What is Remote Sensing?

Defining Remote Sensing

Remote sensing = collection of data about features or phenomena of the earth surface (and near surface) **without being in direct contact**

- Lack of contact with features or phenomena
- Sensors utilize electromagnetic radiation (**EMR**)
- Collection of data
- **Analysis** of data collected

Sensing

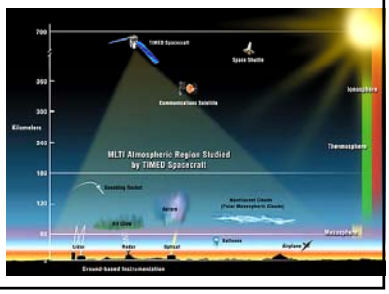
- Data are collected by **sensor**
  - Passive sensor – collection of reflected or emitted electromagnetic radiation
  - Active sensor – Generates signal and collects backscatter from interaction with terrain **(with Flash Lights)**
- Imaging & Non-Imaging (pictures, vs. metal detector)
- Photographic vs. Non-Photographic (pictures, vs. radar signals)

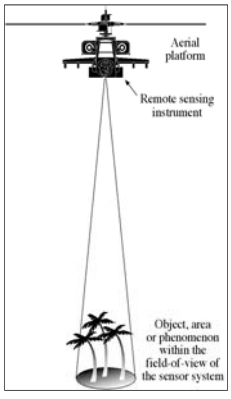
Distance – How remote is remote?

Platforms for sensors operate at multiple levels

- Cranes
- Balloons
- Aircraft
- Satellite

- Permit near-surface to global scale data collection

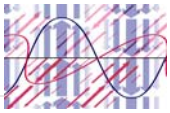


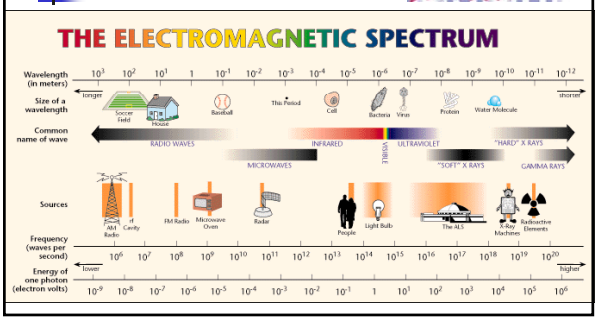


Remote sensing:

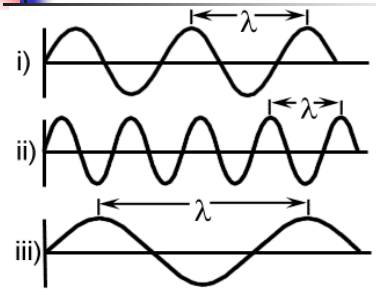
the collection of information about an object without being in direct physical contact with the object.

EMR





Wavelength & Frequency

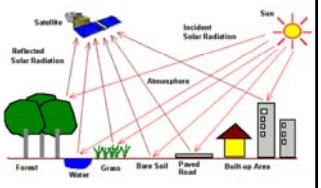


Remote Sensing vs. Aerial Photography

- Remote sensing is performed using a variety of sensors and platforms that may operate in multiple parts of the **EMR spectrum**
- Aerial photography is performed using film-based cameras that sense only in **Ultraviolet (UV), visible**, and **Near-infrared (NIR)** spectrum and are operated on aircraft
- Aerial photography is a subset of remote sensing

Simplified Information Flow

- Passive systems – detect naturally upwelling radiation
- Flow: Source → Surface → Sensor
- Source, the sun, illuminates surface
- Surface reflects/emits radiation
- Sensor detects reflected radiation within its **field of view (FOV).**
- Interpretation – manual or machine



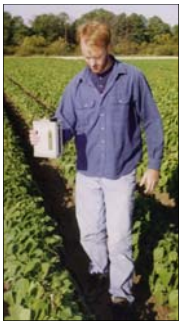
Complexities of Information Flow (cont.)

- **Sensor**/platform variation
  - Attitude
  - Altitude
  - Orbit
  - Film/wavelength sensitivities
  - Calibration or Optics
- **Processing**/interpretation variation
  - Film or digital processing
  - Repeatability of interpretation results

In situ vs. Remote Sensing

- Both attempt to observe/measure phenomena
- ***In situ*** *(at the field – ground truth)*
  - Physical contact
  - Instruments for direct measure
  - Possible source of **error**
    - Interaction with phenomena (example: measuring CO2 or temperature).
    - **Sampling method**
    - Ground reference vs. "ground truth"

In situ or remote sensing?



Ground spectroradiometer measurement of soybeans

Ground Measurement In Support of Remote Sensing Measurement

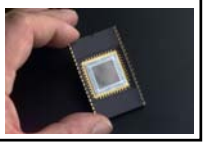
Ground ceptometer leaf-area-index (LAI) measurement

Advantages of Remote Sensing

- Different perspective
- Obtain data for large areas
  - In single acquisition – efficient
  - **Synoptic** (a general view of the whole).
  - Systematic
- Obtain data for inaccessible areas
- No effect/**interaction** with phenomena of interest

Data Collection - Sensors

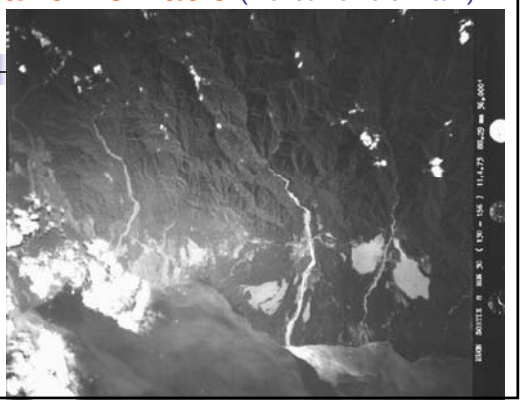
- **Cameras** (film based)
  - Metric, Strip, Panoramic, Multi-spectral
- **Video** Systems
  - Video cameras, Return Beam Vidicon
- **Imaging Radiometers (digital)**
  - Digital frame, Scanners, Pushbroom, Hyperspectral
  - A **charge-coupled device** (**CCD**) is an image sensor
- **Passive Microwave**
- **Radar**
- Operational vs. State-of-the-art



Data Collection - Imagery

- **Panchromatic** (monochrome or B&W) – sensitive across broad visible wavelengths
- **Color** – may provide added discrimination
  - Color film
  - Color composites
- **Thermal** – in region 3 microns to 1 mm, sensitive to temperature
- **Microwave** – all weather capability

Panchromatic (monochrome or B&W)

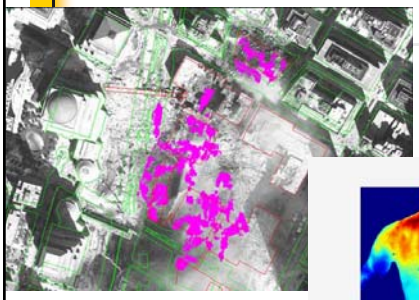


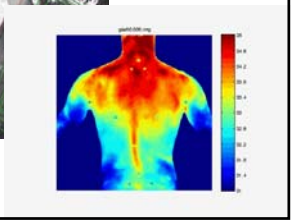
Color

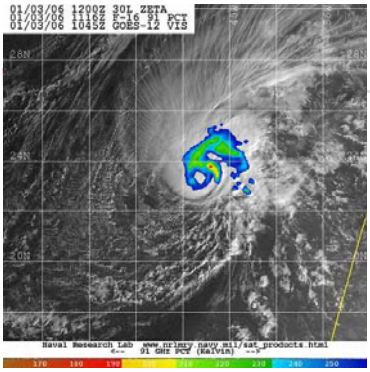
Quickbird

(China) 2004

Thermal Imagery (World Trade Center and Human Body)







- **Microwave**

http://cimss.ssec.wisc.edu/tropic/real-time/marti/2005_EIGHTEEN/webManager/basicGifDisplay48.html

Art vs. Science

- Image interpretation is not exact science
- Interpretations tend to be **probabilistic** not exact
- Successful interpretation depends on
  - **Training** and **experience**
  - Systematic and disciplined approach using knowledge of remote sensing, application area and location
  - Inherent talents

Image Interpretation - Defined

Act of examining images for the purpose of **identifying** and measuring **objects** and phenomena, and judging their significance

Image Interpretation (II) Tasks

- In order of increasing sophistication...
  - **Detection** (easier tasks)
  - Identification
  - Measurement
  - Problem-Solving (most difficult tasks)
- Not necessarily performed sequentially or in all cases

II Tasks - Detection

- Lowest order
- **Presence**/absence of object or phenomena
- Examples: buildings, water, roads and vegetation


II Tasks - Identification

- More advanced than detection
- **Labeling** or typing of the **object**/phenomena
- Tends to occur simultaneously with detection
- Examples: my houses, Lake Murray, highway I-8.


II Tasks - Measurement

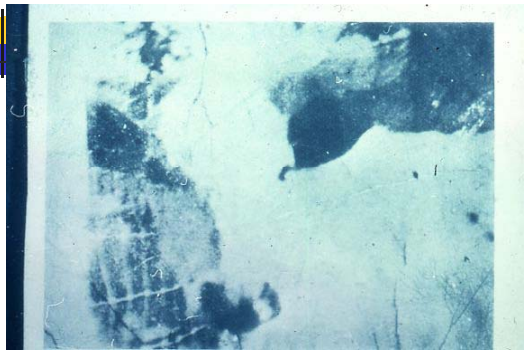
- Quantification of objects / phenomena
- Direct **physical measurement** from the imagery
- Examples
  - Inventories (count) – five lakes in SD county.
  - Length, area and height of objects. Lake Murray: 3.5 acres

II Tasks – Problem Solving

- Most complex task
- Uses information acquired in first three tasks to put objects in assemblages or associations needed for higher-level identification
- With experience, recognition becomes more automatic and tasks become less distinct
- Example: **residential housing density**

Interpreter Requirements - Cognition

- Concerned with how interpreter derives information from the image data
- **Varies from individual to individual**
  - Reasons for differences/inconsistencies among interpreters
- **Cognitive processes** are concerned with perceptual evaluation of elements of interpretation and how they are used in interpretation process



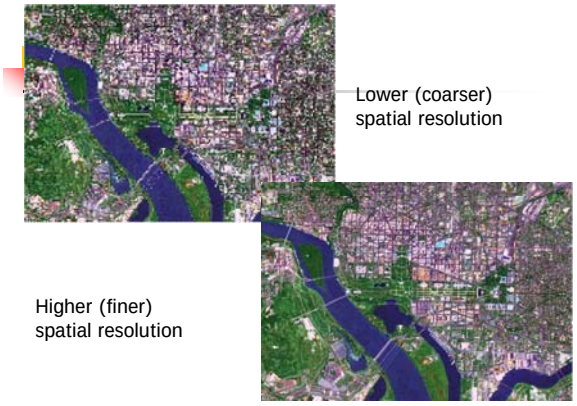
A painting? A Cow?

Imagery Resolution

- Four components of resolution
  - **Spatial**
  - **Spectral**
  - **Radiometric**
  - **Temporal**

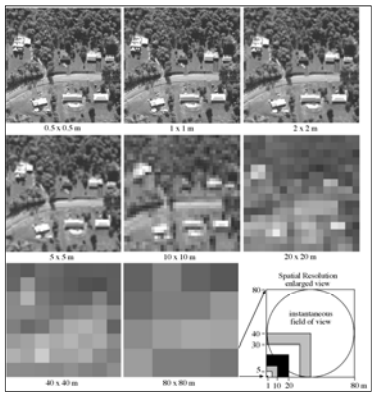
Spatial Resolution

- Indication of how well a sensor records spatial **detail**
- Refers to **the size of the smallest possible feature** that can be detected as distinct from its surroundings
- Aerial Camera: function of of platform **altitude** and film and **optical** characteristics
- Non-film sensor: function of platform **altitude** and **instantaneous field of view (IFOV)**



Lower (coarser) spatial resolution

Higher (finer) spatial resolution

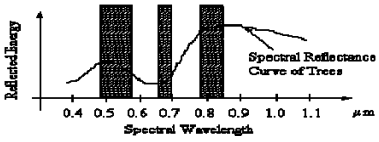


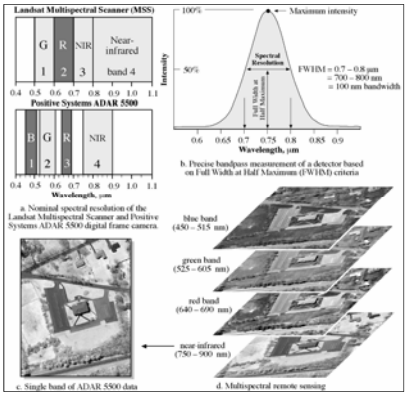
Spatial Resolution

Jensen, 2000

Spectral Resolution

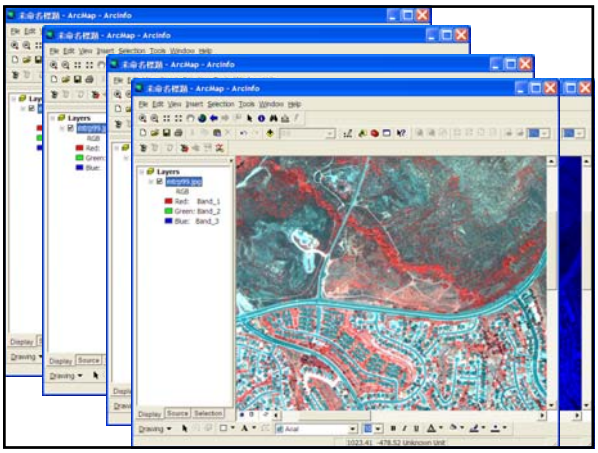
- The width of the specific EMR wavelength band(s) to which sensor is sensitive
- Broadband
  - Few, relatively broad bands
- Hyper-spectral
  - Many, relatively narrow bands

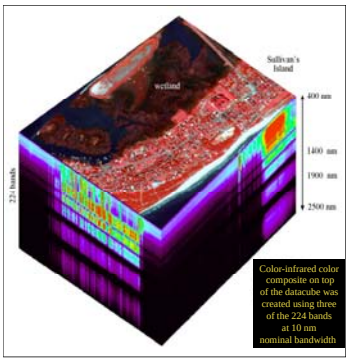




Spectral Resolution

Jensen, 2000





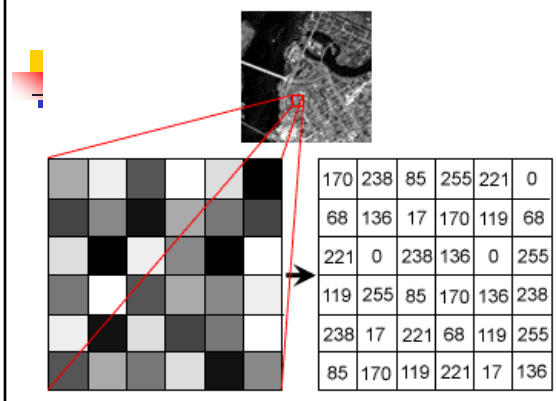
Color-infrared color composite on top of the datacube was created using three of the 224 bands at 10 nm nominal bandwidth

Airborne Visible Infrared Imaging Spectrometer (AVIRIS) Datacube of Sullivan's Island Obtained on October 26, 1998

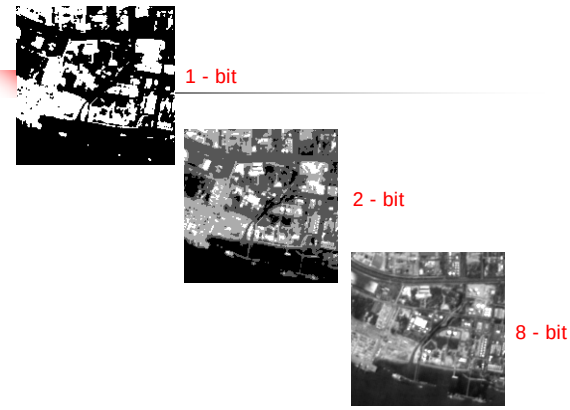
Jensen, 2003

Radiometric Resolution (sensitivity)

- Ability of a sensor to distinguish between objects of similar reflectance
- Measured in terms of the number of energy levels discriminated
  - 2^n, where n = number of 'bits' (precision level)
  - Example: 8 bit data = 2^8 = 256 levels of grey
  - 256 levels = 0-255 range
  - 0 = black, 255 = white
- Affects ability to measure surface properties

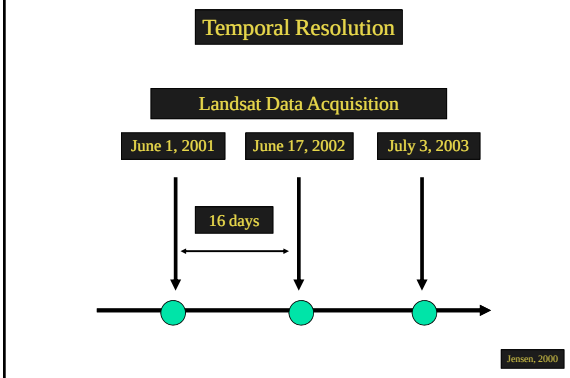


170	238	85	255	221	0
68	136	17	170	119	68
221	0	238	136	0	255
119	255	85	170	136	238
238	17	221	68	119	255
85	170	119	221	17	136



Temporal Resolution

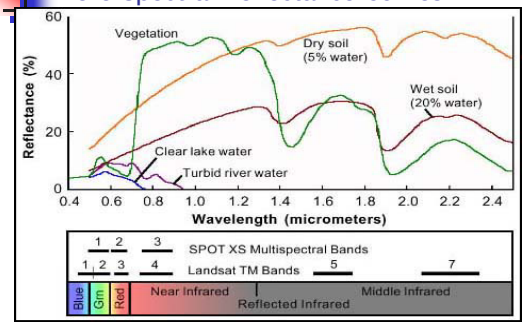
- The ability to obtain repeat coverage for an area
  - Timing is critical for some applications
    - Crop cycles (planting, maximum greenness, harvest)
    - Catastrophic events
  - Aircraft
    - Potentially high
    - Actually (in practice) lower than satellites
  - Satellite
    - Fixed orbit
    - Systematic collection
    - Pointable sensors



Spectral Signature Concept

- Describes spectral **reflectance** of a target at different wavelengths of EMR
- **Spectral reflectance curve** - graphs reflectance response as a function of wavelength
- Key to separating and **identifying** objects
- Selection of optimum wavelength bands

More Spectral Reflectance Curves



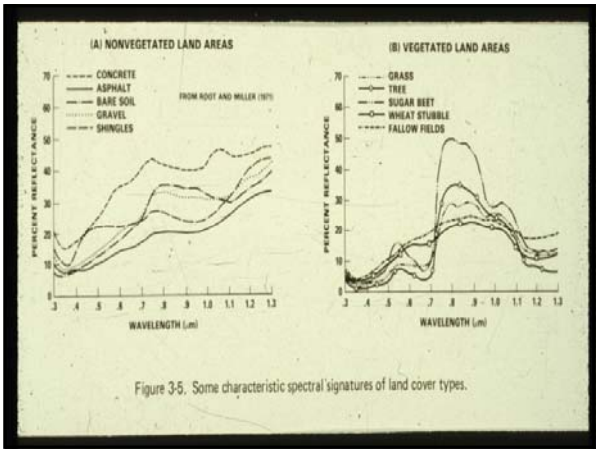
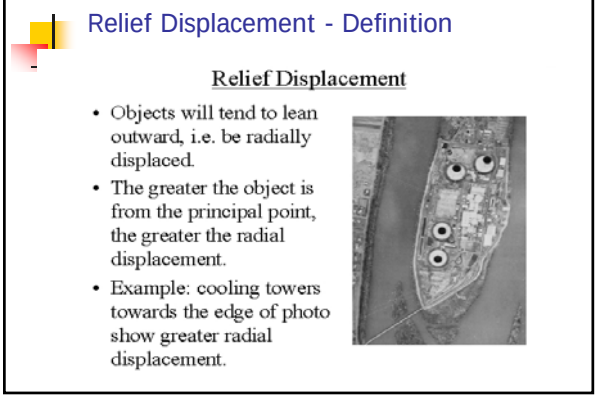
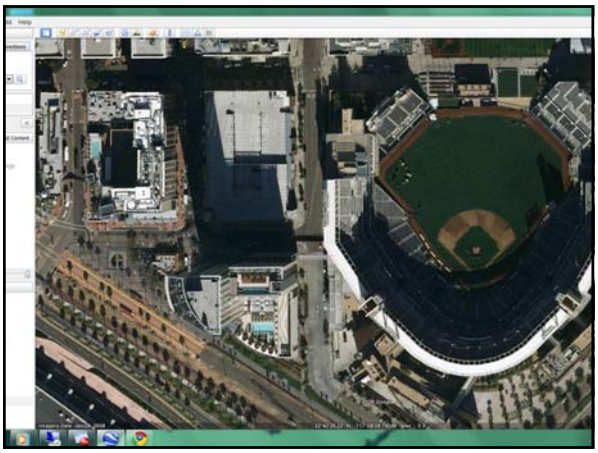


Figure 3-5. Some characteristic spectral signatures of land cover types.

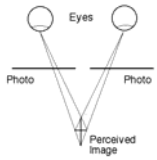
Relief Displacement - Definition

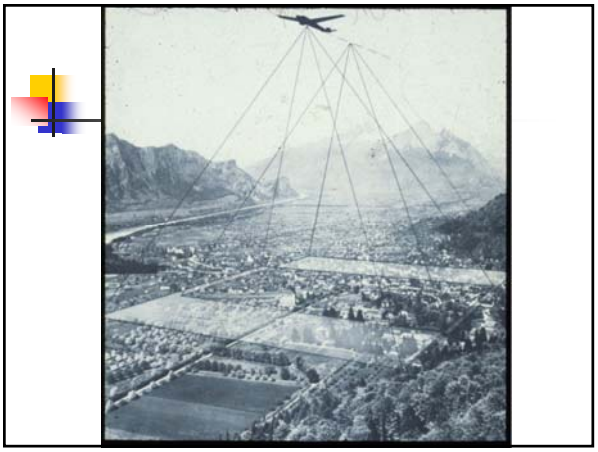


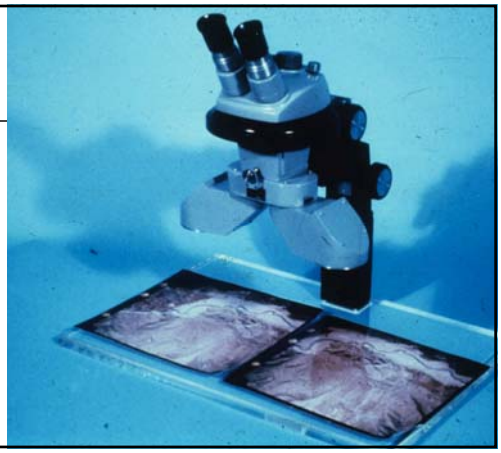


Stereoscopic Viewing

- Provides 3rd dimension to air photo interpretation
  - Identify 3-D form of an object (volcano, building, etc.)
- Stereopairs
  - Overlapping vertical photographs
- Stereoscopes
  - Used to create synthetic visual response by forcing each eye to look at different views of same terrain
  - Gives perception of depth (3-D)







StereoPlotters

- Various types
- Three main components
  - 1. Projection system that creates the terrain model
  - 2. Viewing system so operator can see model stereoscopically
  - 3. Measuring and tracing system to record elevation and trace features onto a map sheet

StereoPlotter

Figure 4.19 Kelsh Model KPP-3B stereoplotter instrument. (Courtesy Kelsh Instrument Division, Danko Arlington, Inc.)

Stereo Model

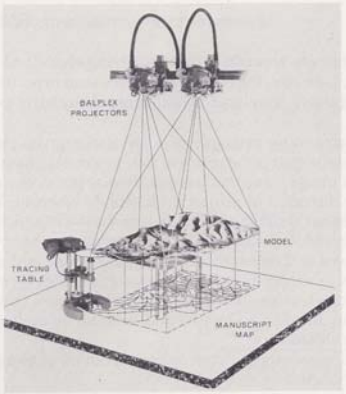


Figure 4.18 Stereomodel projected in a Balplex stereoplotter. (Courtesy TBR Associates, Inc.)

Orthophotography

- Images corrected for **tilt** and **relief** displacement
- Base of features will be shown in their **true planimetric** position
- Feature distortion is not eliminated
  - e.g., tall buildings will still appear to "lean"
- Perspective of the image is changed from point to parallel rays orthogonal to the surface
- Useful as base map

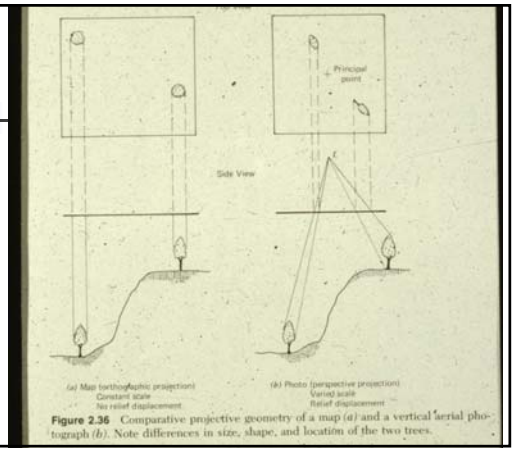


Figure 2.36 Comparative projective geometry of a map (*a*) and a vertical aerial photograph (*b*). Note differences in size, shape, and location of the two trees.

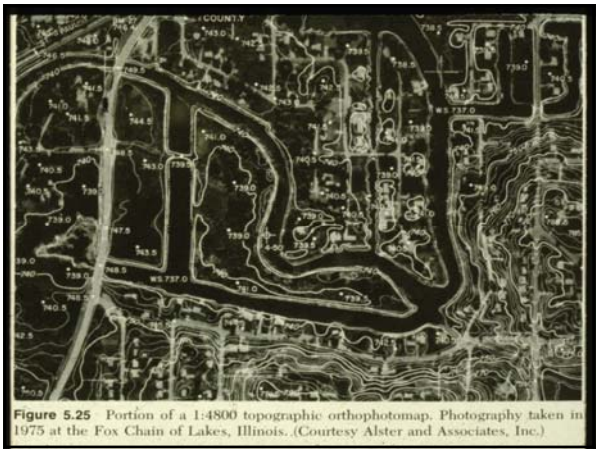


Figure 5.25 Portion of a 1:4800 topographic orthophotomap. Photography taken in 1975 at the Fox Chain of Lakes, Illinois. (Courtesy Alster and Associates, Inc.)

Digital Elevation Models

- Regular **array** of terrain elevations
- Normally stored as a grid of hexagonal pattern
- Created using
  - Ground survey data
  - Cartographic digitization of contour data
  - Photogrammetric measurements
- Other remote sensing approaches
  - Interferometric synthetic aperature radar (InSAR)
  - Scanning LIDAR

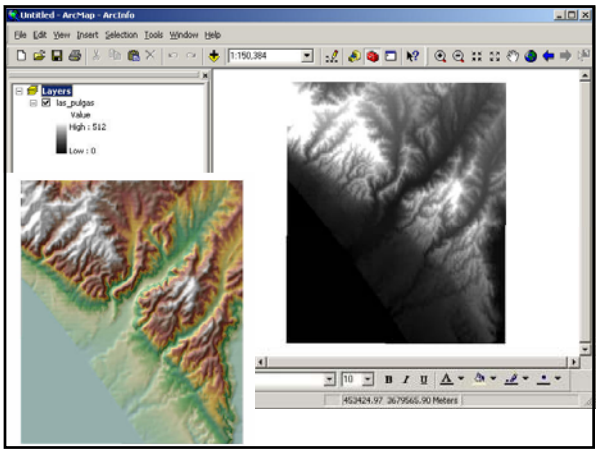
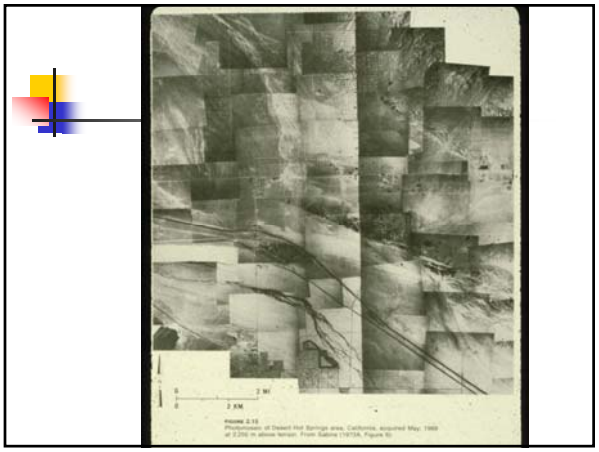
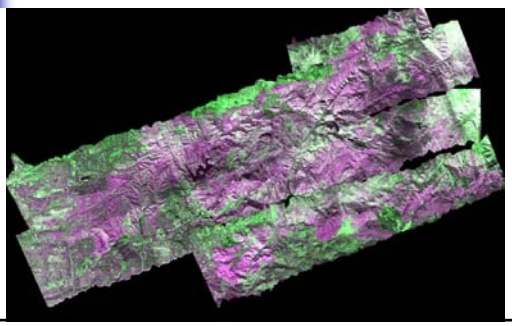


Photo Mosaics

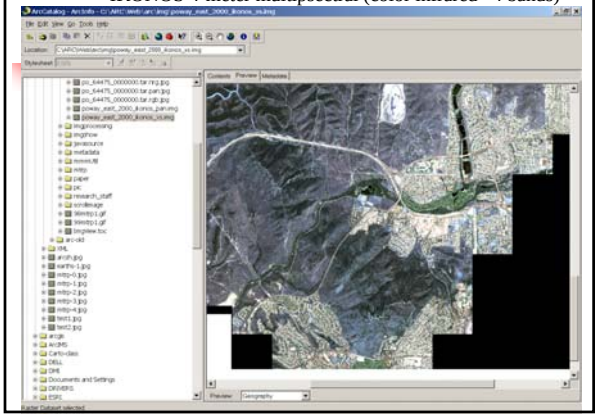
- Stitching together series of aerial photographs to cover large areal extents
- Uncontrolled
  - Photos are matched visually without ground control
  - Generally limited to center of images
  - Scale may not be constant
  - Unequal brightness between photos may make interpretation difficult

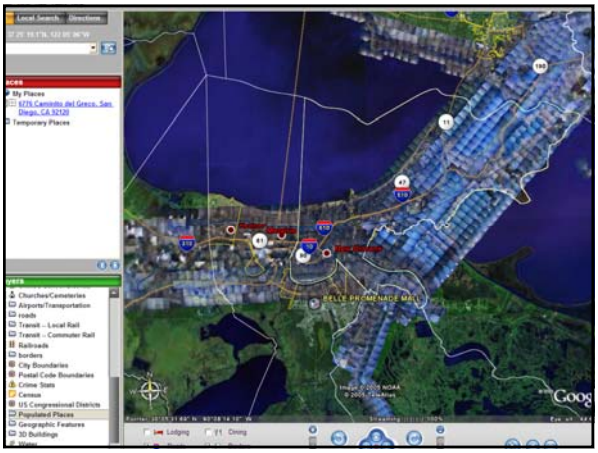


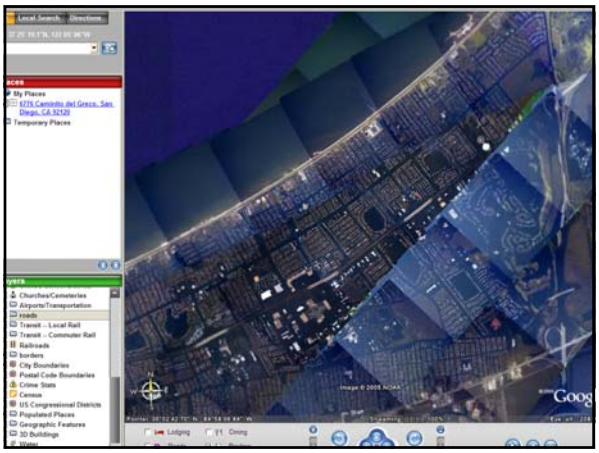
AIRDAS: (NASA Ames; airborne, Cessna 208) 12 meter resolution; multispectral



•IKONOS 4-meter multipsectral (color infrared– 4 bands)






Local Search
Directions
My Places
Temporary Places
Churches/Cemeteries
Airports/Transportation
Roads
Transit -- Local Rail
Transit -- Commuter Rail
Railroads
Borders
City Boundaries
Postal Code Boundaries
Crime Stats
Census
US Congressional Districts
Populated Places
Geographic Features
3D Buildings
Lodging
Dining