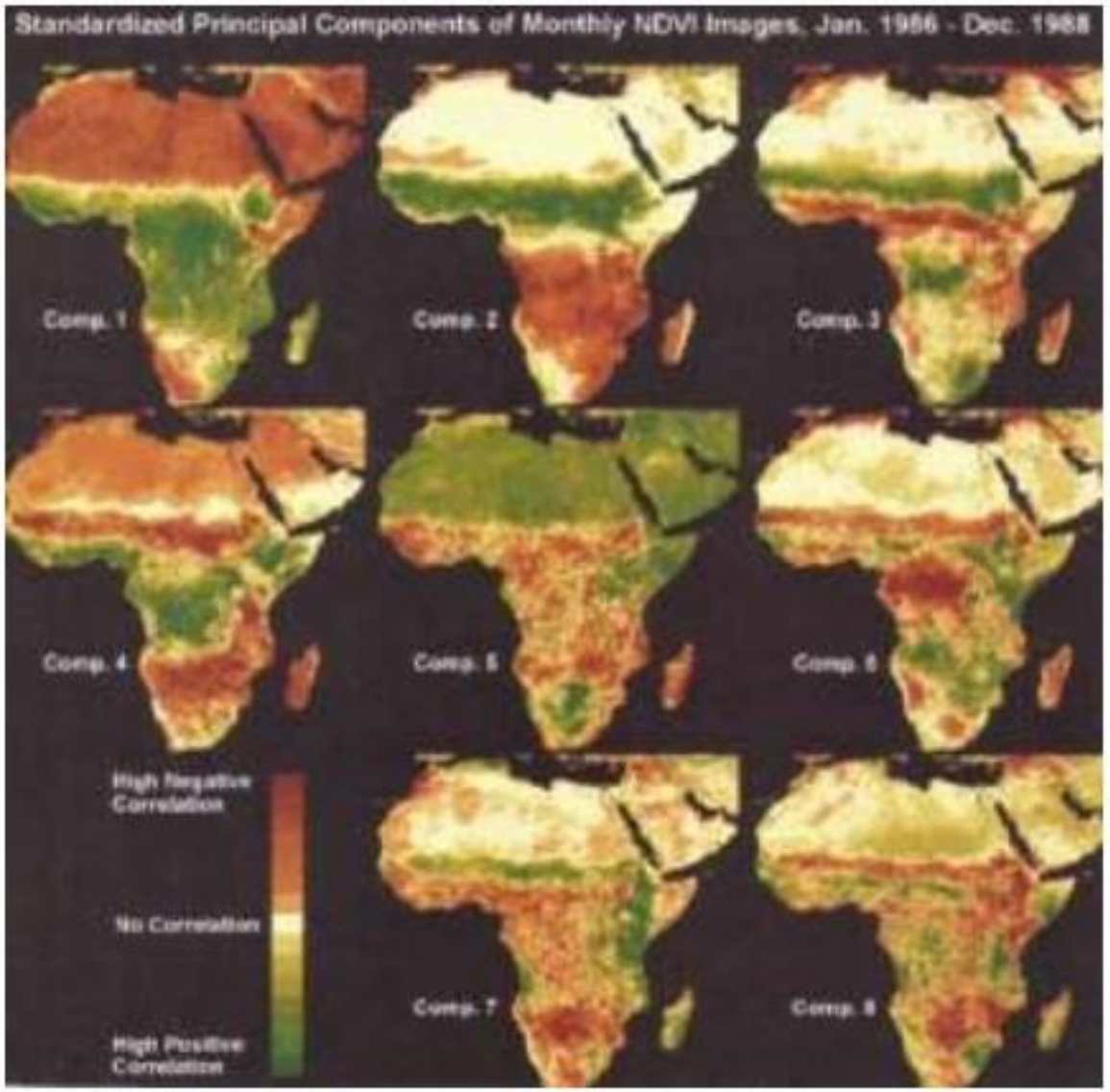
PC2: = seasonal change

PC3: May versus Nov

PC4: Oct /April v Feb/Aug

PC5: apparent NDVI increase due to later time of day (drift)
PC6: NDVI reduction due to forest loss
PC7: impacts of El Nino
PC8 … etc..

Eastman and Fulk, 1993, "Long sequence time series evaluation using standardized principal components" Photogrammetric Engineering and Remote Sensing, 59, 8, (August) 1307-1312.



Decorrelation Stretch: image enhancement 'Catalyst: DECORR'

- **Based on Principal Components Analysis (PCA)**

- **used to Enhance Rock Art Images** By Jon Harman, Ph.D.

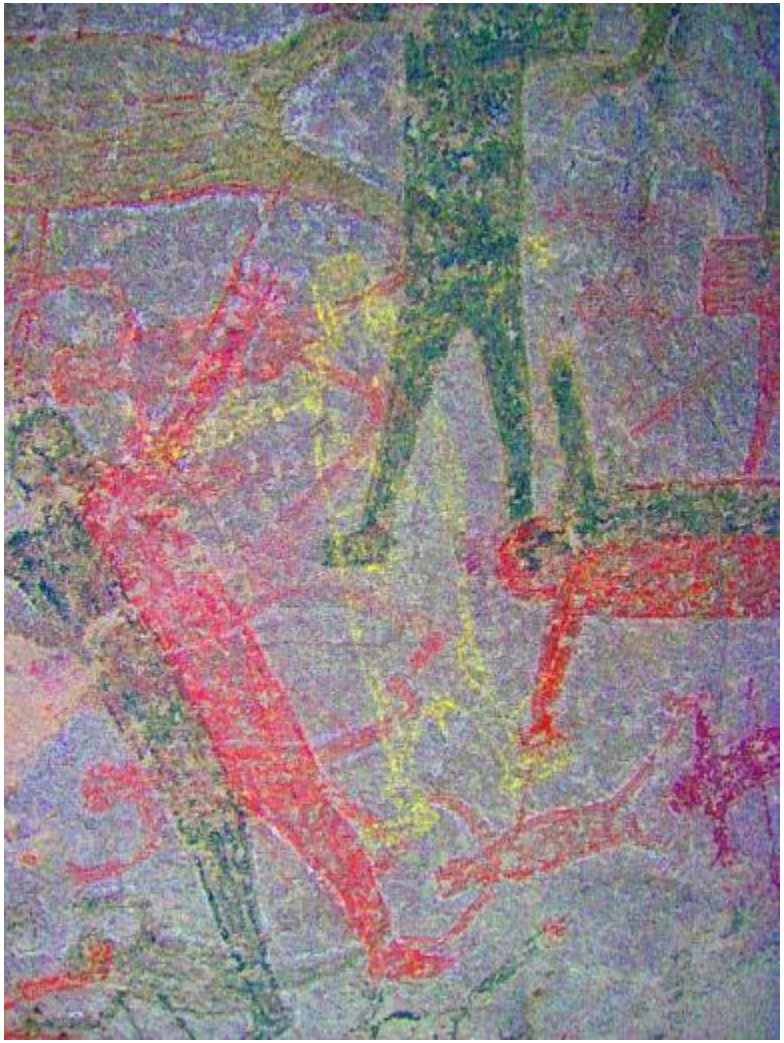


Image fusion -> pansharpening

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

- To create more detail in display

Panchromatic Multispectral Synthetic multispectral

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 TM 5	1984	-	30	x
Landsat ETM+	1999	15	30	
Landsat OLI 8/9	2013	15	30	
SPOT 1-3	1986	10	20	
SPOT 4	1998	10	20	
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]

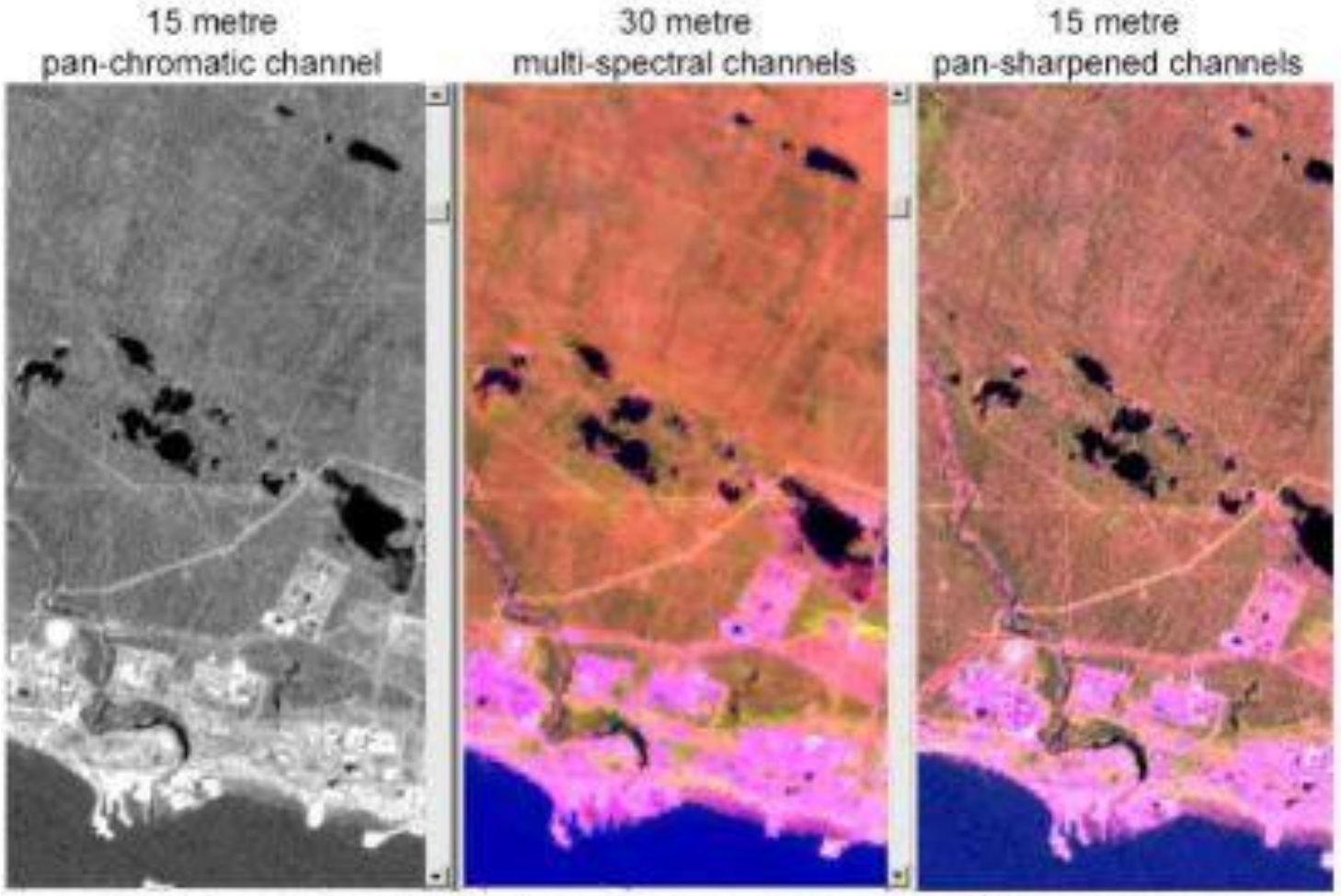
Enhanced Thematic Mapper Plus (ETM+)	Landsat 7	Wavelength (micrometers)	Resolution (meters)
	Band 1	0.45-0.52	30
	Band 2	0.52-0.60	30
	Band 3	0.63-0.69	30
	Band 4	0.77-0.90	30
	Band 5	1.55-1.75	30
	Band 6	10.40-12.50	60 * (30)
	Band 7	2.09-2.35	30
	Band 8	.52-.90	15

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

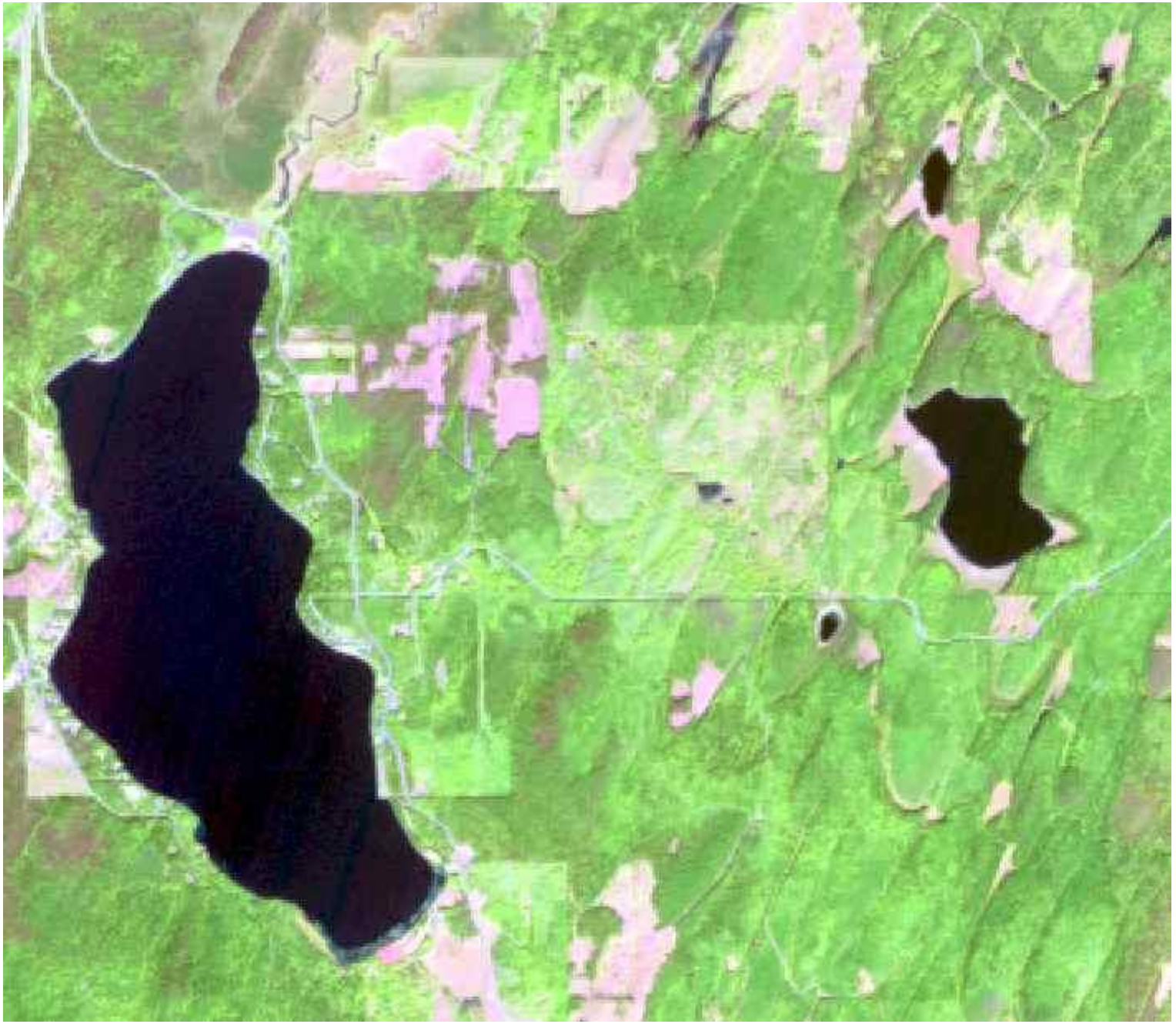
NWT Geomatics imagery

http://www.gnwtgeomatics.nt.ca/RemoteSensing/avhrr/TM7files.asp



This image was ortho-corrected prior to pan-sharpening. 8 bit channels were processed. A simple linear enhancement was made after processing.

SPOT PAN – Tabor Lake 10m



SPOT 20m MS

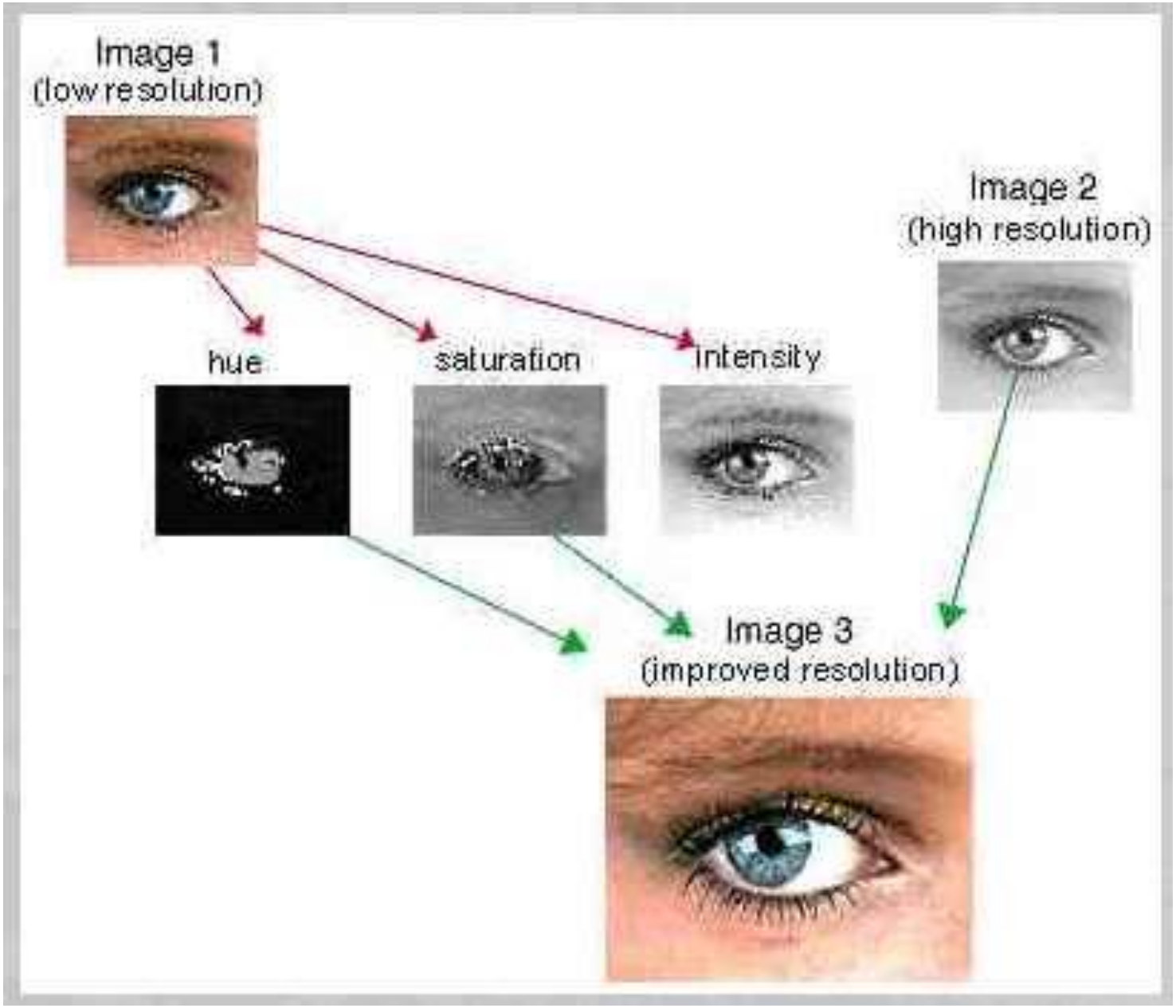
IMGFUSE / PANSHARP

Pansharpening / 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

Sable Island (horses) – fusion of high resolution image plus LiDAR

Marcel Morin mashup, Lost Art Cartography (and the 538 horses survived hurricane Fiona)