Image Transforms

- Single band: spatial domain to frequency domain
- Multiple bands: spectral enhancement
  - The enhancement techniques that require **more than one band** of data.
  - Purposes:
    - extract new bands of data that are more interpretable to the eye (VI, Tasseled Cap)
    - apply mathematical transforms and algorithms (Band ratioing)
    - display a wider variety of information in the three available color guns (R, G, B) (PCA)
    - compress bands of data that are similar (PCA)

Indices

- Band ratioing
- NDVI (Normalized Difference Vegetation Index)

$$\frac{IR - R}{IR + R}$$

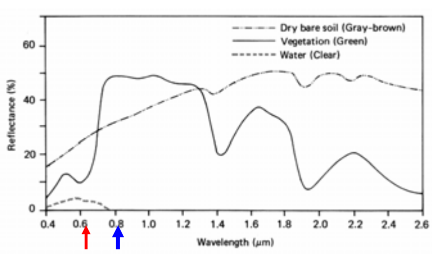


Figure 1.10 Typical spectral reflectance curves for vegetation, soil, and water.

Spectral Properties of Objects

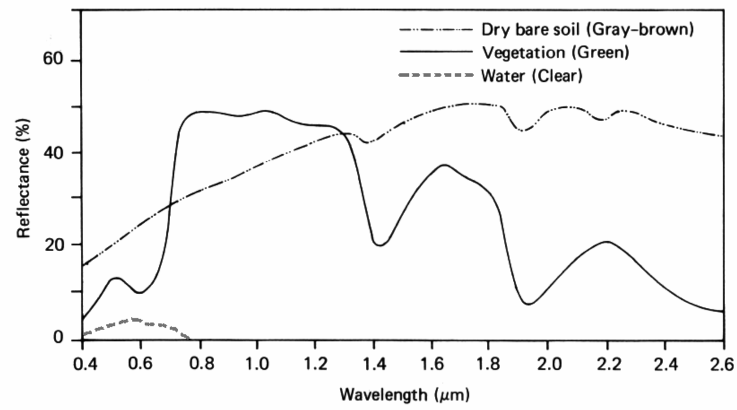
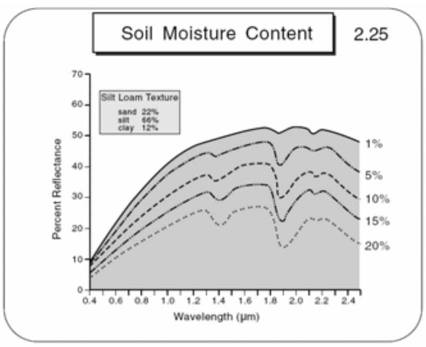
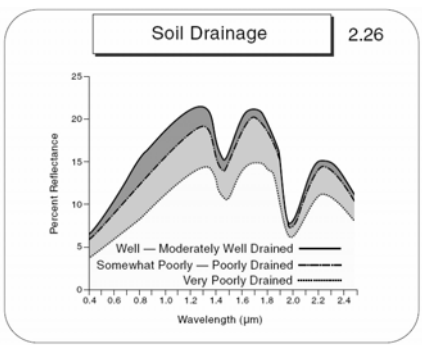


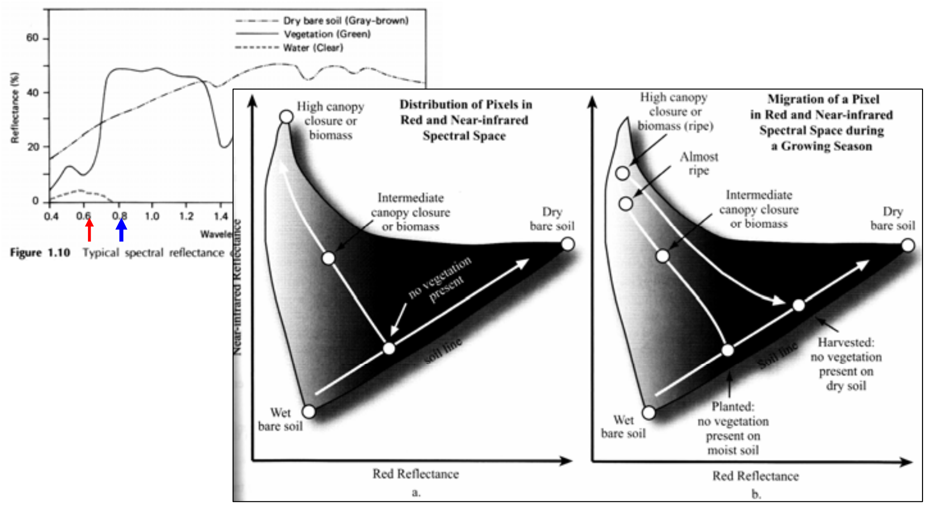
Figure 1.10 Typical spectral reflectance curves for vegetation, soil, and water.

Soil Reflectance Separation

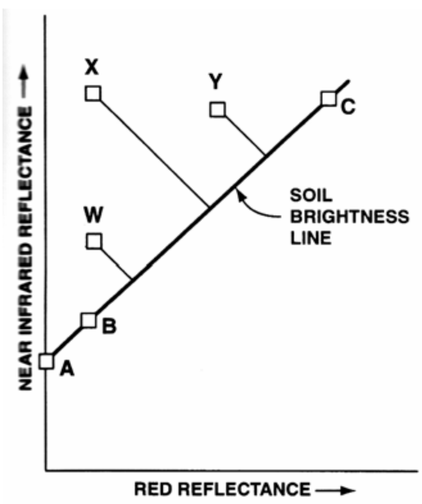




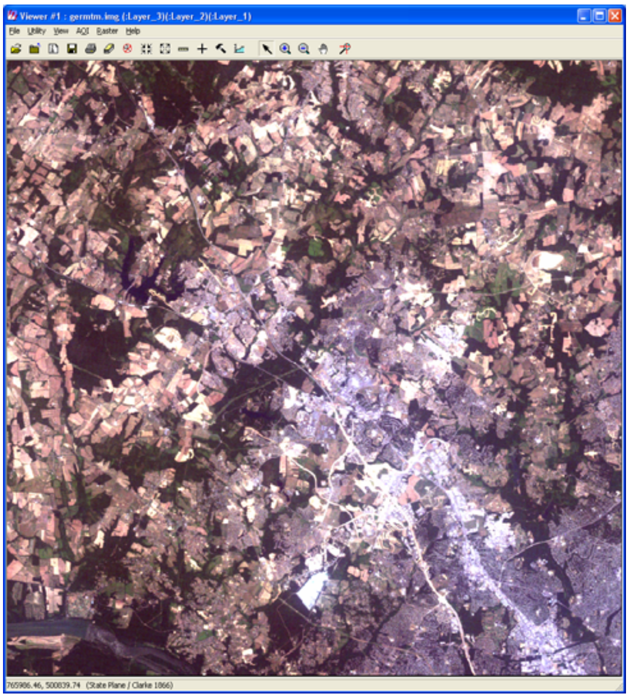
Tasseled Cap Transformation (Spectral Enhancement)



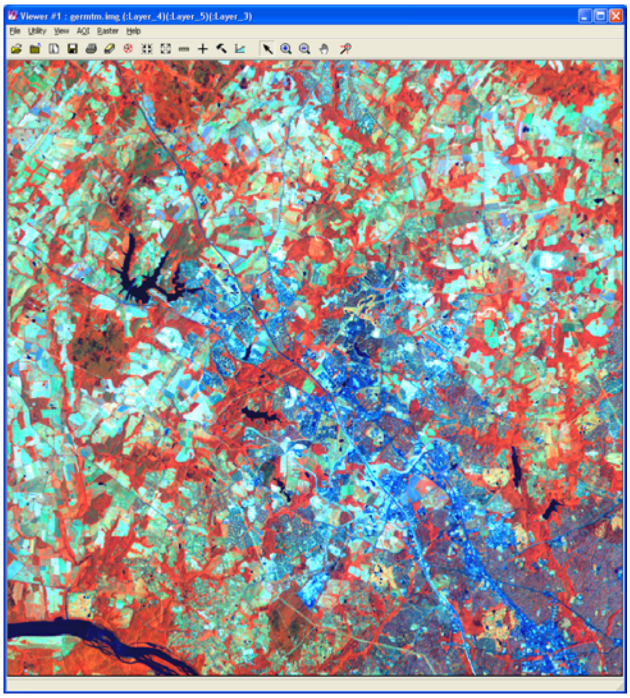
Mixture of Soil & Vegetation Reflectance



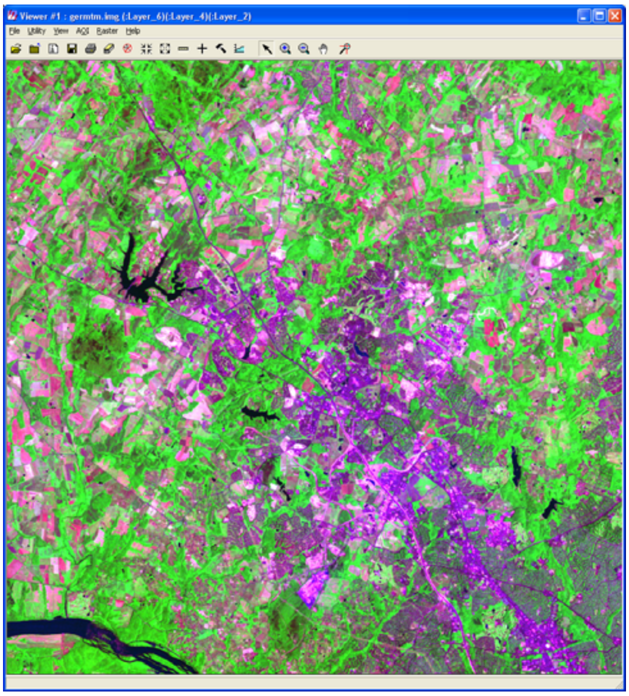
TM
R,G,B = 3,2,1



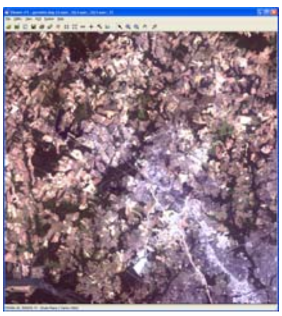
TM
R,G,B = 4,5,3

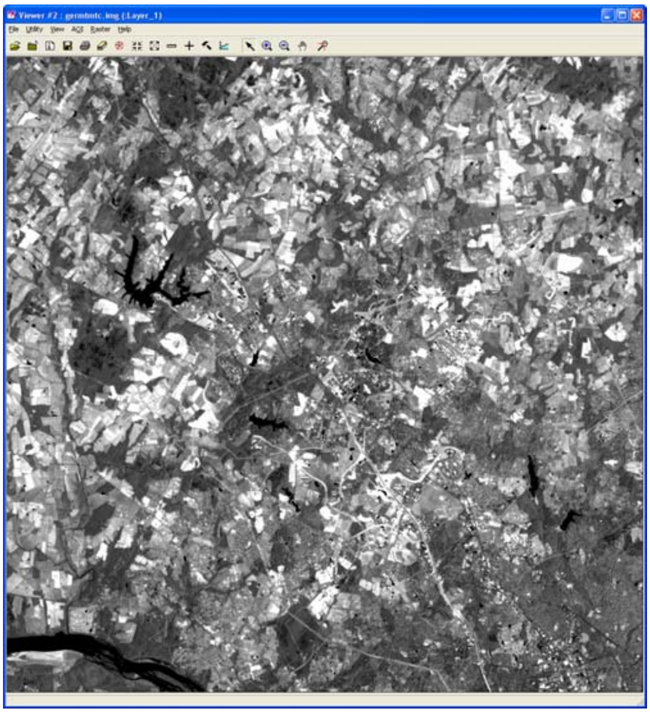


TM
R,G,B = 7,4,2

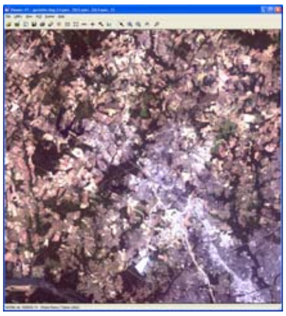


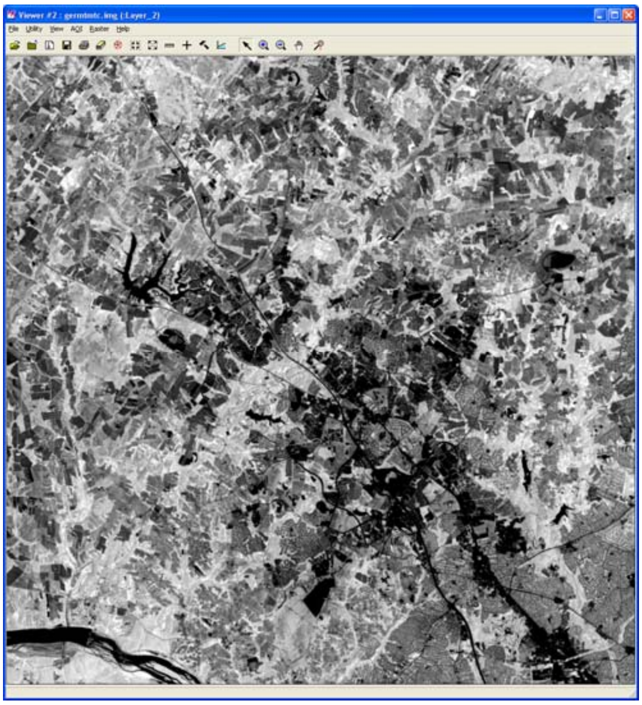
Tasseled Cap:
Brightness



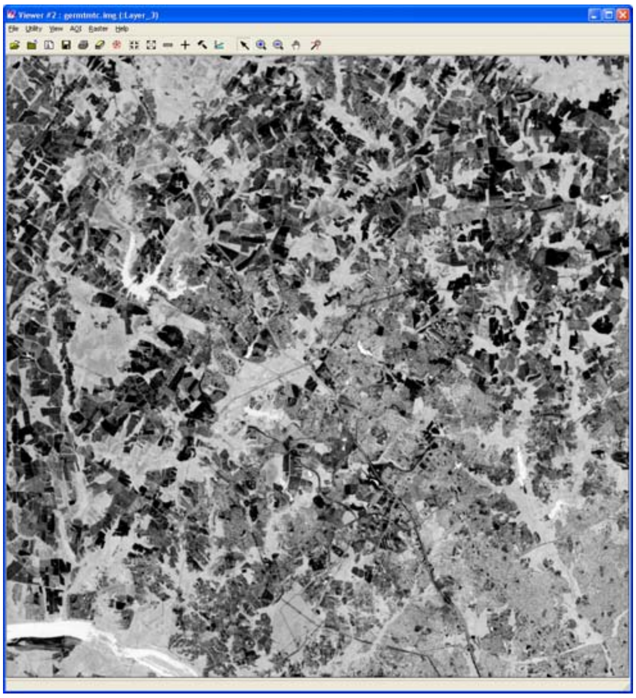


TC:
Greenness

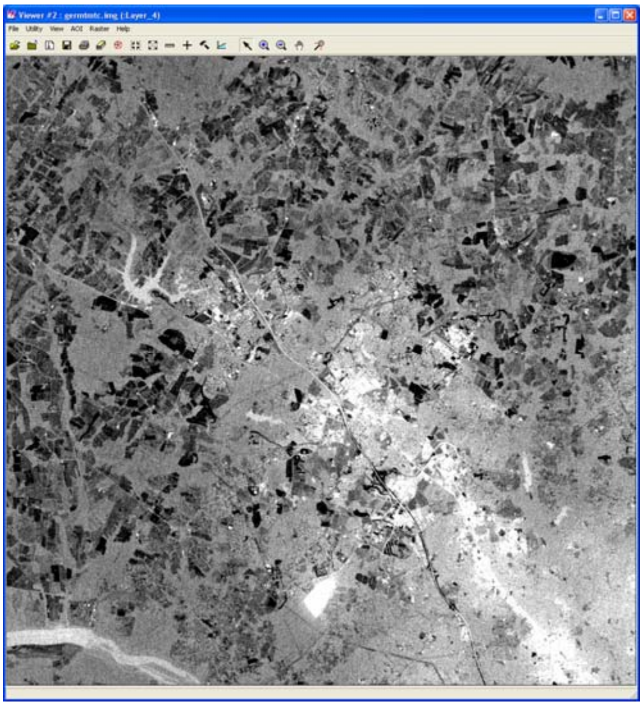


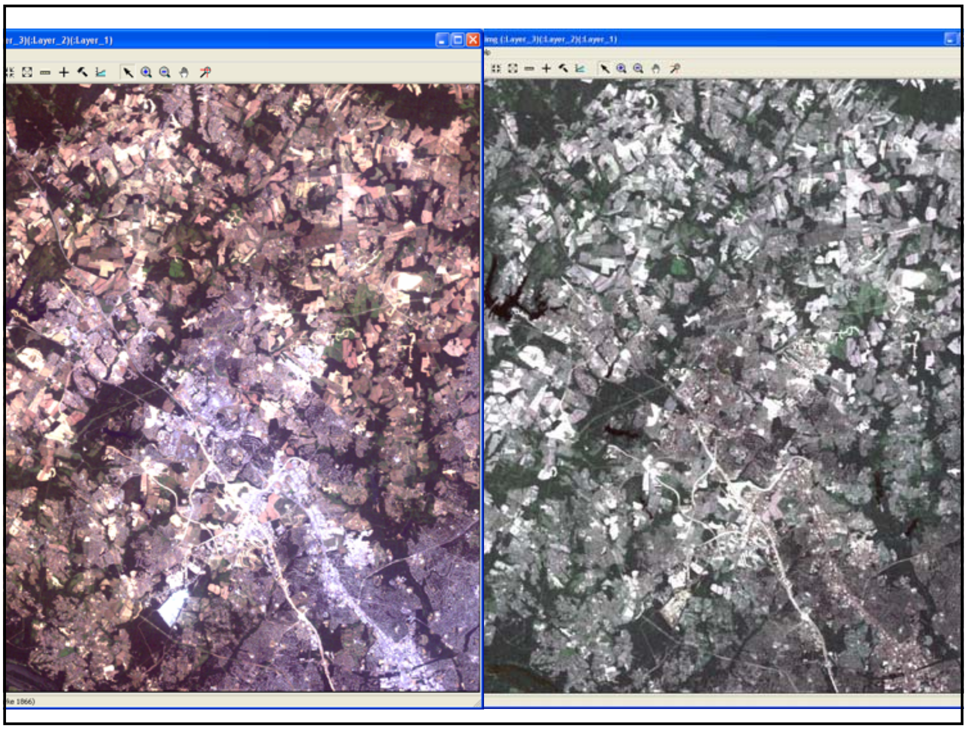


TC:
Wetness



TC:
Haziness





Dehazing Algorithm

- Tasseled Cap Transformation
- Subtracts Haze from the blue band

Brightness = .3037(TM1) + .2793)(TM2) + .4743 (TM3) + .5585 (TM4) + .5082 (TM5) + .1863 (TM7)

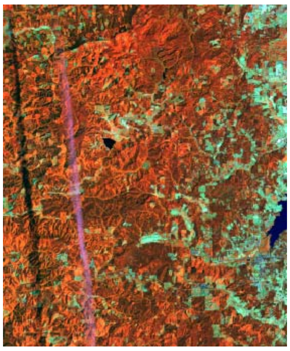
Greenness = -.2848 (TM1) - .2435 (TM2) - .5436 (TM3) + .7243 (TM4) + .0840 (TM5) - .1800 (TM7)

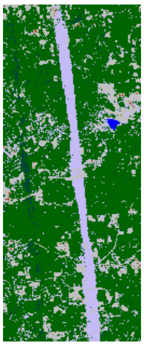
Wetness = .1509 (TM1) + .1973 (TM2) + .3279 (TM3) + .3406 (TM4) - .7112 (TM5) - .4572 (TM7)

Haze = .8832 (TM1) - .0819 (TM2) - .4580 (TM3) - .0032 (TM4) - .0563 (TM5) + .0130 (TM7)

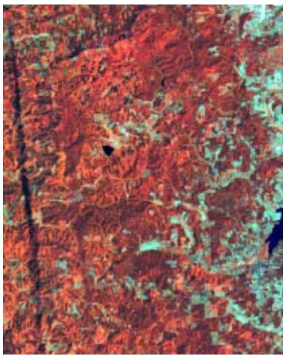
Dehazing

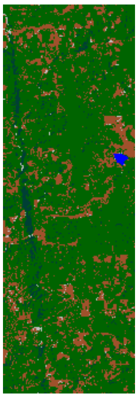
Original





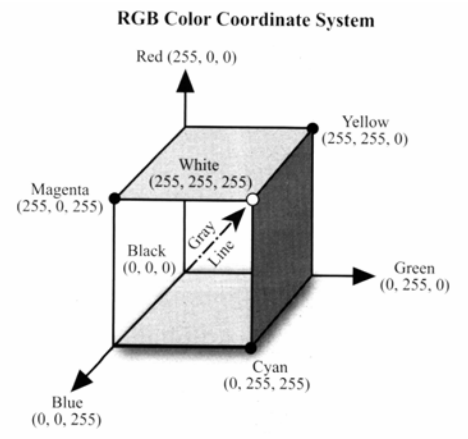
Dehazed



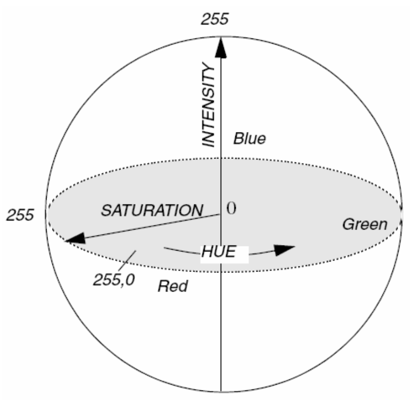


Images produced by B. Beller

RGB / IHS Transform



IHS Color Coordinate System



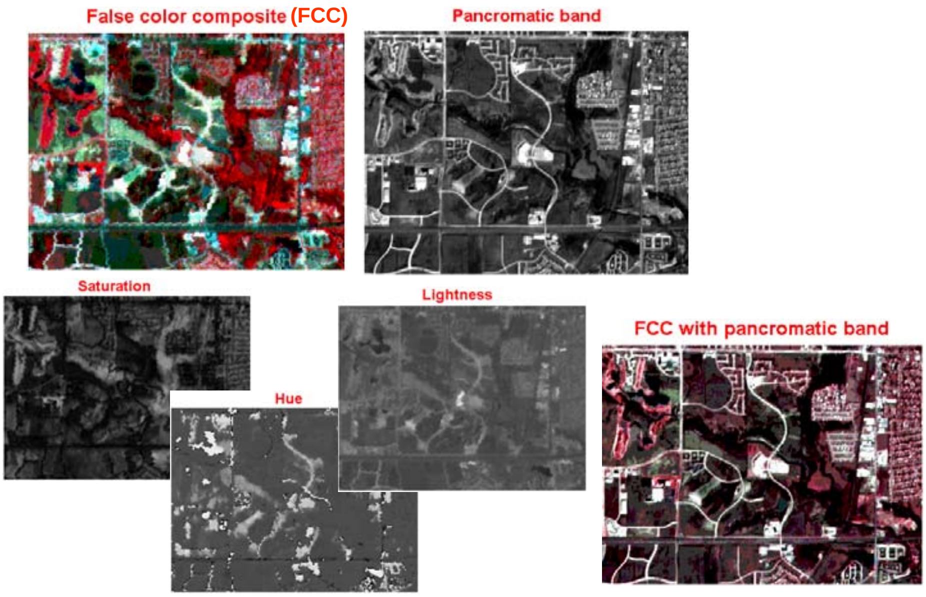
Data Fusion

- Fuse data
  - Resolution merge
    - Merge SPOT 10m pan with 20m multi-spectral
  - Sensor merge
    - Merge Radar intensity with multi-spectral

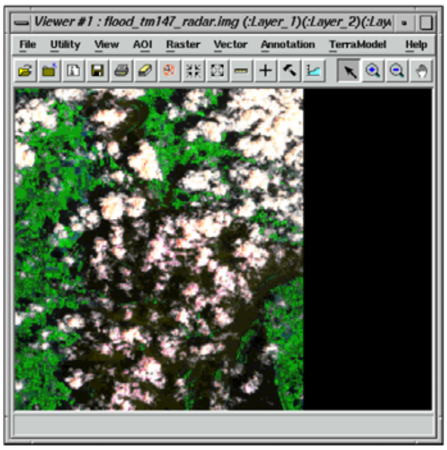
Fusion Procedures

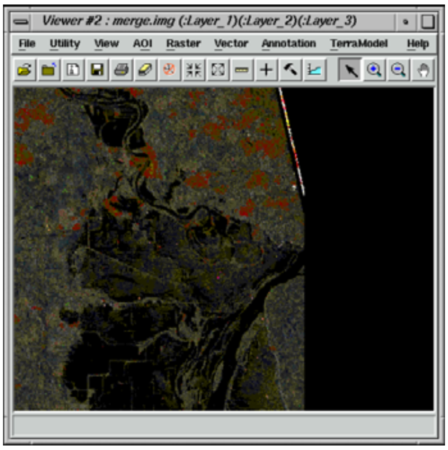
1. Band transformation
   – RGB – IHS
   – PCA, Tasseled Cap
   – Wavelet Analysis
2. Band replacement
3. Band back-transformation

SPOT Resolution Merge - IHS



TM multi-spectral merged with Radar image





Principal Components Analysis (aka Factor Analysis)

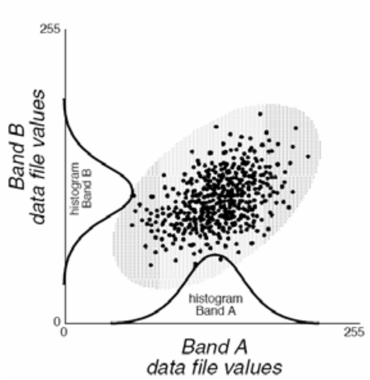
- Capture the main factors & reduce data redundancy
- Based on covariance matrix
  - Covariance measures the tendencies of data file values in the same pixel, but in different bands, to vary with each other, in relation to the means of their respective bands.

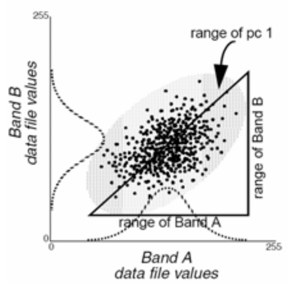
$$var(X) = \frac{\sum_{i=1}^{n}(X_i - \bar{X})(X_i - \bar{X})}{(n-1)} \qquad cov(X,Y) = \frac{\sum_{i=1}^{n}(X_i - \bar{X})(Y_i - \bar{Y})}{(n-1)}$$

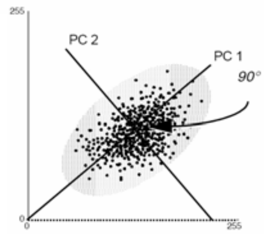
http://csnet.otago.ac.nz/cosc453/student_tutorials/principal_components.pdf

Principal Components Analysis (PCA)

Figure 6-18: Two Band Scatterplot







Covariance Matrix

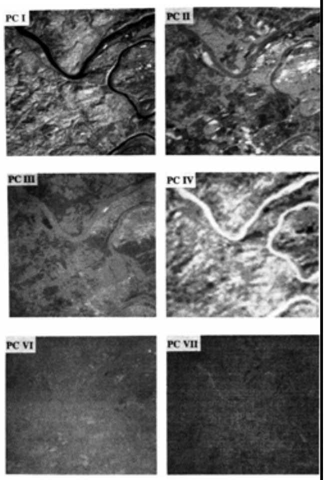
TABLE 10.1. Similarity Matrices for Seven Bands of a TM Scene

	Covariance matrix						
	1	2	3	4	5	6	7
1.	48.8	29.2	43.2	50.0	76.5	0.9	44.9
2.	29.2	20.3	29.0	48.6	65.4	1.5	32.8
3.	43.2	29.0	46.4	59.9	101.2	0.6	53.5
4.	49.9	48.6	59.9	327.8	325.6	12.4	104.32
5.	76.5	65.4	101.2	325.6	480.5	10.2	188.5
6.	0.9	1.5	0.6	12.5	10.2	14.0	1.1
7.	45.0	32.8	53.5	104.3	188.5	1.1	90.8
	Correlation matrix						
	1	2	3	4	5	6	7
1.	1.00						
2.	0.92	1.00					
3.	0.90	0.94	1.00				
4.	0.39	0.59	0.48	1.00			
5.	0.49	0.66	0.67	0.82	1.00		
6.	0.03	0.08	0.02	0.18	0.12	1.00	
7.	0.67	0.76	0.82	0.60	0.90	0.02	1.00

PCA of Landsat TM

TABLE 10.2. Results of Principal Components Analysis of Data in Table 10.1

	Component						
	I	II	III	IV	V	VI	VII
				Eigenvectors			
% var.:	82.5%	10.2%	5.3%	1.3%	0.4%	0.3%	0.1%
EV:	848.44	104.72	54.72	13.55	4.05	2.78	0.77
	0.14	0.35	0.60	0.07	–0.14	–0.66	–0.20
	0.11	0.16	0.32	0.03	–0.07	–0.15	–0.90
	0.37	0.35	0.39	–0.04	–0.22	0.71	–0.36
	0.56	–0.71	0.37	–0.09	–0.18	0.03	–0.64
	0.74	0.21	–0.50	0.06	–0.39	–0.10	0.03
	0.01	–0.05	0.02	0.99	0.12	0.08	–0.04
	0.29	0.42	–0.08	–0.09	0.85	0.02	–0.02
				Loadings			
Band 1	0.562	0.519	0.629	0.037	–0.040	–0.160	–0.245
Band 2	0.729	0.369	0.529	0.027	–0.307	–0.576	–0.177
Band 3	0.707	0.528	0.419	–0.022	–0.659	–0.179	–0.046
Band 4	0.903	–0.401	0.150	–0.017	0.020	0.003	–0.003
Band 5	0.980	0.098	–0.166	0.011	–0.035	–0.008	–0.001
Band 6	0.144	–0.150	0.039	0.969	0.063	0.038	–0.010
Band 7	0.873	0.448	–0.062	–0.033	0.180	0.004	–0.002



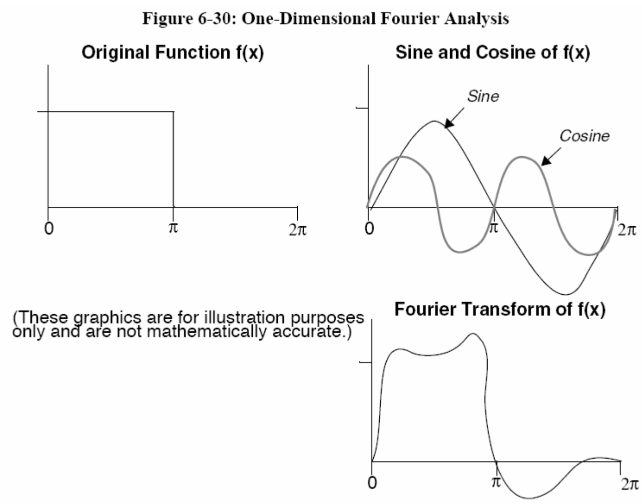
PC I: NIR, II: Visible, III: Vis-B, IV: Temperature

Calculating Components

- Component A

  $A = C_1X_1 + C_2X_2 + C_3X_3 + C_4X_4$
- Component coefficients
  - $C_1=0.35$, $C_2=-0.08$, $C_3=0.36$, $C_4=0.86$
- BV of input bands
  - $X_1=28$, $X_2=29$, $X_3=21$, $X_4=54$
- What is the BV of component A?

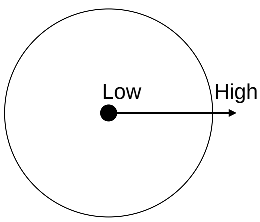
Fourier Transformation

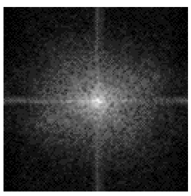


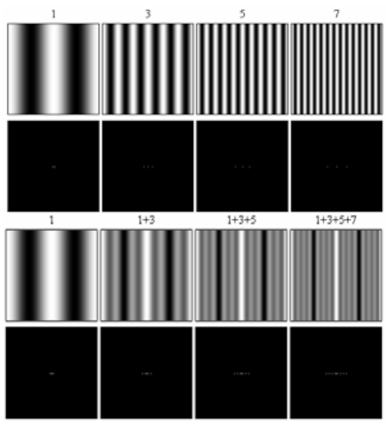
Sinusoids

Image Domains

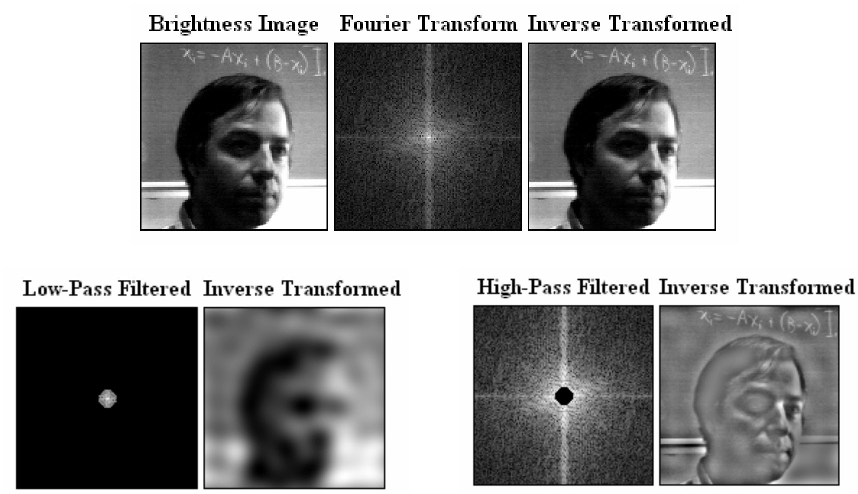
- Spatial domain (2D images)
- Spectral domain (Feature space plots, scatterplots)
- Frequency domain (Fourier Transformation)



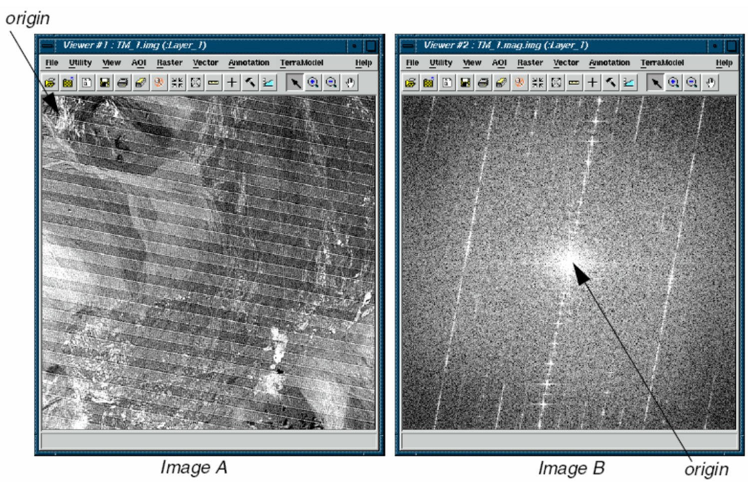




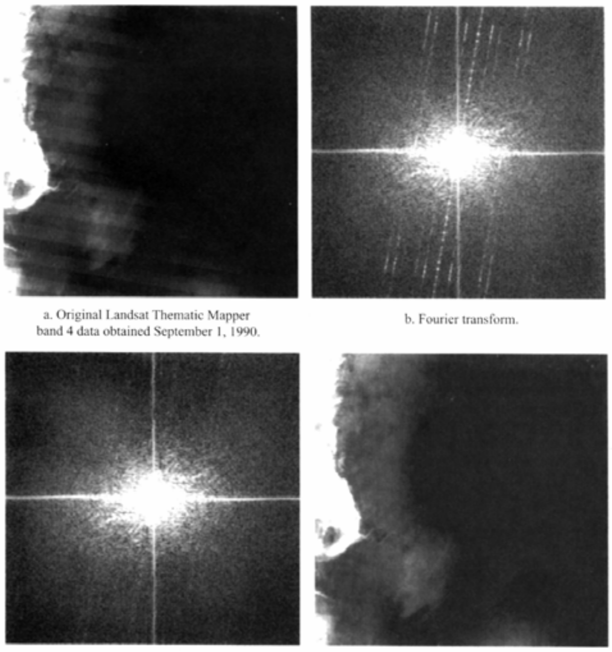
Fourier Filtering



Fourier Analysis (http://cns-alumni.bu.edu/~slehar/fourier/fourier.html)



Application of a Fourier Transform to Landsat Thematic Mapper Data of an Area Near Al Jubail, Saudi Arabia to Remove Striping



a. Original Landsat Thematic Mapper band 4 data obtained September 1, 1990.

b. Fourier transform.

c. Interactively cleaned Fourier transform.

d. Corrected Landsat Thematic Mapper band 4 data.

Wavelet Transform

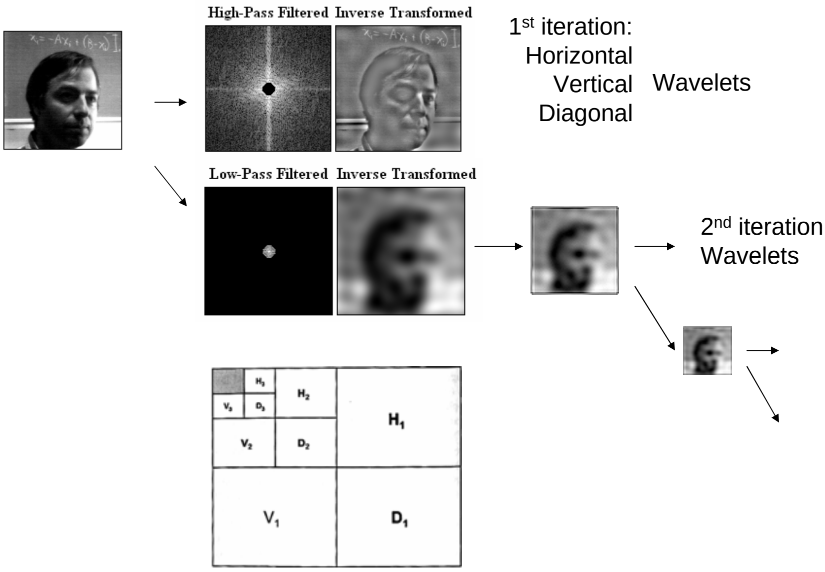


Figure 63: Wavelet Resolution Merge