Multispectral Remote Sensing

Lectures 5-6
September 12, 14, 2005
Multispectral Remote Sensing

- Multispectral remote sensing is defined as the collection of reflected, emitted, or backscattered energy from an object or area of interest in multiple bands of electromagnetic spectrum; while Hyperspectral remote sensing involves data collection in hundreds of bands.

- Instead of cameras and 1 or 4 bands for photogrammetry, Remote sensing use detectors that are sensitive to hundreds of bands in the electromagnetic spectrum. Measurements made by detectors are always stored in a digital format.
Remote Sensing Raster (Matrix) Data Format

Picture element (pixel) at location
Line 4, Column 4, in Band 1 has a Brightness Value of 24, i.e., \( \text{BV}_{4,4,1} = 24 \).

Jensen, 2000
Detector configurations: breaking up the spectrum

- **Discrete Detectors and scanning mirrors**
  - MSS, TM, ETM+, GOES, AVHRR, SeaWiFS, AMS, ATLAS

- **Linear Arrays**
  - SPOT, IRS, IKONOS, ORBIMAGE, Quickbird, ASTER, MISR

- **Liner and area arrays**
  - AVIRIS, CASI, MODIS, ALI, Hyperion, LAC
Types of Sensors

Scanning mirror and single discrete detectors (whiskbroom) and filters: 1 detector per spectral band. Rotating mirror changes the angle of the incident light (and therefore what portion of the ground is being detected). The length of time a detector measures a ground target is the dwell time. There are filters to restrict the wavelengths.

Pixel width is a function of the mirror rotation rate and the IFOV.
Pixel length is a function of the IFOV, sensor speed, and sampling rate.

Ustin, 2003
Types of Sensors

Scanning mirror and multiple discrete detectors (whiskbroom) and filters: uses a linear array of detectors for each spectral band. The mirror angles the light across these multiple detectors instead of just one. Uses filters to restrict the wavelengths for each band.

A pushbroom sensor may have thousands of detectors per spectral band, scanning mirror sensors usually only have a few. If there are 6 detectors per array, every 6th pixel in the image is from a given detector.
Types of Sensors

Scanning mirror and multiple discrete detectors (whiskbroom) and dispersing element: instead of wide band filters, a dispersing element (a prism) breaks the incoming light into component wavelengths. Light is dispersed across a linear array of detectors. A rotating mirror and forward movement create the spatial arrangement of pixels.

The advantage of a dispersing element vs. filters is that narrow bands can be detected in a small instrument.

Ustin, 2003
Types of Sensors

Linear array ("pushbroom"): has 1 row of detectors with one array per band (uses filters to restrict bandpass); the array moves forward with plane/satellite, and radiance is measured at regular intervals.

Pixel width is easily calculated. Pixel length is a function of the IFOV, forward speed, and detector sampling rate.

© CCRS / CCT
Types of Sensors

Hyperspectral area array: Combines a pushbroom linear array with a dispersing element.

Ustin, 2003
Field of View (FOV), Instantaneous Field of View (IFOV)
Dwell time is the time required for the detector IFOV to sweep across a ground cell. The longer dwell time allows more energy to impinge on the detector, which creates a stronger signal.

Sabin, 1997
IFOV and FOV

\[ \text{FOV} = 2 \tan^{-1} \left( \frac{D}{2f} \right) \text{ (degree)} \]

\[ \text{IFOV} = 2 \tan^{-1} \left( \frac{d}{2f} \right) \approx \frac{d}{f} \text{ (radians)} \] (d is the detector size, f is the focal length). The general unit of IFOV is milliradians \((10^{-3} \text{ radians})\).

\[ 1^\circ = 0.01745 \text{ radians} = 17.45 \text{ milliradians} \]

\[ 1 \text{ milliradian} = 0.057 \, ^\circ \]
### Comparing Sensor Types

<table>
<thead>
<tr>
<th>Sensor Type</th>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Digital Frame Camera Area Array</td>
<td>Well defined geometry; long integration time</td>
<td>Many detectors required</td>
</tr>
<tr>
<td>Linear Array (Pushbroom)</td>
<td>Uniform detector response in along-track direction; no mechanical scanner; somewhat long integration time</td>
<td>Many detectors per line required; complex optics</td>
</tr>
<tr>
<td>Whiskbroom: Scanning mirror and single discrete detector (filters)</td>
<td>Uniformity of detector response over the scene; simple optics</td>
<td>Short dwell time per pixel; high band width and time response of detector</td>
</tr>
<tr>
<td>Whiskbroom: Scanning mirror and multiple discrete detectors (filters)</td>
<td>Uniformity of detector response over swath; simple optics</td>
<td>High band width and time response of detector</td>
</tr>
<tr>
<td>Whiskbroom: Scanning mirror and discrete detectors (dispersing element)</td>
<td>Uniformity of detector response over the scene or swath; simple optics; more and narrower bands possible</td>
<td>Many detectors per line required; complex optics; high time response of detector</td>
</tr>
<tr>
<td>Hyperspectral Area Array</td>
<td>Uniform detector response in along-track direction; no mechanical scanner; somewhat long integration time; more and narrower bands possible</td>
<td>Many detectors per line required; complex optics</td>
</tr>
</tbody>
</table>

Ustin, 2003
Whiskbroom Sensors

• **LANDSAT (NASA)**
  - **Multispectral Scanner (MSS); LANDSAT 1-5**
    - 4 6-bit bands: 0.5-0.6 μm (green), 0.6-0.7 μm (red), 0.7-0.8 μm (NIR), 0.8-1.1 μm (NIR), 10.4-12.7 μm (TIR, LANDSAT 3 only)
    - IFOV = 79 x 79 m; swath width 185 km.
    - Images the earth about once every 18 days (LANDSAT 1-3); 16 days (LANDSAT 4-5); 1972 to 1983
  - **Thematic Mapper (TM); LANDSAT 4-5**
    - 7 8-bit bands: 0.45-0.52 μm (blue); 0.52-0.60 μm (green); 0.63-0.69 μm (red); 0.76-0.90 μm (NIR); 1.55-1.75 μm (Mid IR); 10.4-12.5 μm (TIR); 2.08-2.35 μm (Mid IR)
    - IFOV 30 x 30m (bands 1-5 and 7), 120 x 120m (band 6); swath width 185 km.
    - Images the earth once every 16 days; 1982 to present
  - **Enhanced Thematic Mapper Plus (ETM+); LANDSAT 6-7**
    - 8 8-bit bands: bands 1-7 are the same as TM; additional panchromatic band 8, 0.52-0.90 μm
    - IFOV 30 x 30m (bands 1-5 and 7), 60 x 60m (band 6), 15 x 15m (band 8); swath width 185 km.
    - Images the earth once every 16 days; 1999 to present

Ustin, 2003
# Landsat satellite series

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<thead>
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<th></th>
<th>MSS</th>
<th>TM</th>
<th>ETM+</th>
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</thead>
<tbody>
<tr>
<td>0.5-0.6</td>
<td>0.45-0.52</td>
<td>0.45-0.52</td>
<td></td>
</tr>
<tr>
<td>0.6-0.7</td>
<td>0.52-0.60</td>
<td>0.52-0.61</td>
<td></td>
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<tr>
<td>0.7-0.8</td>
<td>0.63-0.69</td>
<td>0.63-0.69</td>
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<tr>
<td>0.8-1.1</td>
<td>0.76-0.90</td>
<td>0.78-0.90</td>
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</tr>
<tr>
<td>10.4-12.6</td>
<td>1.55-1.75</td>
<td>1.55-1.75</td>
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<td>10.4-12.5</td>
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<td></td>
<td>2.08-2.35</td>
<td>2.09-2.35</td>
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<tr>
<td></td>
<td></td>
<td>0.52-0.90</td>
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<table>
<thead>
<tr>
<th></th>
<th>79m</th>
<th>30</th>
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<tr>
<td>240m</td>
<td>120</td>
<td>60</td>
<td>15</td>
</tr>
<tr>
<td>6 bits</td>
<td>8</td>
<td>8</td>
<td>8</td>
</tr>
<tr>
<td>103 m/c</td>
<td>99</td>
<td>99</td>
<td>99</td>
</tr>
<tr>
<td>18 days</td>
<td>16</td>
<td>16</td>
<td>16</td>
</tr>
<tr>
<td>919km</td>
<td>705</td>
<td>705</td>
<td>705</td>
</tr>
<tr>
<td>185km</td>
<td>185</td>
<td>185</td>
<td>185</td>
</tr>
</tbody>
</table>

Launch and Retirement Dates:
- Landsat 1 - July 23, 1972, to January 6, 1978
- Landsat 2 - January 22, 1975, to July 27, 1983
- Landsat 3 - March 5, 1978, to September 7, 1983
- Landsat 4 - July 16, 1982
- Landsat 5 - March 1, 1984
- Landsat 6 - October 5, 1993, did not achieve orbit
- Landsat 7 - April 15, 1999
Inclination (99°) of the Landsat Orbit to Maintain A Sun-synchronous Orbit

- Sun-synchronous orbit mean that the orbital plane processed around Earth at the same angular rate at which Earth moved around the Sun
- The satellite cross the equator at approximately the same local time (9:30 to 10:00 am)
Today’s Landsat 7 orbits and acquisition

TexasView Remote Sensing Consortium

Free Landsat 7 imagery available from TexasView

Advantages of ETM+ over TM

- Increased spatial resolution of thermal IR (band 6) data from 120m to 60m.
- Improved radiometric calibration process.
- Addition of panchromatic (band 8) data at 15m spatial resolution.
- Improved band-to-band registration will assist in generating the merged (Pan + multispectral) products quicker and more accurately.
- Two gain states - low gain and high gain. For thermal band data (band 6), both low and high gain data are available by default. For other bands (1 to 5, and 7) the satellite will acquire image data in one of two possible gain settings. The low gain setting measures a greater radiance range but with decreased sensor sensitivity, while high gain measures a lesser radiance range but with increased sensitivity.
Currently implemented gain setting strategy for Landsat 7

- Based on surface cover types of the earth and the sun elevation angle. The gains for bands 1-3 are currently always changed together as are the gains for bands 5 and 7.
- Cover types:
  - Land (non-desert, non-ice)
  - Desert
  - Ice/Snow
  - Water
  - Sea ICE
  - Volcano/Night
- Each Landsat-7 Path/Row of the Worldwide Reference System (WRS) is categorized into one of these six types.
Whiskbroom Sensors

- Geostationary Operational Environmental Satellites (GOES, NOAA)
  - GOES Imager
    - 5 10-bit bands: 0.52-0.72 μm (green and red), 3.78-4.03 μm (TIR), 6.47-7.02 μm (TIR), 10.2-11.2 μm (TIR), 11.5-12.5 μm (TIR)
    - IFOV 1 x 1 km (band 1), 4 x 4 km (bands 2, 4 and 5), 8 x 8 km (band 3); 2 satellites (GOES East and GOES West) swath width 8 km. per scan line; total coverage for GOES East and West 20°W to 165°E, 77° N to 77°S.
    - Scans continental U.S. every 15 minutes, most of northern hemisphere every 30 minutes, all of hemisphere every 3 hours; 1994 to present
  - GOES Sounder
    - 19 13-bit bands: 1 visible and 18 TIR
    - IFOV 8 x 8 km, same swath as GOES Imager.
    - Same repeat time as GOES Imager
Welcome to the Geostationary Operational Environmental Satellites (GOES) spacecraft status page. This site provides up to date status information on each spacecraft and its various subsystems.

Select a spacecraft from the list below for a detailed status summary of that spacecraft. For more advanced reporting, select the Filter link.

<table>
<thead>
<tr>
<th>Spacecraft</th>
<th>Operational Status</th>
<th>Status</th>
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<tbody>
<tr>
<td>GOES 8</td>
<td>Decommissioned</td>
<td>RED</td>
</tr>
<tr>
<td>GOES 9</td>
<td>Backup</td>
<td>YELLOW</td>
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<tr>
<td>GOES 10</td>
<td>Operational West</td>
<td>GREEN</td>
</tr>
<tr>
<td>GOES 11</td>
<td>Stored</td>
<td>GREEN</td>
</tr>
<tr>
<td>GOES 12</td>
<td>Operational East</td>
<td>GREEN</td>
</tr>
</tbody>
</table>

http://www.oso.noaa.gov/goesstatus/
GOES
Hurricane Katrina in the Gulf of Mexico
Credit: GOES 12 Satellite, NASA, NOAA

Whiskbroom Sensors

• TIROS-N, NOAA 8-15
  - Advanced Very High Resolution Radiometer (AVHRR, NOAA)
    • 4-5 10-bit bands: 0.58-0.68 μm (green and red),
      0.725-1.10 μm (NIR), 3.55-3.93 μm (Mid IR),
      10.50-11.50 μm (NOAA 6,8,10) or 10.30-11.30 μm
      (NOAA 7,9,11,12-15) (TIR), 11.50-12.50 μm
      (NOAA 7,9,11,12-15) (TIR)
    •IFOV 1.1 x 1.1 km, swath width 2700 km
    • Images the earth once every 24 hours; 1978 to present
Advanced Very High Resolution Radiometer (AVHRR) Bandwidths

Jensen, 2000

1.1 km
Global Normalized Difference Vegetation Index (NDVI) Image Produced Using Advanced Very High Resolution Radiometer (AVHRR) Imagery

Jensen, 2000
Whiskbroom Sensors

- SeaStar (ORBIMAGE, Inc. and NASA)
  - Sea-viewing Wide Field of view Sensor (SeaWiFS)
    - 8 10-bit bands: bandcenter (nm) 412, 443, 490 (blues), 510, 555 (greens), 670 (red), 765, 865 (near IRs); bandwidth 20 nm (bands 1-6) and 40 nm (bands 7-8)
    - IFOV 1.13 x 1.13 km; swath width 2800 km
    - Images the earth once every 24 hours
California Watersheds and Calibrated SeaWiFS Sediment Concentration 09-02-1998
Global Chlorophyll $a \, (g/m^3)$ Derived from SeaWiFS Imagery
Obtained from September 3, 1997 through December 31, 1997
Pushbroom Sensors

- **SPOT** (French, CNES) 1-5
  - **High-resolution visible** (HRV, SPOT 1-3)
    - 4 8-bit bands: 0.50 – 0.59 μm (green), 0.61-0.68 μm (red), 0.79-0.89 μm (NIR), 0.51-0.73 μm (panchromatic).
    -IFOV 20 x 20m (bands 1-3, SWIR band), 10 x 10m (pan); swath width 60 km +/- 50.5° (max 80 km).
    - Images the earth once every 26 days; 1986 to present
  - **HRVIR** (SPOT 4-5)
    - 5 8-bit bands: green, red and NIR HRV bands (no 0.51-0.73 μm band) plus an additional 1.58-1.75 μm (SWIR) band.
    - IFOV same as HRV, 0.61-0.68 μm band can run in 10 x 10m resolution, SWIR band 20 x 20 m; swath width 60 km +/- 27°.
    - Same repeat as HRV; 1998 to present
  - **Vegetation** (SPOT 4-5)
    - 4 8-bit bands: 0.43-0.47 μm, 0.61-0.68 μm, 0.78-0.89 μm, 1.58-1.75 μm
    - IFOV 1.15 x 1.15 km; swath width 2250 km +/- 50.5°
    - Same repeat and life as HRVIR
  - **HRS** (SPOT 5)
    - 1 8-bit band: 0.49-0.69 μm
    - IFOV 10 x 10 m; swath width 120 km
    - Same repeat as HRVIR, 2002 to present
SPOT Satellite System Components

b. Vertical viewing

Oblique viewing

HRV 1 (SPOT 1-3) or HRVIR 1 (SPOT 4)

HRV 2 (SPOT 1-3) or HRVIR 2 (SPOT 4)

Vegetation sensor (SPOT 4)

a. Calibration unit

HRV or HRVIR sensors

Bus

Solar panel

Orbit

60 km swath width
3 km overlap
117 km total width

Equator

60 km

Oblique viewing

Vertical viewing

b.

c. SPOT Nadir Viewing

Jensen, 2000

Courtesy of SPOT Image, Inc.
Geographic Coverage of the SPOT HRV and Landsat Thematic Mapper Remote Sensing Systems

Jensen, 2000
Pushbroom Sensors

• EOS Terra
  – **ASTER**
    • 15 8-bit (VNIR and SWIR), 12-bit (TIR) bands: 4 VNIR (1 NIR off-nadir); 6 SWIR; 5 TIR
    • IFOV 15 x 15m (VNIR), 30 x 30m (SWIR), 90 x 90m (TIR); swath width 60 km.
    • Images are not acquired based on researcher scheduling; 1999 to present
  – **MISR**
    • 4 VNIR bands at 9 different angles
    • IFOV 275 x 275 m to 1.1 x 1.1 km (depending on view angle); swath width 360 km.
    • 9 day global coverage; 1999 to present
Terra Satellite

- MODIS
- ASTER (TIR)
- ASTER (SWIR)
- ASTER (VNIR)
- MISR
- MOPITT
- CERES
ASTER Characteristics

- **Wide Spectral Coverage**
  
  3 bands in VNIR (0.52 – 0.86 μm)
  
  6 bands in SWIR (1.6 – 2.43 μm)
  
  5 bands in TIR (8.125 – 11.65 μm)

- **High Spatial Resolution**
  
  15m for VNIR bands
  
  30m for SWIR bands
  
  90m for TIR bands

- **Along-Track Stereo Capability**
  
  B/H 0.6
  
  DEM Elevation accuracy: 15m (3σ)
  
  DEM Geolocation accuracy: 50m (3σ)
<table>
<thead>
<tr>
<th></th>
<th>ASTER</th>
<th>TM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Repeat Orbit:</td>
<td>16 d</td>
<td>16 d</td>
</tr>
<tr>
<td>Scene</td>
<td>60km</td>
<td>185km</td>
</tr>
<tr>
<td>Bands:</td>
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<tr>
<td>Pan</td>
<td>0</td>
<td>15m</td>
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<tr>
<td>VIS</td>
<td>2 15m</td>
<td>3 30m</td>
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<tr>
<td>NIR</td>
<td>1 30m</td>
<td>1 30m</td>
</tr>
<tr>
<td>*SWIR</td>
<td>6 30m</td>
<td>2 30m</td>
</tr>
<tr>
<td>*TIR</td>
<td>5 90m</td>
<td>1 90m</td>
</tr>
</tbody>
</table>

![Graph showing reflectance vs. wavelength with ASTER and TM data]
ASTER Images of San Francisco Bay

False Color Image (VNIR)  Sediment Load (VNIR)  Water Temperature (TIR)
9 view angles at Earth surface

7 minutes to view each scene from all 9 angles

Multi-angle Imaging Spectro-Radiometer
Multi-angle Imaging Spectroradiometer (MISR) Onboard Terra

Nadir is the point of the Earth surface that is vertically downward from the observer

<table>
<thead>
<tr>
<th>Sensors</th>
<th>Df</th>
<th>Cf</th>
<th>Bf</th>
<th>Af</th>
<th>An</th>
<th>Aa</th>
<th>Ba</th>
<th>Ca</th>
<th>Da</th>
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<tbody>
<tr>
<td>View angle</td>
<td>70.5°</td>
<td>60°</td>
<td>45.6°</td>
<td>26.1°</td>
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<td>26.1°</td>
<td>45.6°</td>
<td>60°</td>
<td>70.5°</td>
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<td>425 – 467 nm</td>
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<td>543 – 571 nm</td>
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<td>660 – 682 nm</td>
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<tr>
<td>846 – 886 nm</td>
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</tr>
</tbody>
</table>

Jensen, 2000

f: forward, a: after
Pushbroom Sensors

• Hyperspatial sensors
  – Quickbird
    • 5 11-bit bands: Blue, Green, Red, NIR, panchromatic
    • IFOV 2.44 m VNIR, 61 cm (that’s not a typo!) panchromatic; swath width 16.5 km +/- 25°
    • Revisit time 2 to 11 days; 2000 to present
  – IKONOS
    • 5 11-bit bands: Blue, Green, Red, NIR, panchromatic
    • IFOV 4.0 m VNIR, 1.0 m panchromatic; swath width 11.3 km +/- 26°
    • Revisit time ~ 3 days; 1999 to present
IKONOS Panchromatic Images of Washington, DC

1 x 1 m spatial resolution

Jensen, 2000
IKONOS Panchromatic Stereopair of Columbia, SC Airport

Jensen, 2000

November 15, 2000
IKONOS Imagery of Columbia, SC Obtained on October 28, 2000

Panchromatic 1 x 1 m

Pan-sharpened multispectral 1 x 1 m
Linear and Area Arrays

• EOS Terra
  – Moderate Resolution Imaging Spectrometer (MODIS, NASA)
    • 36 12-bit bands: 0.620 μm – 14.385 μm
    • IFOV: 2 250 x 250 m VNIR bands, 5 500 x 500 m VNIR bands, 29 1 x 1 km VNIR/TIR bands; swath width 2330 km
    • Earth images once every 2 days; 1999 to present

Terra launched 12/18/1999
MODIS Nadir BRDF-Adjusted Reflectance

May 25–June 9 2001
False Color Image
NIR–Red–Green
Extended Summer Drought will increase frequency and intensity of wildfires

MODIS Composite Image
October 27, 2003
Earth Observing System Aqua – PM (launched 5/4/02)

- mission is collecting about the Earth's water cycle, including evaporation from the oceans, water vapor in the atmosphere, clouds, precipitation, soil moisture, sea ice, land ice, and snow cover on the land and ice. Additional variables also being measured by Aqua include radiative energy fluxes, aerosols, vegetation cover on the land, phytoplankton and dissolved organic matter in the oceans, and air, land, and water temperatures.

- The six instruments are:
  - **AIRS**: the Atmospheric Infrared Sounder
  - **AMSU-A**: the Advanced Microwave Sounding Unit,
  - **HSB**: the Humidity Sounder for Brazil,
  - **AMSR-E**: the Advanced Microwave Scanning Radiometer for EOS,
  - **MODIS**: the Moderate-Resolution Imaging Spectroradiometer, and
  - **CERES**: Clouds and the Earth's Radiant Energy System.


All Terra and Aqua and many other data can be downloaded from: [http://edcimswww.cr.usgs.gov/pub/imswelcome/](http://edcimswww.cr.usgs.gov/pub/imswelcome/)
Earth Observing System Aura
(launched 7/15/04)

- The Aura mission researches the composition, chemistry and dynamics of the Earth’s atmosphere as well as the ozone, air quality and climate.
- The six instruments are
  - HIRDLS: HIgh Resolution Dynamics Limb Sounder
  - MLS: Microwave Limb Sounder
  - OMI: Ozone Monitoring Instrument
  - TES: Tropospheric Emission Spectrometer

Information about Aura: http://aura.gsfc.nasa.gov/index.html
### Summary

#### Land Observing Sensors and their Features

<table>
<thead>
<tr>
<th>Sensor Name</th>
<th>Pixel Resolution</th>
<th>Swath Width, km</th>
<th>No. Spectral Bands</th>
<th>Spectral Coverage</th>
<th>Temporal Repeat, days</th>
</tr>
</thead>
<tbody>
<tr>
<td>AVHRR</td>
<td>1.1km</td>
<td>2700</td>
<td>5</td>
<td>VNIR, TIR</td>
<td>4&quot;day</td>
</tr>
<tr>
<td>SPOT Vegetation</td>
<td>1.15km</td>
<td>2250</td>
<td>4</td>
<td>VNIR, SWIR</td>
<td>26</td>
</tr>
<tr>
<td>MODIS</td>
<td>0.25,0.5,1km</td>
<td>2330</td>
<td>36</td>
<td>VNIR, SWIR, TIR</td>
<td>2&quot; day</td>
</tr>
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#### Regional Satellites

<table>
<thead>
<tr>
<th>Sensor</th>
<th>m</th>
<th>km</th>
<th>bands</th>
<th>Spectral Coverage</th>
<th>Repeat</th>
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<tbody>
<tr>
<td>ASTER</td>
<td>15, 30, 90</td>
<td>60</td>
<td>16</td>
<td>VNIR, SWIR, TIR</td>
<td>16</td>
</tr>
<tr>
<td>Landsat TM</td>
<td>30, 120</td>
<td>185</td>
<td>7</td>
<td>VNIR, SWIR, TIR</td>
<td>16</td>
</tr>
<tr>
<td>Landsat ETM+</td>
<td>30, 60, 15</td>
<td>185</td>
<td>8</td>
<td>Pan + TM</td>
<td>16</td>
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<tr>
<td>SPOT HRV</td>
<td>10, 20</td>
<td>60</td>
<td>4</td>
<td>Pan, VNIR</td>
<td>26</td>
</tr>
<tr>
<td>SPOT HRVIR</td>
<td>10, 20</td>
<td>60</td>
<td>5</td>
<td>SWIR + HRV</td>
<td>26</td>
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</table>

#### Local Coverage Satellites

<table>
<thead>
<tr>
<th>Sensor</th>
<th>m</th>
<th>km</th>
<th>bands</th>
<th>Spectral</th>
<th>Repeat</th>
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<tbody>
<tr>
<td>Quickbird</td>
<td>0.61 Pan, 2.44</td>
<td>16.5</td>
<td>5</td>
<td>Pan, VNIR</td>
<td>2 to 11</td>
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<tr>
<td>IKONOS</td>
<td>1.0 Pan, 4</td>
<td>11.3</td>
<td>5</td>
<td>Pan, VNIR</td>
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#### AIRBORNE Instruments

<table>
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<tr>
<th>Sensor</th>
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<th>bands</th>
<th>Spectral Coverage</th>
<th>Repeat</th>
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<tbody>
<tr>
<td>AVIRIS, Hymap</td>
<td>4, 20</td>
<td>2 km, 10 km</td>
<td>168 - 224</td>
<td>VNIR, SWIR</td>
<td>on demand</td>
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<tr>
<td>CASI-2</td>
<td>5-Jan</td>
<td>1 km - 2.5 km</td>
<td>48-288</td>
<td>VNIR</td>
<td>on demand</td>
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<tr>
<td>ADAR-5500</td>
<td>0.5 - 3</td>
<td>1 km - 2.5 km</td>
<td>4</td>
<td>VNIR</td>
<td>on demand</td>
</tr>
</tbody>
</table>

Ustin, 2003
Watching a movie about satellite, sensors and applications from NASA

About 15 minutes