Wed. Mar. 28, 2018

- Ch. 8 Digital Image Processing
  Remaining topics including
  - Image Correction/Calibration
  - Digital Filtering
  - Principal Component Analysis

- Lab Projects for final two weeks of lab

3 Divisions of Image Processing

- Image Restoration
  - Corrects for instrumental “problems”, producing “true” image
- Image enhancement
  - Simple operations to highlight info of interest
- Information extraction
  - Convert image into information about surface

Image Restoration

- "Photometric" corrections
  - Correct periodic line striping (16 detectors / scan in TM)
  - Correct for atmospheric scattering
  - Filter random noise (could consider this "enhancement")
  - Calibrate data (book doesn't discuss this)
    - Reflectance for "in-sunlight" images
    - Radiance ($W\ m^{-2}\ \mu m^{-1}\ str^{-1}$) for thermal emission

- "Geometric" corrections
  - Restore line offsets, replace bad lines by interpolation, correct scan or camera distortions

Image Enhancement

- Contrast enhancement
- Density slicing
- Edge enhancement
- Form digital mosaics
- Transform (Intensity, Hue, Saturation)
- Merge data sets (upcoming lab)
- Create synthetic stereo images from topography information or multiple looks

Information Extraction

- Image Ratios (to extract composition info.)
- Band Depth Ratios (to estimate mineral abundance)
- Temperature, thermal inertia modeling
- Change detection (to look for variability)
- Principle-components analysis
- Multispectral classification

- More complex math operations such as:
  - NDVI (Normalized Digital Vegetation Index)

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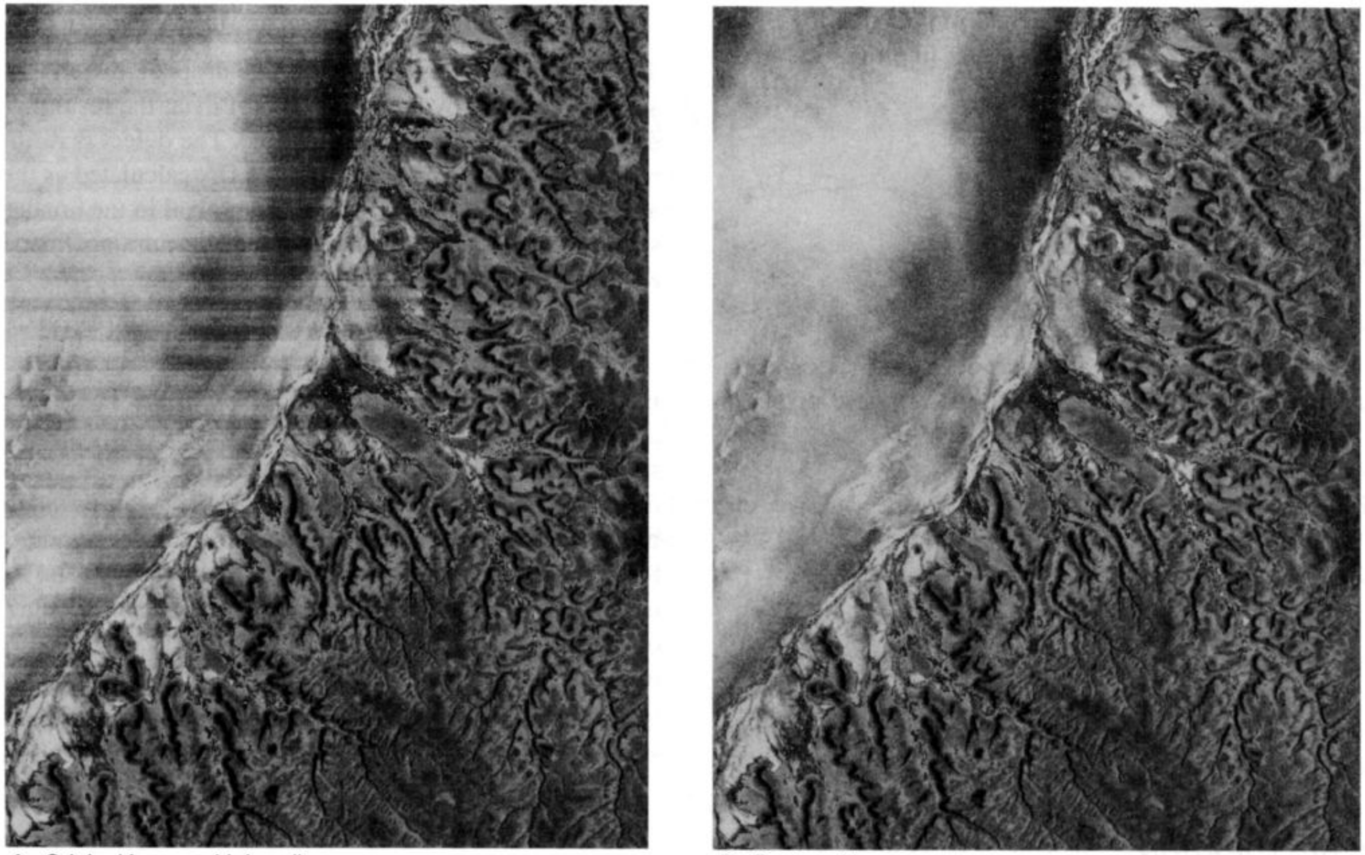
TM Striping



A. Original image with banding.

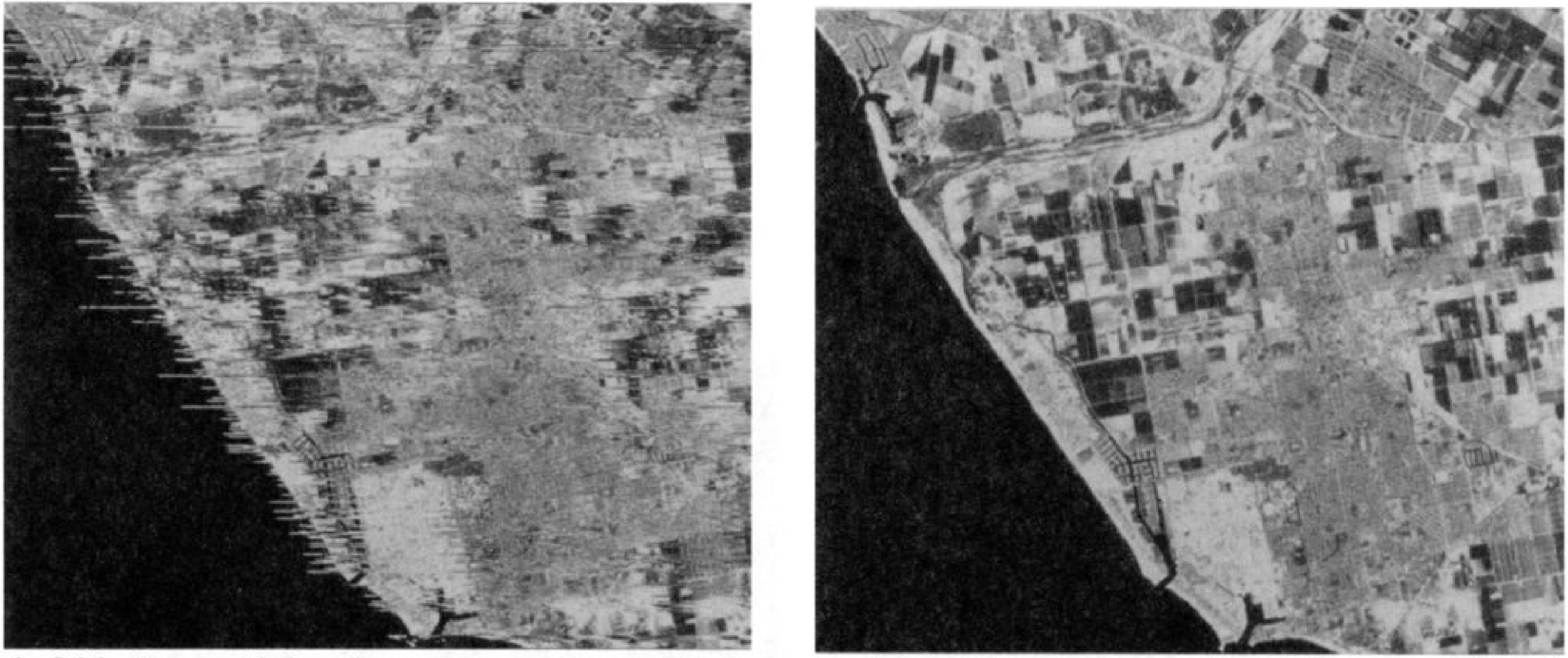
B. Restored image.

Figure 8-6 Restoring banding on a Landsat TM image of the Red Sea coast of Yemen.

From our text by Sabins

- TM really has 16 detectors / band, recording 16 pixels per cross-scan
- Different (and varying) sensitivities of 16 detectors result in repeated "stripe" pattern
- More prominent in older Landsat data – better corrected in newer data

TM Line Offsets



A. Original image with line offsets.

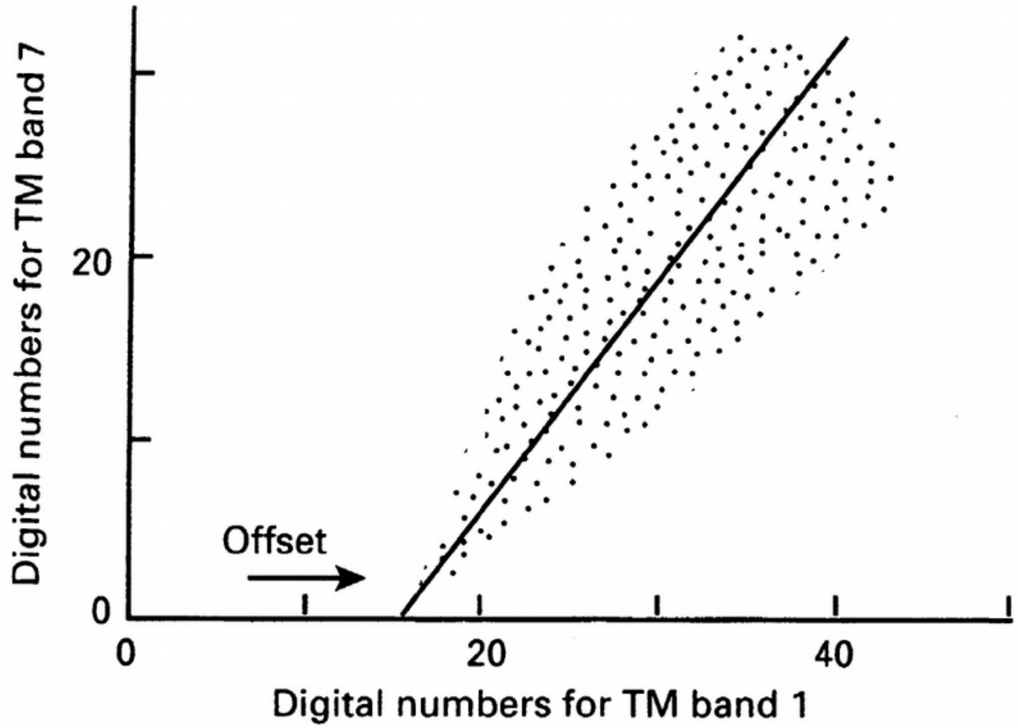
B. Restored image.

Figure 8-7 Restoring offset scan lines. Landsat TM band 4 image of Oxnard, California.

From our text by Sabins

- Transmission (or mirror scan errors) can shift lines, or groups of them
- Examining location of “linear” features like coastline or roads can provide offsets
- Again – newer Landsat data has fewer problems

Atmospheric Scattering

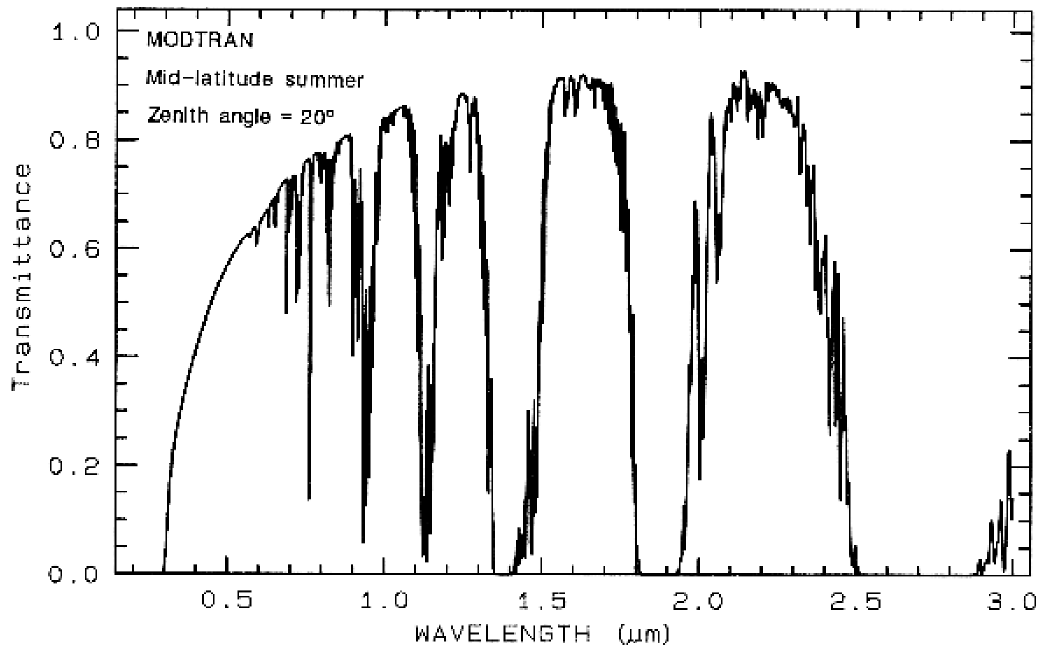


A. Plot of TM band 7 versus band 1 for an area with shadows. Offset of the line of least-squares fit along band 1 axis is caused by atmospheric scattering in that band.

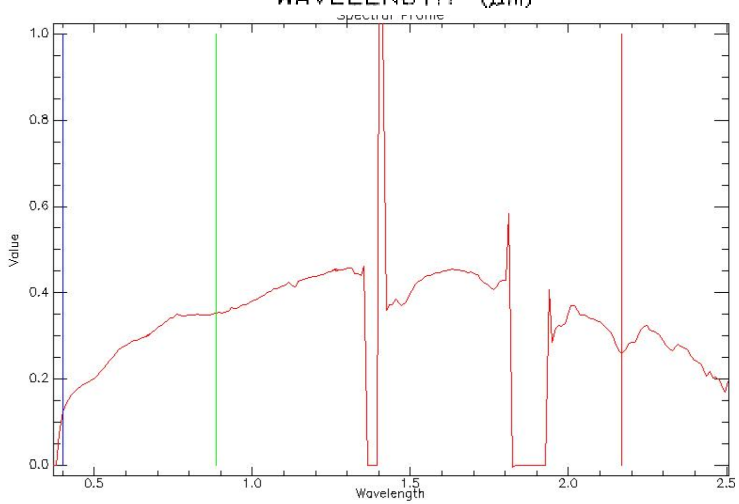
- Worst at short wavelengths (TM Band 1)
- Some fraction of light lost from all regions of image
- "Uniformly" added into all pixels, producing offset.
- Percent effect is greatest for what should be dark (shadowed) regions

From our text by Sabins

Atmospheric Absorption

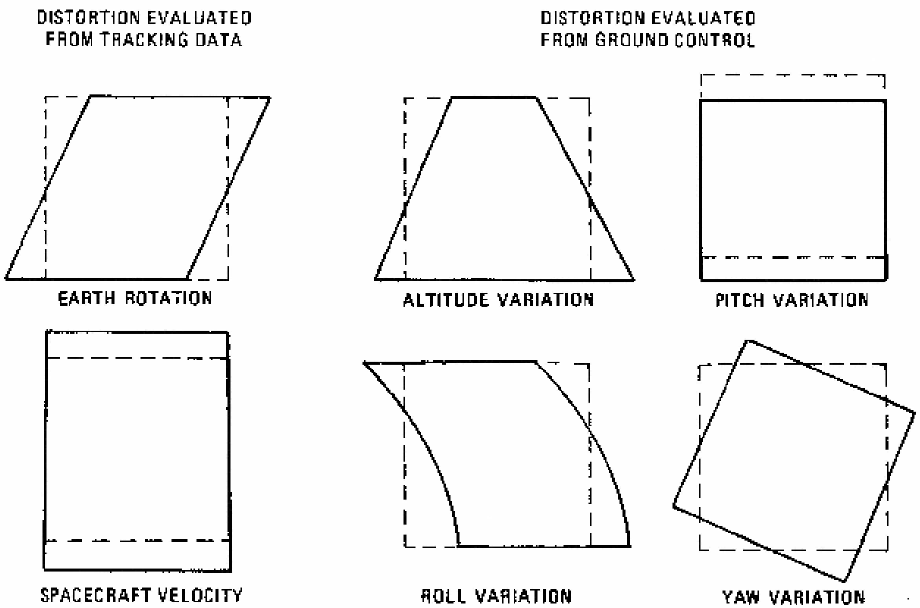


- Divide actual spectrum by transmission curve for atmosphere
- In regions where transmission is ~0, get 0/0 so very noisy

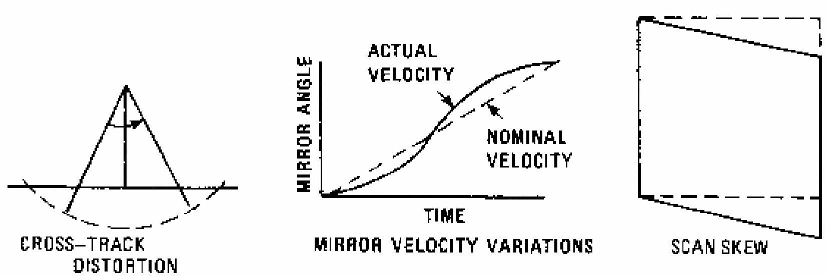


Corrected spectra from Lab 8 (Goldfield NV – AVIRIS)

Geometric Distortions



A. Nonsystematic distortions. Dashed lines indicate shape of distorted image. Solid lines indicate shape of restored image.



B. Systematic distortions.

Figure 8-10 Geometric distortions of Landsat images. From Bernstein and Fernyhough (1975, Figure 3).

- Systematic distortions usually corrected in Landsat data before images released
- Nonsystematic distortions can remain

From our text by Sabins

Distortion Correction

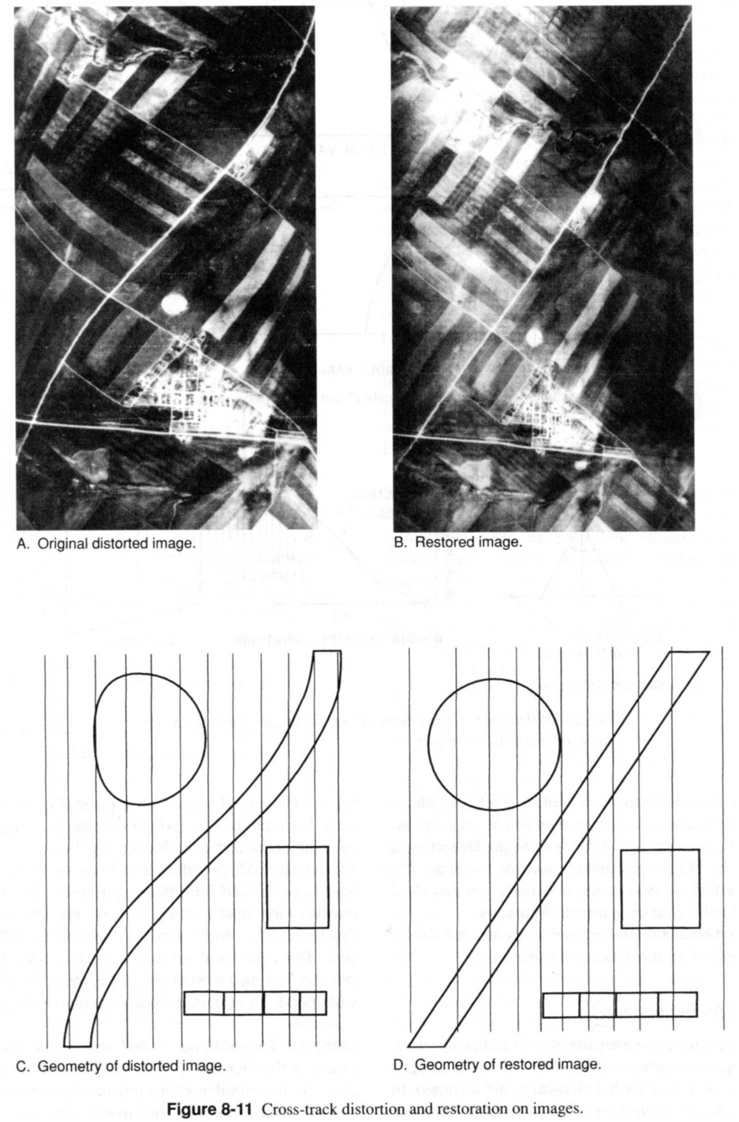
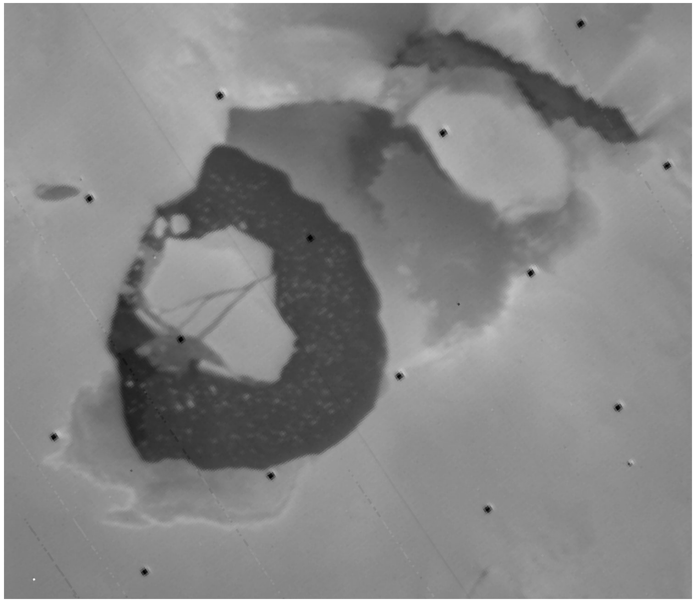


Figure 8-11 Cross-track distortion and restoration on images.



- Can correct distortion using known shape of regular (linear?) features
- Fiducial (reseau) marks sometimes superposed on original images

From our text by Sabins

Typical Intensity Calibration with Modern Cameras

- Subtract "dark frame" exposure taken with shutter closed,
  to eliminate electronic offset and also electrons that "leak" into the detector pixels over time.

$$I_{\mathrm{Calibrated}} = \frac{I_{\mathrm{Raw}} - I_{\mathrm{Dark}}}{I_{\mathrm{Flat}} - I_{\mathrm{Dark}}}$$

- Divide image by "flat field" exposure of uniform brightness source, to correct for sensitivity variations among the pixels.

$$R = I_{\mathrm{Calibrated}} / I_{Solar}$$

where I_{Solar} is expected signal from an albedo = 1 surface.

- "Non-linear" detectors can require more complicated corrections

- To produce "reflectance", divide by expected solar reflected flux from an albedo=1 surface.

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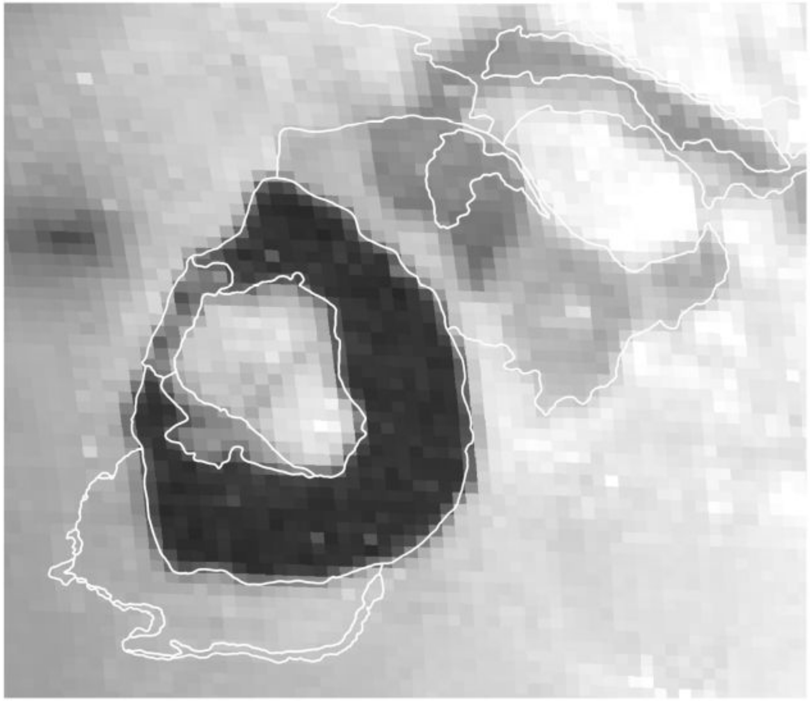
Filtering



40	60	50	40	50
40	0	40	90	60
40	60	60	40	50

Replace the 0 and the 90 by the average of the 9 around that location: 43 and 53

Can implement "threshold" replacement.

Sabins pg. 261

Sharpening

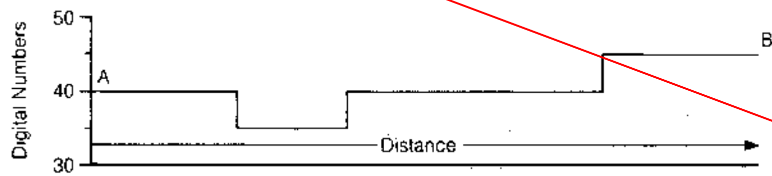
0	-1	0
-1	4	-1
0	-1	0

	40	40	40	40	35	35	35	40	40	40	40	40	40	40	45	45	45	45
	40	40	40	40	35	35	35	40	40	40	40	40	40	40	45	45	45	45
A●	40	40	40	40	35	35	35	40	40	40	40	40	40	40	45	45	45	45 ● B
	40	40	40	40	35	35	35	40	40	40	40	40	40	40	45	45	45	45

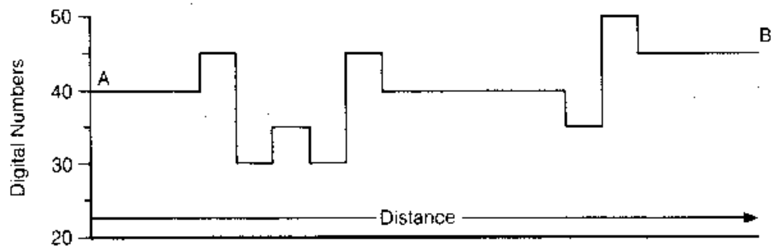
A. Original data and Laplacian filter kernel.

		40	40	45	30	35	30	45	40	40	40	40	40	35	50	45	45	45
A●		40	40	(45)	30	35	30	45	40	40	40	40	40	35	50	45	45	45 ● B
		40	40	45	30	35	30	45	40	40	40	40	40	35	50	45	45	45

B. Enhanced data.



C. Profile of the original data.



D. Profile of the enhanced data.

Figure 8-16 Nondirectional edge enhancement using a Laplacian filter.

From our text by Sabins

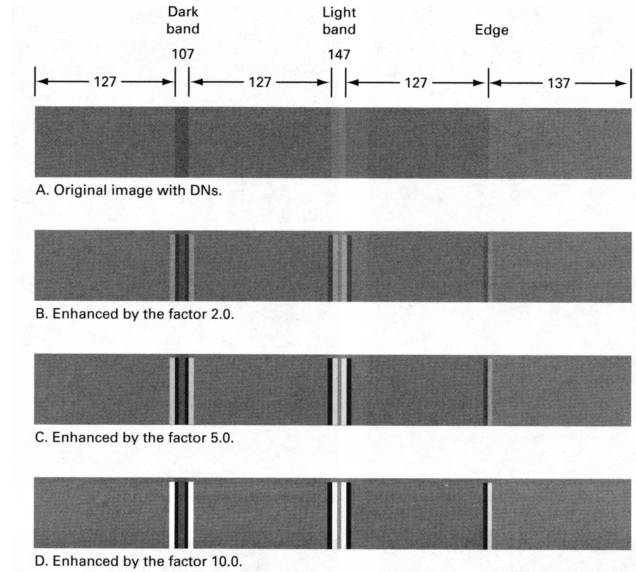


Figure 8-17 Computer-generated images illustrating nondirectional edge enhancement with a Laplacian filter and different weighting factors.

4x40 -1×40 -1×40 -1×40 -1×35 = 5 so add 5 to center pixel

To avoid necessity of <u>adding</u> result to center value, many people would actually write kernel as following (i.e. increase center by 1)

0	-1	0
-1	5	-1
0	-1	0

You then just <u>copy</u> result to center pixel.

Edge Detection

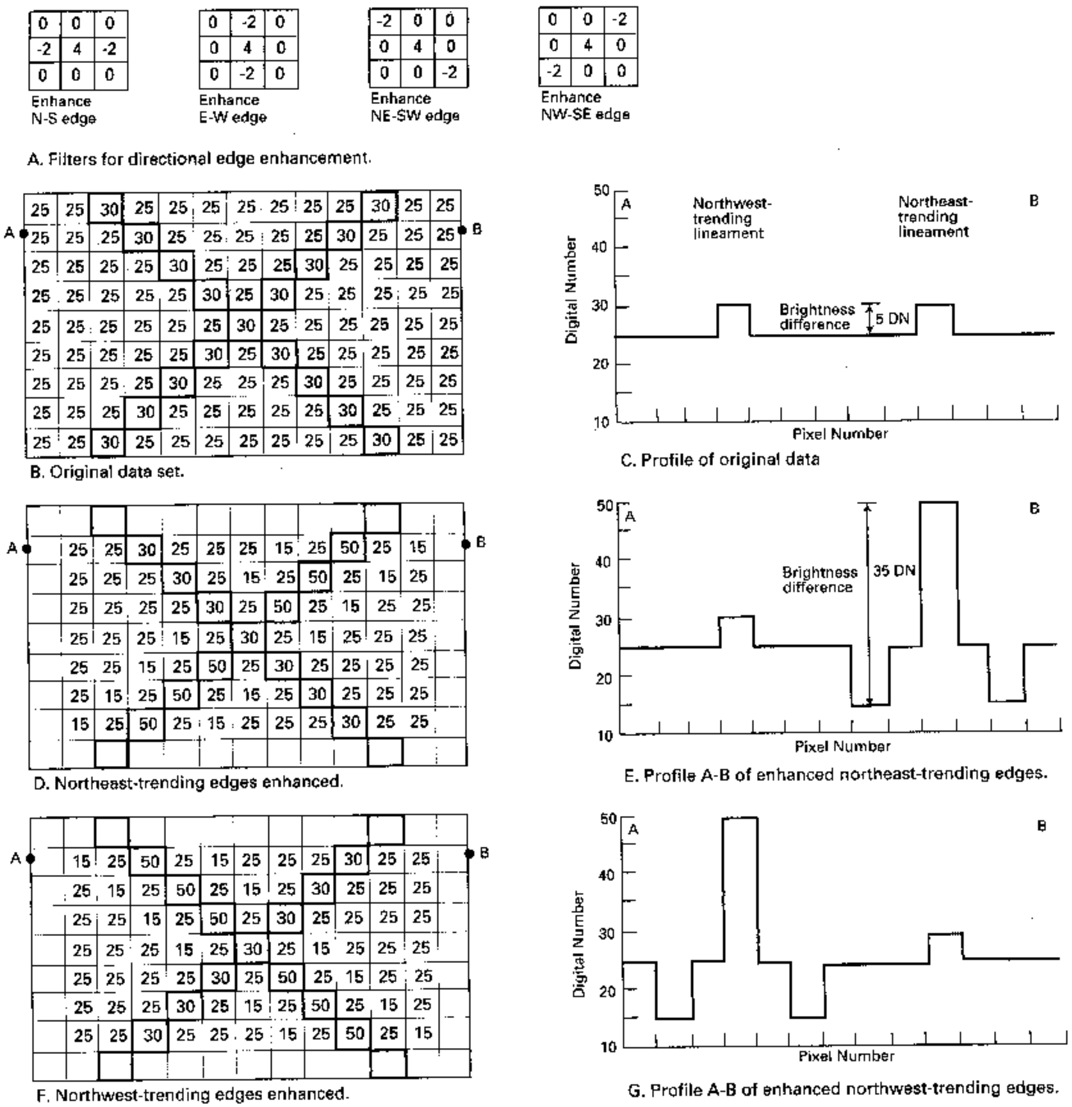


Figure 8-20 Edge enhancement using a directional filter.

From our text by Sabins

Edge Detection

A. Original image.

B. Nondirectional enhancement.

C. Directional enhancement of northeast-trending lineaments.

D. Directional enhancement of northwest-trending lineaments.

Figure 8-18 Edge enhancements of TM images of the Jabal an Naslah area, northwest Saudi Arabia.

Sabins Fig. 8-18 (pg. 272)

Color Transformations

- Because of properties of eye (three separate sensors for Red, Green, Blue), it takes 3 numbers to specify <u>perceived</u> properties of light

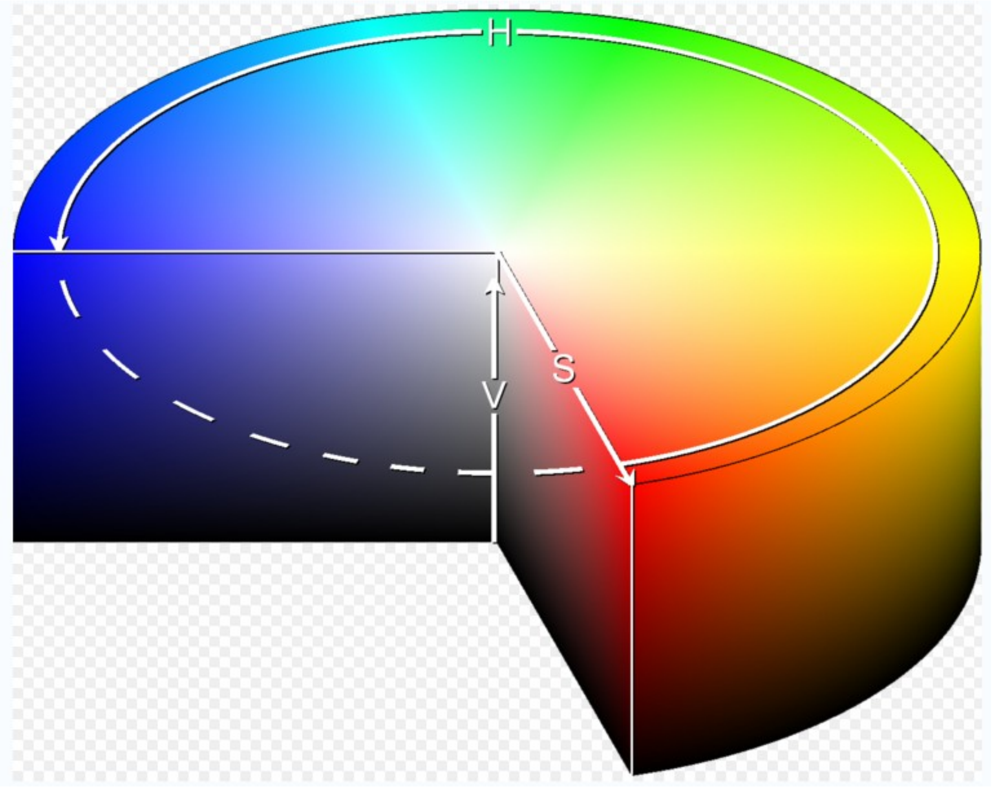
  - Simplest is RGB (tied closely to how "eye" works)
    - R: Intensity in red channel
    - G: Intensity in green channel
    - B: Intensity in blue channel

  - Sabins describes the alternate system IHS (tied closely to how "brain" works)
    - I: Intensity (i.e. bright vs. dim)
    - H: Hue (i.e. red vs. yellow vs. green vs. cyan vs. blue vs. magenta)
    - S: Saturation (i.e. deep red vs. pink or deep blue vs. light blue) – a kind of "Color contrast"
    - This system is often called HSL (Hue, Saturation, Lightness)

  - ENVI supports related systems
    - HSV (Hue, Saturation, Value)
    - HLS (Hue, Lightness, Saturation)

HSV System

- Hue measured as angle around cylinder
- Saturation measured as distance from central axis (=white)
- Value measured from bottom (black) to top (bright)



Merging color data

- Often one has:
  - High spatial resolution data in only one band
  - Lower spatial resolution data in multiple bands

- Often
  - Intensity varies rapidly and in complex way because of topography, shadowing, etc.
  - Color varies "slowly" because only a limited number of different compositions are present.
    - Note: The boundaries between different compositions could still be sharp but there are not a lot of those boundaries.

- Your "eye", or at least your "brain" is use to observing the above difference.
  - It "demands" higher resolution in intensity than it does in color information.

- To merge data
  - Convert the low resolution color information into HSV or HLS
  - Discard the low resolution V or L "intensity" with the high resolution intensity from the single band
  - Convert the resulting HSV or HLS data back into RGB to display

- To your "eye" it will look like much like a high resolution color image
- You may see "artifacts" at places where there are sharp intensity AND color boundaries

Raster vs. Vector Data

- Raster data:
  - An matrix of cells, each of which contains some value
    - Good for:
      - Intensity in an image
      - Radar reflectivity vs. position
      - Height vs. position
  - There is some implicit relationship between row and column index (i, j) and position in space (x, y)
    - If there is a constant scale the relationship is simple and linear

- Vector data:
  - A list of (x, y) coordinates, and often some value specified at that coordinate
    - Good for:
      - Plotting lines in space (roads, rivers, borders, contours, etc)
      - Heights of discrete locations such as mountain peaks
      - Locations of discrete features

- ENVI deals primarily with raster data, but can incorporate vector data from "maps"

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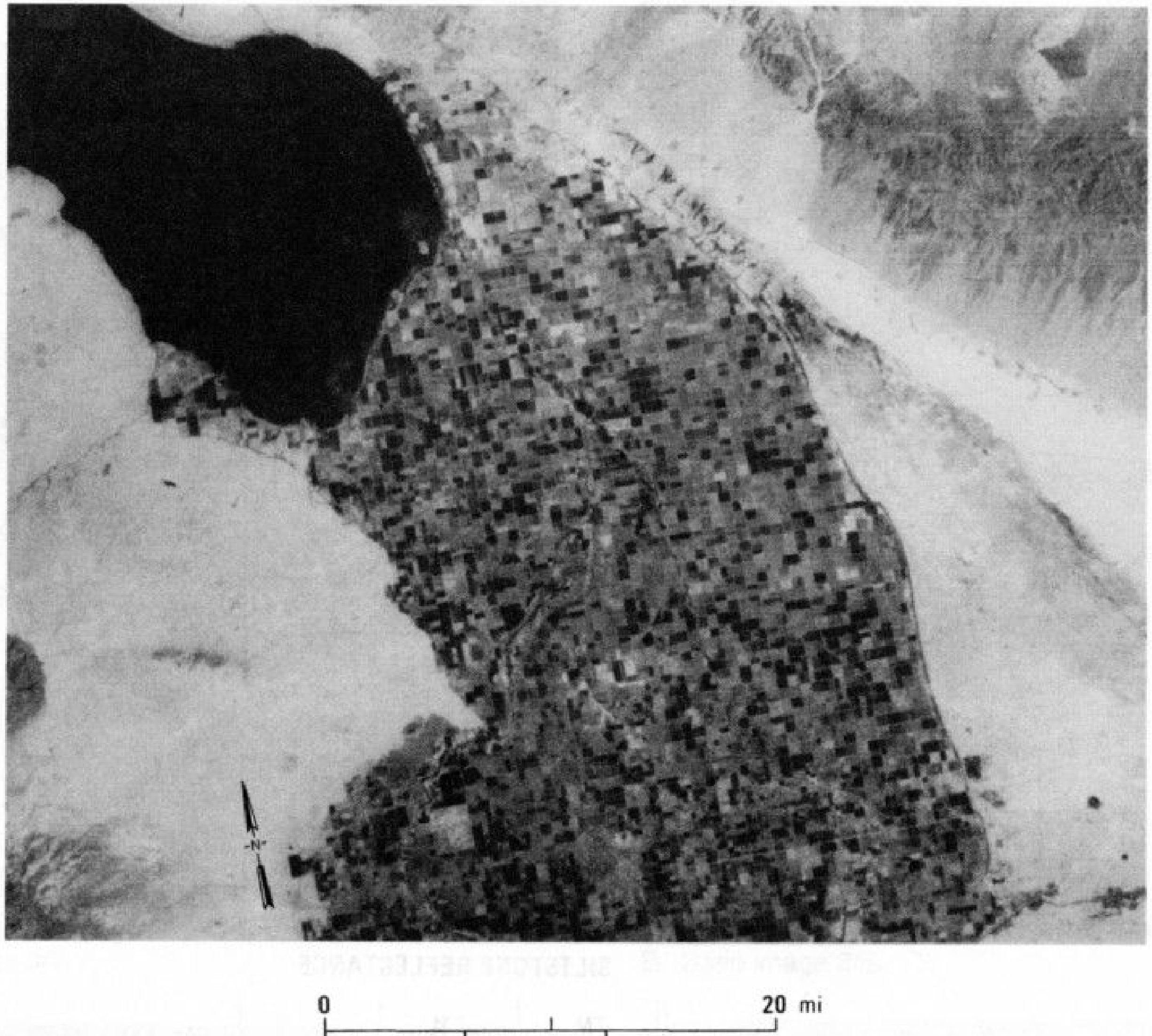
Multispectral Classification: Cluster Analysis

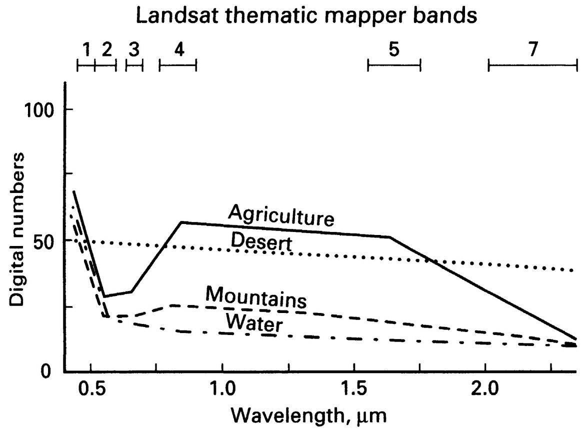


A. Landsat image.

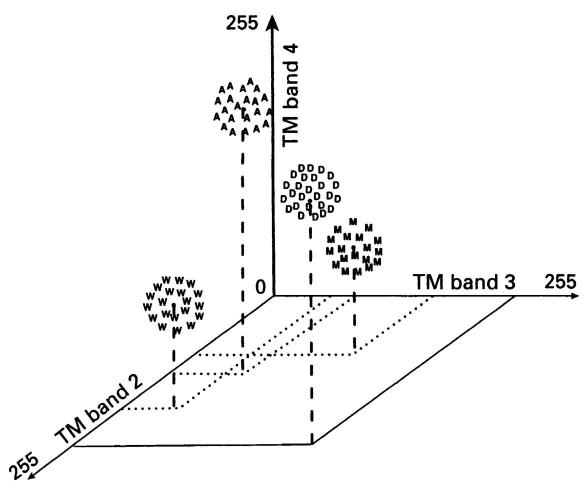
- Salton Sea, CA.
- By eye – four general types of terrain:
  - Water
  - Agriculture
  - Desert
  - Mountains

From our text by Sabins

Multispectral Classification: Cluster Analysis



A. Spectral reflectance curves derived from TM bands. The high values in band 1 are caused by selective atmospheric scattering.



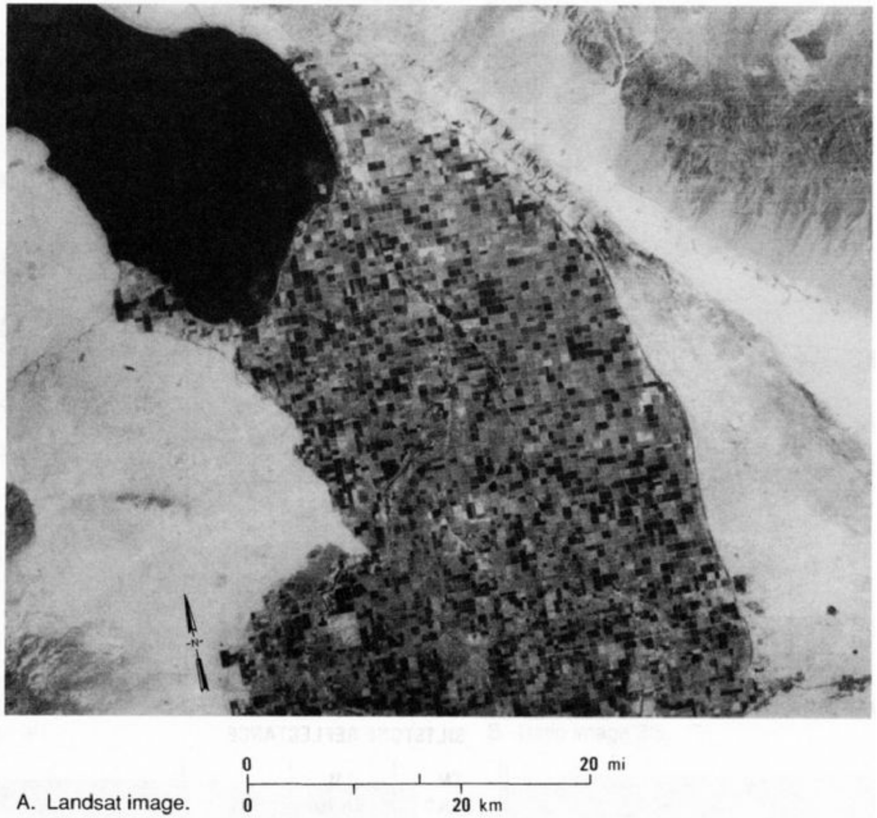
B. Three-dimensional cluster diagram for classification.

Figure 8-32 Landsat data used to classify image of the Salton Sea and the Imperial Valley, California.

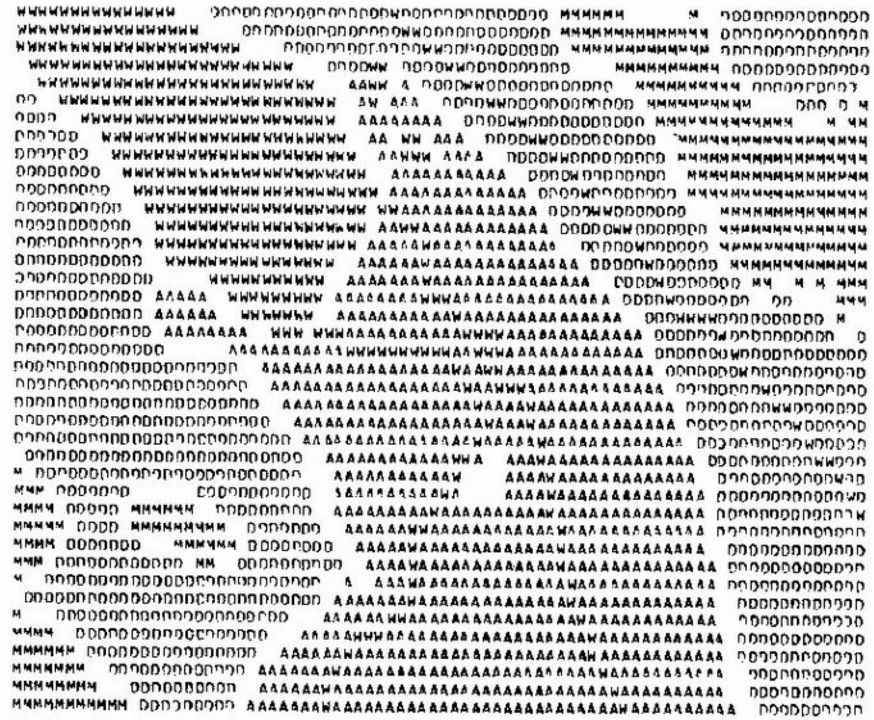
From our text by Sabins

- Use bands #2, #3, #4
  - Plot #2, #3, #4 for each pixel
  - Look for clusters in data
    - 4 clusters with gaps between
  - Define 4 ellipsoids:
    - If pixel falls inside given cluster it is classified as type 1,2,3,4
    - If pixel falls outside ellipsoid it will not be classified (unknown or mix)
    - Surface of ellipsoid: Decision boundary
    - Volume in ellipsoid: Decision space
- Note – we can only plot 3 – but computer could look for 6-D clusters using all 6 bands

Multispectral Classification: Results



A. Landsat image.

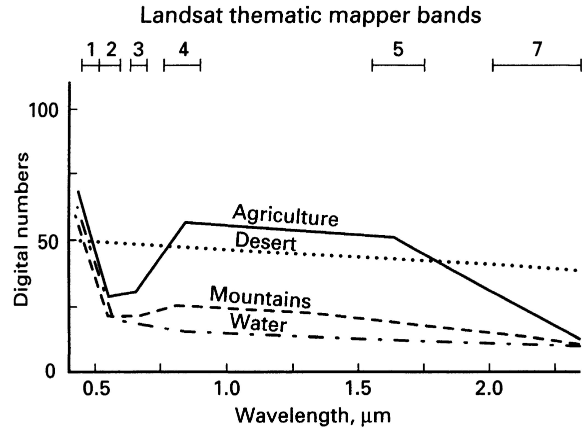


B. Classification map. A = agriculture, D = desert, M = mountains, W = water, blank = unclassified.

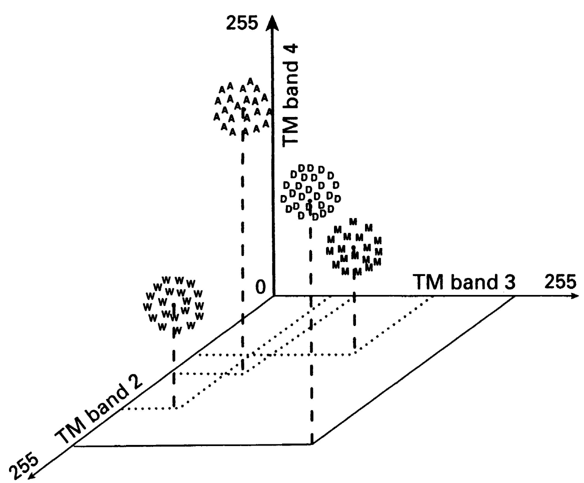
Figure 8-31 Multispectral classification of Landsat data for the Salton Sea and the Imperial Valley, California.

From our text by Sabins

K-Means: Way to determine clustering



A. Spectral reflectance curves derived from TM bands. The high values in band 1 are caused by selective atmospheric scattering.



B. Three-dimensional cluster diagram for classification.

Figure 8-32 Landsat data used to classify image of the Salton Sea and the Imperial Valley, California.

- Unsupervised Classification
- Iterative cluster analysis technique
- Works best if clusters are "round", not long and skinny.

  Can use other techniques first (like PCA) to get around that.

1) Divide data into "K" classes

   (in first iteration this assignment is "random")

2) Find "center" of each class in n-dimensional data space as defined by the "Mean"

3) Find distance of each data point (each pixel) from center of all the classes and <u>reassign</u> it to the closest class

Repeat steps 2 and 3 until either:

"Few" pixels jump from one class to another

or

Reach specified max. number of iterations

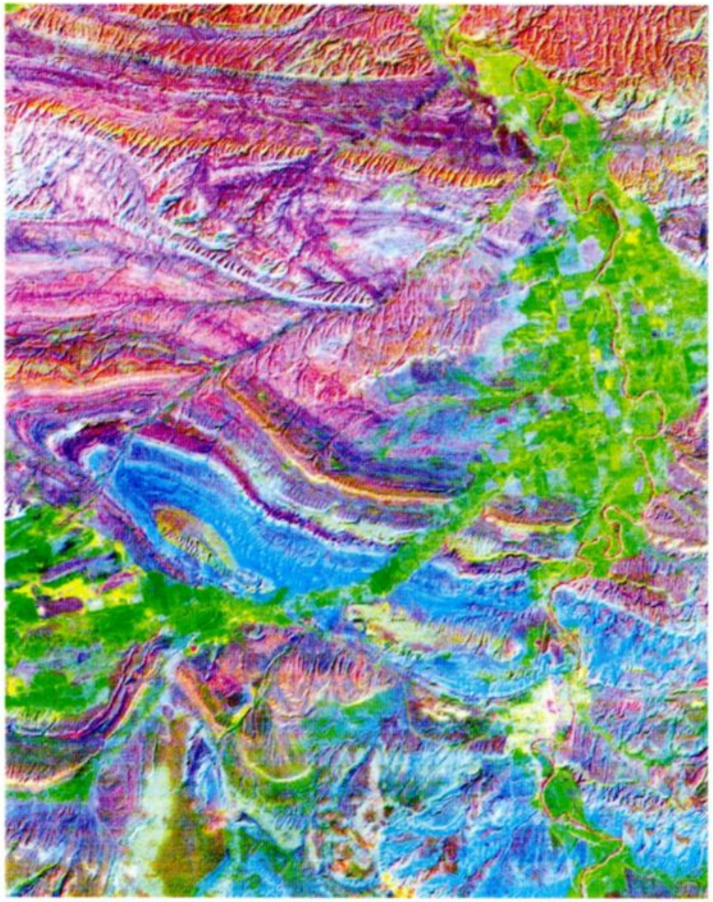
From our text by Sabins

Image Classification:

- Supervised Classification
  - Specify "training sites" with ground-truth or specify "type spectra"
- Unsupervised Classification
  - Search for statistical regularities in data without additional information

	Advantages	Disadvantages
Supervised	Identifies types of terrain.	Need ground-truth or lab spectra.
	Using extra information, can recognizing subtle differences.	Gets confused if additional unknown classes are present
Unsupervised	Needs no additional information.	Doesn't identify surface type.
		Confused by subtle differences.

Thermopolis Example



B. TM principal-component color image, Thermopolis, Wyoming.
PC 2 = red, PC 3 = green, PC 4 = blue.

From our text by Sabins

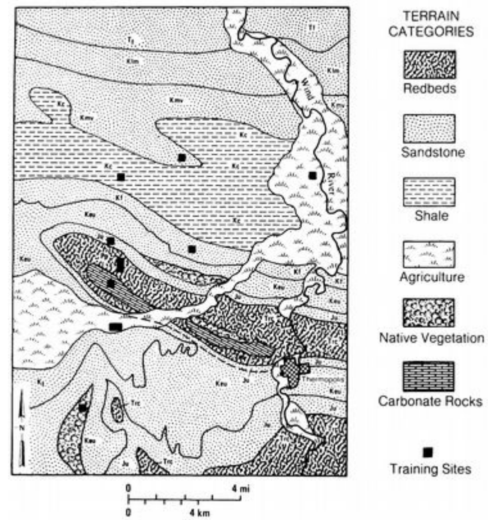


Figure 8-33 Terrain categories and training sites for supervised classification of the Thermopolis, Wyoming, subscene. Abbreviations for formations are given in Figure 3-8.

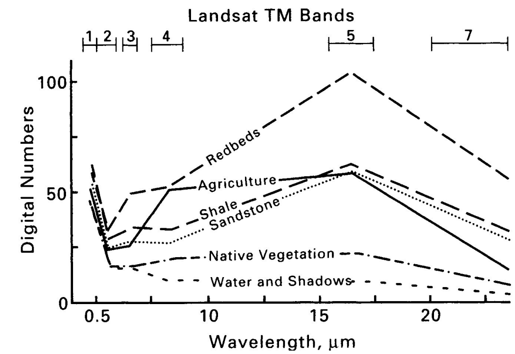
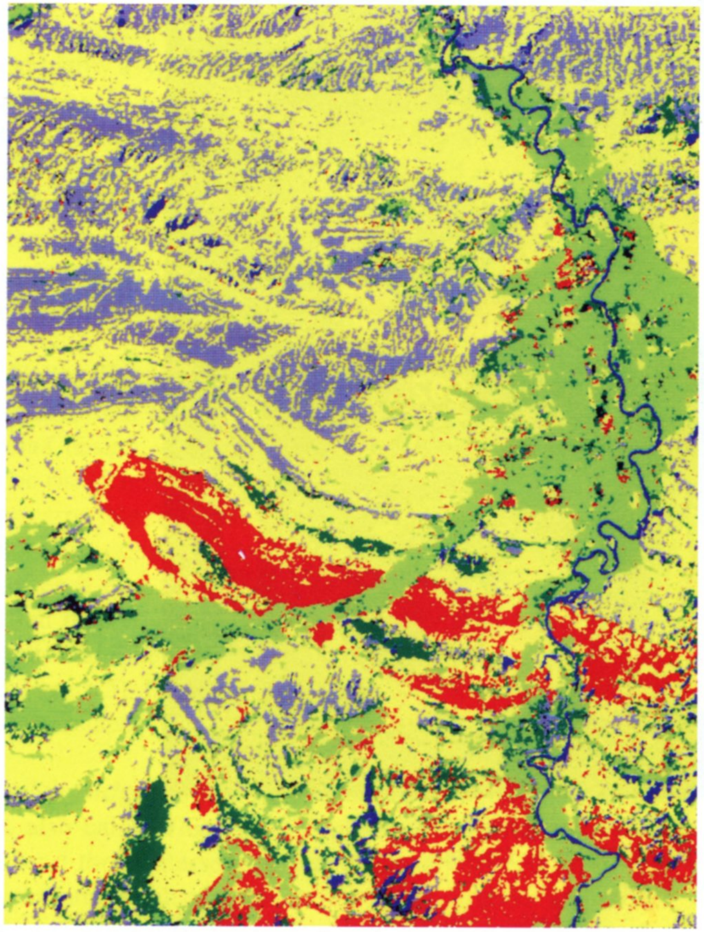


Figure 8-34 Reflectance spectra (from TM bands) of terrain categories shown in Figure 8-33

- Supervised classification
  - You pick "training sites" of known character.
- Unsupervised classification
  - Program decides on it's own different types of terrain.
  - You usually specify # of types, etc.

Thermopolis: Supervised Classification

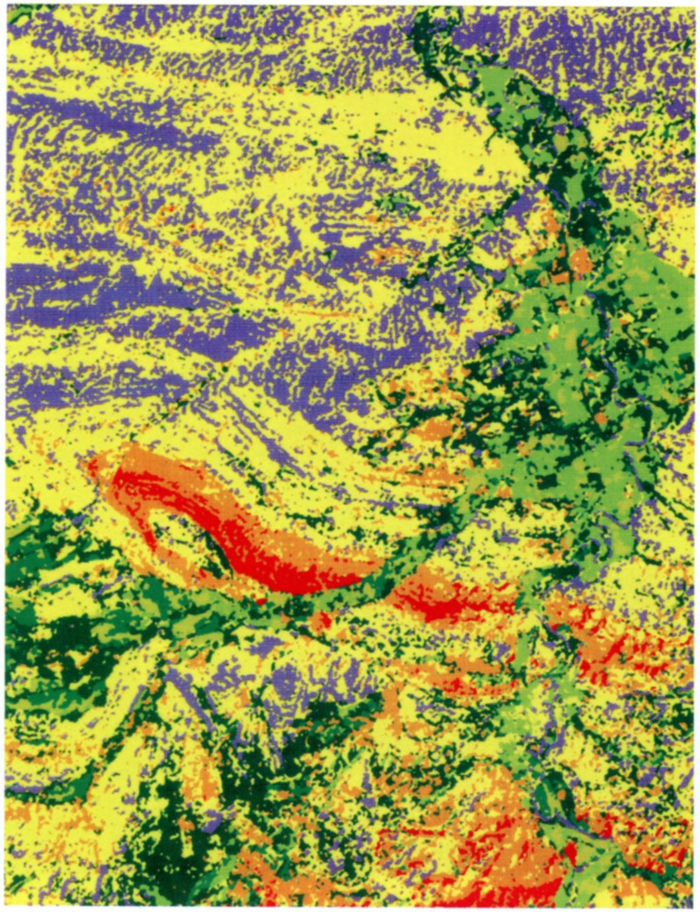


SYMBOL	CLASS	PERCENT
	Redbeds	8.4
	Sandstone	48.3
	Shale	18.9
	Agriculture	16.2
	Native vegetation	5.2
	Water and shadows	1.9
	Unclassified	1.1

A. Supervised-classification map and explanation.

From our text by Sabins

Thermopolis: Unsupervised Classification



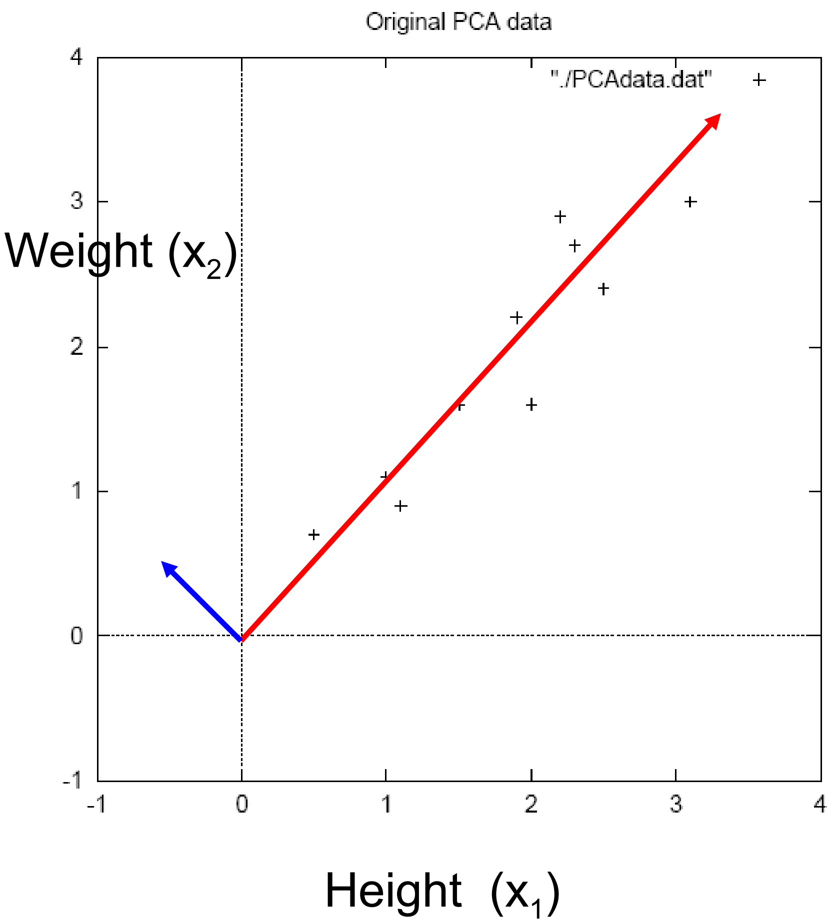
SYMBOL	CLASS	PERCENT
	Redbeds, lower	2.2
	Redbeds, upper	11.7
	Sandstone	38.2
	Shale	22.3
	Agriculture, A	6.5
	Native vegetation	13.7
	Agriculture, B	2.7
	Agriculture, C	2.7

B. Unsupervised-classification map and explanation.

Plate 15 Digital classifications of TM image, Thermopolis, Wyoming.

From our text by Sabins

Principal-components



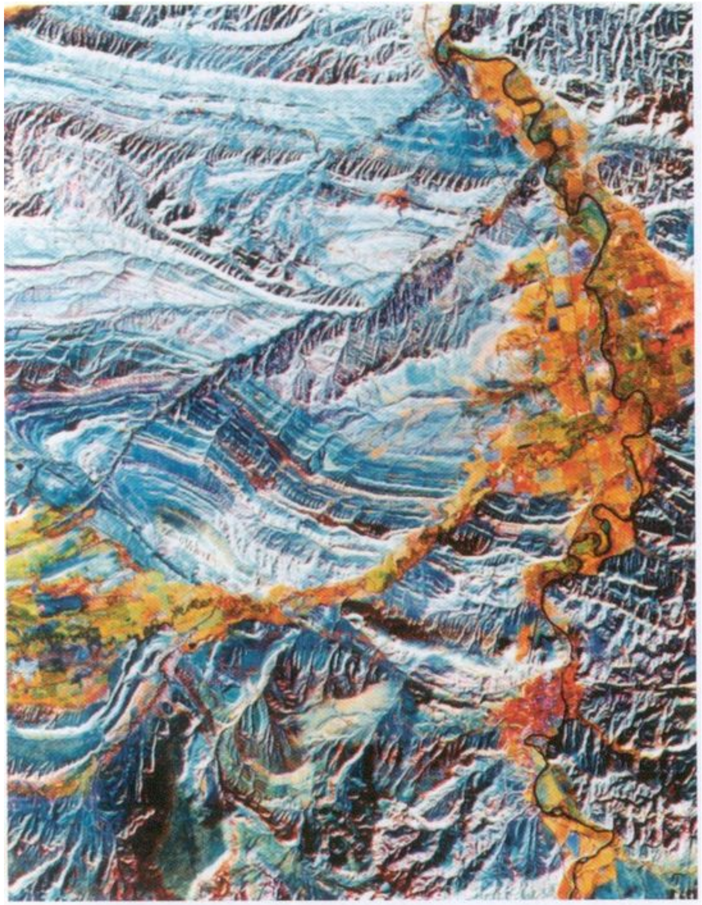
- Statistical method for determining "different ways" in which data vary
- Suppose you measure weight, height for each person in room, and plot that data.
- Most of the variation falls along a single line which could be described as "big people" vs. "small people"
  - Define 1st eigenvector: bigness = W + H
- Smaller variation falls along a line at right angles to this:
  - Define 2nd eigenvector: heaviness = W – H
- If you had a third measurement – kg of body-fat, you could define a 3rd eigenvector which distinguished between being heavy because you were fat, or heavy because you had lots of muscle.
- In general:

$$y_1 = a_{11}\, x_1 + a_{12}\, x_2$$
$$y_2 = a_{21}\, x_1 + a_{22}\, x_2$$

- For remote sensing
  - Different measurements x_1, x_2, ... different bands
  - First eigenvector y_1 might be light rocks vs. dark rocks
  - Second eigenvector might be tan vs. red rocks
  - Third eigenvector might be "clay rich" vs. "clay poor"
- Total # of "eigenvectors" equal original # of bands
- First eigenvectors explains most of variation
- Last eigenvectors may just be "noise"

Thermopolis TM Data

A. Normal color. Bands 1-2-3 = BGR.



C. All IR color. Bands 4-5-7 = BGR.

From our text by Sabins

- 6 TM bands (excluding TIR), so expect 6 PC Eigenvectors

Thermopolis TM Data

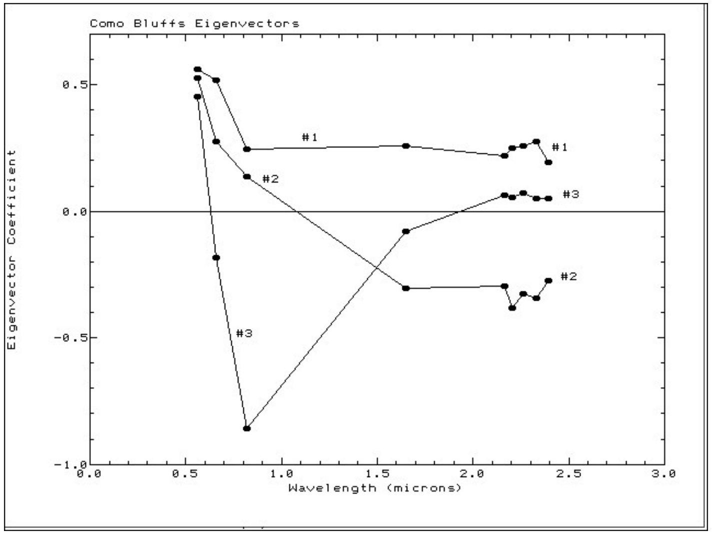
A. PC image 1 (88.4 percent).

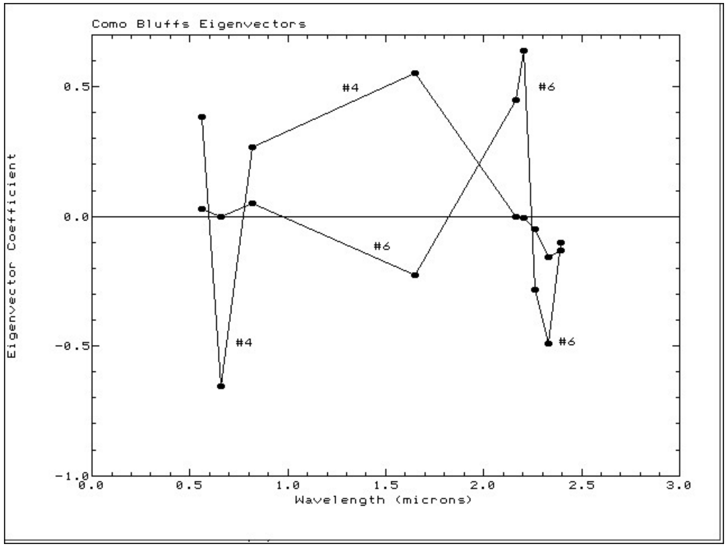
B. PC image 2 (6.6 percent).

From our text by Sabins

- PC Components from Fig. 08.27
- First component is often mostly topography related shading
- Second component is often the dominant “color” differences

Principal-components





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- In general:

$$y_1 = a_{11}\, x_1 + a_{12}\, x_2$$
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- For remote sensing
  - Different measurements x_1, x_2, ... different bands
  - First eigenvector y_1 might be light rocks vs. dark rocks
  - Second eigenvector might be tan vs. red rocks
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- Total # of "eigenvectors" equal original # of bands
- First eigenvectors explains most of variation
- Last eigenvectors may just be "noise"

Thermopolis TM Data

C. PC image 3 (2.4 percent).

E. PC image 5 (0.5 percent).

From our text by Sabins

- 3rd, 4th, etc. components may be more subtle "color" variations
- Last components are mostly noise, or minor "color" differences