Environmental Science From Space
Remote Sensing and the Electromagnetic Spectrum

Note: All images from NASA unless otherwise noted
Remote Sensing

= learning about an object or phenomenon without touching, usually using satellites or airplanes

Videos

LandSat video: [http://landsat.gsfc.nasa.gov/about/](http://landsat.gsfc.nasa.gov/about/)
Terra orbit animation:
## Landsat 7

<table>
<thead>
<tr>
<th>Band</th>
<th>Bandwidth (nm)</th>
<th>Radiation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>450-515</td>
<td>Blue</td>
</tr>
<tr>
<td>2</td>
<td>525-605</td>
<td>Green</td>
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<tr>
<td>3</td>
<td>630-690</td>
<td>Red</td>
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<tr>
<td>4</td>
<td>750-900</td>
<td>Near Infrared</td>
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<tr>
<td>5</td>
<td>1,550-1,750</td>
<td>Shortwave Infrared</td>
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<tr>
<td>6</td>
<td>10,400-12,500</td>
<td>Thermal Infrared</td>
</tr>
<tr>
<td>7</td>
<td>2,090-2,350</td>
<td>Shortwave Infrared</td>
</tr>
</tbody>
</table>
Landsat 7: 7 bands

Watsonville
3/4/2012
SPECTRAL SIGNATURES OF EARTH FEATURES

Percent Reflectance (Log scale)

Wavelength (nm)

400 nm 600 nm 800 nm

- Snow and Ice
- Clouds
- Broadleaf Vegetation
- Needleleaf Vegetation
- Dry Soil
- Wet Soil
- Turbid Water
- Clear Water

Infrared

http://missionscience.nasa.gov/ems/09_visiblelight.html
## LandSat Spectral Signatures

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**BUILDINGS**

**WATER**

**TREES**

**ROCKS**
Pixels & RGB Codes

© CCRS / CCT

<table>
<thead>
<tr>
<th>Color Code</th>
<th>RGB Values</th>
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<tbody>
<tr>
<td>Red</td>
<td>255,0,0</td>
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<tr>
<td>Green</td>
<td>0,255,0</td>
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<tr>
<td>Blue</td>
<td>0,0,255</td>
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<tr>
<td>White</td>
<td>255,255,255</td>
</tr>
<tr>
<td>Black</td>
<td>0,0,0</td>
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<tr>
<td>Pink</td>
<td>255,0,255</td>
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<tr>
<td>Cyan</td>
<td>0,255,255</td>
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</table>
ACTIVITY:

Creating & Interpreting Remote Sensing Images

(Derived from NASA’s Remote Sensing Math)
# Key to Pixels

<table>
<thead>
<tr>
<th>Feature</th>
<th>Symbol</th>
<th>Color</th>
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<tbody>
<tr>
<td>Sky</td>
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<td>Ice</td>
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<td>Plants</td>
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<tr>
<td>Water</td>
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<td>Blue</td>
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<tr>
<td>Ice</td>
<td>I</td>
<td>White</td>
<td>1,1,1</td>
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<td>Land</td>
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<td>Brown</td>
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</table>
# The Electromagnetic Spectrum

<table>
<thead>
<tr>
<th>Wavelength (in meters)</th>
<th>10^3</th>
<th>10^2</th>
<th>10^1</th>
<th>1</th>
<th>10^{-1}</th>
<th>10^{-2}</th>
<th>10^{-3}</th>
<th>10^{-4}</th>
<th>10^{-5}</th>
<th>10^{-6}</th>
<th>10^{-7}</th>
<th>10^{-8}</th>
<th>10^{-9}</th>
<th>10^{-10}</th>
<th>10^{-11}</th>
<th>10^{-12}</th>
</tr>
</thead>
<tbody>
<tr>
<td>Size of a wavelength</td>
<td>Soccer Field</td>
<td>House</td>
<td>Baseball</td>
<td>This Period</td>
<td>Cell</td>
<td>Bacteria</td>
<td>Virus</td>
<td>Protein</td>
<td>Water Molecule</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Common name of wave</td>
<td>RADIO WAVES</td>
<td>INFRARED</td>
<td>ULTRAVIOLET</td>
<td>SOFT X RAYS</td>
<td>HARD X RAYS</td>
<td>GAMMA RAYS</td>
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## Sources
- AM Radio
- FM Radio
- Microwave Oven
- Radar
- People
- Light Bulb
- The Advanced Light Source
- X-Ray Machines
- Radioactive Elements

## Frequency (waves per second)

## Energy of one photon (electron volts)
Reviewing Waves

- _______________ \( (\lambda) \) = distance from any point on a wave to an identical point on the next wave
- _______________ \( (f) \) = number of cycles or vibrations per unit of time (1 Hz = 1/s)
- _______________ \( (v) \) = distance/time
- _______________ = _______________ * _______________

- Speed of light \( (c) \) in vacuum = \( 3.8 \times 10^8 \) m/s
  (186,000 miles/second)
Problem #1: Visible Light

- Which color has the longest wavelength?
- Which color has the highest frequency?
- Which color has the highest speed?

http://science.hq.nasa.gov/kids/imagers/ems/index.html
We can only see a small amount of the light that surrounds us all the time.

http://science.hq.nasa.gov/kids/imagers/ems/index.html
Radio Waves

• Carry TV, AM & FM radio, cell phone, & other communication signals

• Used by radio telescopes to study radiation emitted by objects in space

Carbon Monoxide (CO) gases in our Milky Way galaxy
Problem #2: Radio

- What’s the frequency of your favorite radio station?
- Calculate its wavelength.
Microwaves

- Heat food by making molecules rotate fast
- Used to detect & measure distance to objects, such as airplanes & weather, with radar

http://science.hq.nasa.gov/kids/imagers/ems/micro.html
Microwaves

Background radiation in the universe gives clues to the Big Bang

http://missionscience.nasa.gov/ems/06_microwaves.html
Infrared Waves

- **Heat** – used to determine temperature of objects
- **Uses**
  - Keeping food, spaces, animals warm (heat lamps)
  - TV remote signal
  - Firefighting
  - Rattlesnakes use to detect warm-blooded animals
  - Remote sensing
    - Determine temperature of land, water
    - Map clouds, vegetation

Image of Phoenix (AZ) with near infrared as red

This false-color composite of Jupiter combines near-infrared and visible-light data of sunlight reflected from Jupiter's clouds. Since methane gas in Jupiter's atmosphere limits the penetration of sunlight, the amount of reflected near-infrared energy varies depending on the clouds' altitude. The resulting composite image shows this altitude difference as different colors. Yellow colors indicate high clouds; red colors are lower clouds; and blue colors show even lower clouds in Jupiter's atmosphere.

The Near Infrared Camera and Multispectral Imaging System (NICMOS) on NASA's Hubble Space Telescope captured this image at the 9th of a rare alignment of three of Jupiter's largest moons—Io, Ganymede, and Callisto—across the planet's face.

For more information on ocean temperatures, visit: http://www.osdpd.noaa.gov/ml/ocean/sst/sst_50km.html

For more information on Jupiter, visit: http://missionscience.nasa.gov/ems/07_infraredwaves.html
Infrared Imaging

• What object is in the image below?
Visible Light

Visible Light Region of the Electromagnetic Spectrum

- Only wavelengths we can see
- Sources: sun, light bulbs
- Uses
  - Human vision
  - Photosynthesis of plants
  - Remote sensing: map height of mountains, trees, clouds, etc.
Laser Altimetry (LiDAR)

Where are the tallest trees?

http://www.nasa.gov/topics/earth/features/forest-height-map.html

Outside Davenport, north of Santa Cruz 
www.nps.edu/Faculty/Olsen/Student_theses/11Sep_Harmon.pdf
Problem #3: Technology

- Choose one of the following devices
  - Bluetooth (2400 MHz)
  - GPS (1575.42 MHz)
  - Wi-Fi (5 GHz)

- What wavelength is this?
- What type of radiation is this?
Ultraviolet Light

- Causes sunburn
- Partially blocked by ozone in atmosphere
- Astronomers use to study stars

UV image of Earth taken from Moon

Bees can see UV!
Hubble Space Telescope

spiral galaxy Messier_100

stars forming in the Eagle Nebula

Wikipedia
X-Rays

- Image bones & teeth for medicine
- Astronomers use to study very hot objects such as stars, supernova & black holes
**Gamma Rays**

- **Sources:**
  - Radioactive atoms
  - Nuclear explosions
  - Lightning strikes
  - Supernova explosions (death of star)
  - Black holes

- **Uses:**
  - Detect spread of cancer
  - Kill cancer cells
  - Scan shipping containers for security
  - Detect elements on other planets
Mapping Vegetation

Normalized Difference Vegetation Index
NDVI = (NIR − Red) / (NIR + Red)

North America seasonal NDVI animation:
http://www.nasa.gov/topics/earth/features/obscure_data.html
Problem #4: Mapping Vegetation

- Calculate NDVI for the healthy tree.

- Calculate NDVI for the stressed tree.

Normalized Difference Vegetation Index

\[ \text{NDVI} = \frac{(\text{NIR} - \text{Red})}{(\text{NIR} + \text{Red})} \]

http://earthobservatory.nasa.gov/Experiments/ICE/panama/panama_ex2.php
Vegetation Index Products

Figure 1: NASA satellite image of the global biosphere in 2008. Green shading on land shows the normalized difference vegetation index (NDVI), which is strongly correlated with plant primary production. Blue shading in the oceans depicts surface chlorophyll concentrations; chlorophyll concentrations are directly related to the abundance of microscopic marine plants, or phytoplankton, and can be used to quantify marine primary production. (Courtesy of NASA Earth Observatory)
Activity:
Remote Sensing of Barro Colorado Island

NASA’s Rainforest at the Crossroads
http://earthobservatory.nasa.gov/Experiments/ICE/panama/
Visible Light Region of the Electromagnetic Spectrum

0.7 μm  0.6 μm  0.5 μm  0.4 μm
Infrared  |  |  |  Ultra Violet