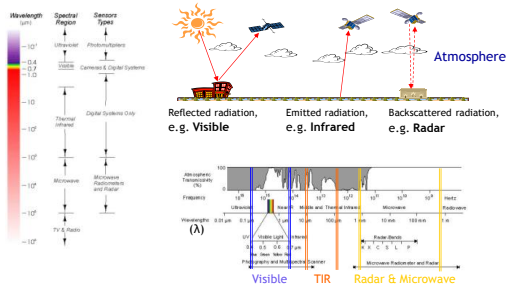
Remote Sensing and GIS



Definitions and Considerations

- Remotely sensed data – acquired without physical contact
  - Photographs and related data acquired by aircraft or satellite
  - Spectroscopy/Spectrometry
  - Principle advantages
    - Unbiased (nonselective) sampling
    - Rapid acquisition
    - Large footprints, synoptic bird's eye view
    - Acquisition of data spanning non-visible portion of the em spectrum; multispectral, multi-scale

Definitions and Considerations

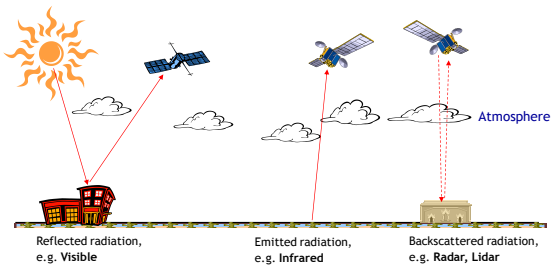
- Photograph – conventional picture by camera in the visible region of the em spectrum; analog
- Image, imagery – acquired by electronic detectors in the visible and/or nonvisible portion of the spectum; digital

Principle Land Mapping Applications

- Land Use/Land Cover, especially change over time- (categorical data)
- Planimetric location (x, y)
- Topographic/bathymetric elevation (x, y, z)
- Color and spectral signature
  - Vegetation biomass, chlorophyll absorption characteristics, moisture content
  - Soil moisture content
  - Temperature
  - Composition (spectrometry)
- Texture/Surface roughness

Principles

- Gather reflected, emitted or backscattered radiation

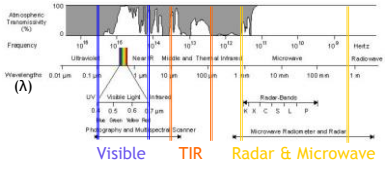


Remote Sensing Classifications

- Passive – either analog or digital radiation *samplers*, e.g. cameras, TIR detectors, multispectral scanners
- Active – send out signal and record reflected radiation, e.g. imaging radar, synthetic aperture radar (SAR)
- Aerial platforms – e.g. aerial photography; large scale (<1:25,000)
- Space platforms – space station or satellite, e.g. SIR, Landsat; small scale (>1:750,000)

Atmospheric attenuation and scattering

- Scattering strongest at short wavelengths (blue sky: u.v. & blue scattered more strongly than rest of visible)
- Ozone absorbs x-rays & u.v., clouds scatter and absorb visible and I.R., except in certain windows, e.g. TIR
- Windows for radar and microwaves at 1mm – 1 m λ



Interactions at the surface

- **Reflection, absorption (±refraction & transmission)**
  - Absorbed energy re-emitted at longer wavelengths (e.g. thermal I.R.)
  - Reflection characteristics depend upon:
    - surface roughness (diffused and brighter for rough vs. mirror-like and dark for smooth)
    - amount of absorption ~ composition of material
  - Result is a complex "Tonal Signature"

Resolution Characteristics

- Four basics aspects of resolution:
  - Spatial 
  - Spectral 
  - Radiometric 
  - Temporal 

Spatial Resolution

- Spatial detail; sharpness of an image
  - Analog resolution:
    - Factor of resolving power of lens & film
    - Calibrate with line pair target. Best obtainable is ~ 60 line pairs/mm
    - Ground Resolution = scale factor/width of minimum resolved line

  E.g. For photo at scale of 1:10,000 and 60 lp/mm

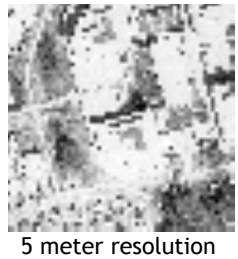
  GR = 10,000/60 = 17 cm

Spatial Resolution

- Digital Image resolution
  - Function of detector characteristics (summarized by instantaneous field of view; IFOV) and height
  - Raster resolution (e.g. meters/pixel) is proxy for resolution, though at least 2 pixels are required to derive same content as analog image
  - Number of pixels required to achieve same resolution as best 9" x 9" analog aerial photo is ~700 megapixels! (c.f. "retina display" of ~8.6 Mpixels)

Spatial Resolution Comparisons

10 meter resolution



5 meter resolution

Spatial Resolution Comparisons

2.5 meter resolution

1 meter resolution

Spatial Resolution Comparisons

1 meter resolution

50 cm resolution

Spatial Resolution Comparisons

25 cm resolution

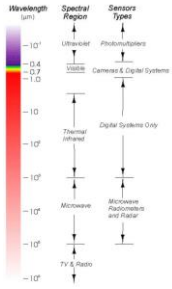
10 cm resolution

High Spatial Resolution Satellites

- Quickbird-2 (DigitalGlobe)
  - ~0.5m panchromatic, ~0.5m multispectral
- IKONOS-2 (Space Imaging, "GeoEye")
  - 1m panchromatic, 4m multispectral (4 bands)
- SPOT (French Commercial Satellite)
  - 2.5m panchromatic
- Landsat 7 ETM+ & 8 (NASA/USGS)
  - 15m panchromatic, 30m multispectral
- EOS Terra ASTER radiometer (NASA)
  - 15m in three visible to near-IR bands

Spectral Resolution

- Wavelength(s) to which the detector is sensitive. Depends upon:
  - Number of wavelength bands (channels)
  - Width of each band
- Low spectral res. – Panchromatic photograph; one wide band (~0.4-0.7μm)
- High spectral res. = narrow bandwidth for many bands
  - e.g. EOS-Terra ASTER
    - 14 narrow bands that span visible to TIR (0.5-12 μm)

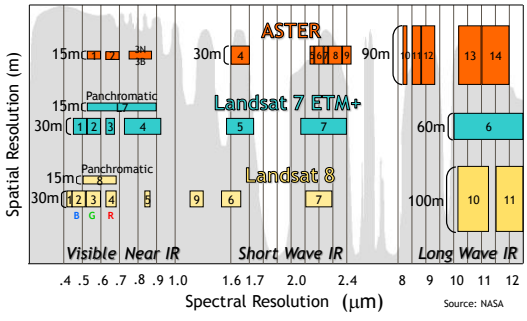


"Hyperspectral" Resolution

- = Very high spectral resolution
  - EOS-Terra and Aqua MODIS
    - 21 bands within UV to near IR, 15 bands within TIR, all with narrow bandwidths
    - Simultaneously observe cloud cover, sea and land temps., land cover, vegetation properties
  - EOS-Terra ASTER
    - 14 narrow bands that span visible to TIR
  - JPL AVIRIS
    - 224(!) narrow bands at 20-m spatial resolution from high altitude NASA aircraft

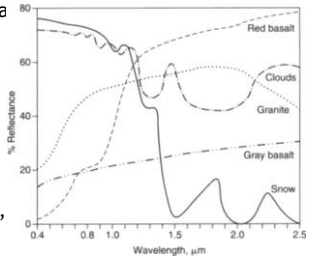
Aqua/MODIS

Spectral Resolution: ASTER, Landsat 7 ETM+ and 8

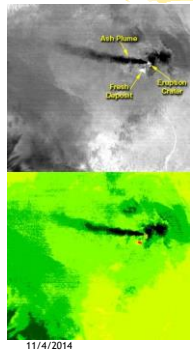


Why high spectral resolution?

- Spectral reflectance is a sensitive indicator geology, water content, vegetation type, etc.
- Applications in ecology, geology, snow&ice hydrology, atmospheric sciences, coastal and inland waterway studies, hazards assessment



Example: Aster TIR Band Image



June 4, 2001 thermal image of Shiveluch volcano on Kamchatka Peninsula.

A lava dome is the hot spot visible on the summit of the volcano. The second hot area is either a debris avalanche or hot ash deposit.

An ash plume is seen as a cold "cloud" streaming from the summit.

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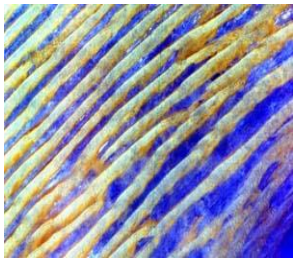
Example: Aster VNIR Band Image



Saudi Arabia sand dunes, 6-25-02

Depicts linear dunes in Rub' Al Khali or Empty Quarter in Saudi Arabia.

Dunes are yellow due to iron oxide minerals; inter-dune areas are made up of clays and silt and appears blue due to high reflectance in Band 1

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Example: Aster Band Image

Lake Garda, Italy - June 29, 2000

Lake Garda lies in the provinces of Verona, Brescia, and Trento. It is 51 km long and 3 to 18 km wide.

The image on the right was contrast stretched to display variations in sediment load

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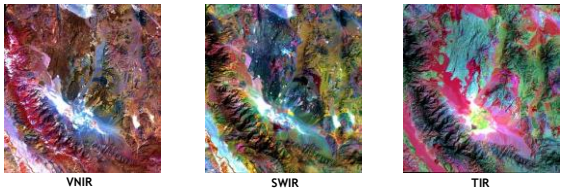
Aster Multi-band Band Images



VNIR SWIR TIR

Saline Valley, California

- VNIR (3,2,1) – vegetation appears red, snow and dry salt lakes are white, exposed rocks are brown, gray, yellow, and blue
- SWIR (4,6,8) – clay, carbonate, and sulfate minerals result in distinctive colors; limestones are yellow-green and kaolinite rich areas are purple
- TIR (13,12,10) – variations in quartz content are shades of red; carbonates are green and mafic volcanic rocks are purple

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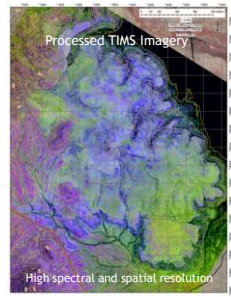
Thermal Infrared Multispectral Scanner (TIMS)

- Six spectral bands between 8-12 um
- ~2 meter resolution
- Processed so hues and tones record differences in quartz, olivine and carbonate contents



Radiometric Resolution

- Smallest detectable difference in radiant energy
  - Analog – high contrast film has higher radiometric res. – more shades of gray resolved
  - Digital – number of (quantization) levels a band can be divided into; what is the possible range of values a pixel may obtain?
    - "7-bit" = 128 levels (Landsat MSS detectors)
    - "8-bit" = 256 levels (Landsat TM)
    - "12-bit" = 4095 levels (AVIRIS)

Temporal Resolution

- Frequency of data collection – time between repeated coverage
  - E.g. Landsat 5, 7 & 8 – 16 days
  - MODIS – 1 to 2 days
  - Higher temporal resolution yields better chance of cloud-free coverage
  - Match frequency with phenomena to be mapped