Introduction to Remote Sensing
Synopsis of Class 19, GIS in Water Resources, Fall 2011

The purpose of this lecture is to provide background information on remote sensing and its uses. Remotely sensed images are recorded from a distance, and are referred to as *remotely sensed* data, as compared to information recorded on-site using gaging or sampling that is referred to as *directly sensed* data. Remotely sensed data acquisition is done without making physical contact with the object. The most common type of remotely sensed information is aerial and satellite images, which provide a permanent record of spatial and attribute data for the regions they depict. The lecture will describe the electromagnetic spectrum used for remote sensing and measures used to describe remote sensing images. The lecture will also describe common airborne and satellite remote sensing systems and some typical applications of remote sensing data in water resources including mapping or monitoring land cover/land use, measuring biomass area and volume, surface temperature, and extent and impact of natural hazards (i.e. storm, fire).

Light is the principal energy form detected in remote sensing. Sensors record the amount of reflected electromagnetic energy from an object or surface, which is used to create an image. Light energy is characterized by its wavelength, the distance between peaks in the wave forms making up the electromagnetic spectrum. Each color of light has a distinctive wavelength. For instance, the human eye perceives light with a wavelength between 0.4 and 0.7 micrometers in the visible portion of the electromagnetic spectrum.

The data recorded by the sensor system are brightness values obtained using a scanner and could be in the form of *analog* (e.g. hardcopy, aerial photography, video data) or *digital* information (sequences or arrays of numbers). Data is collected using either active or passive remote sensing instruments. *Passive sensors* record electromagnetic radiation that is reflected or emitted by the object. They usually rely on solar energy, so they are not very useful during cloudy or extremely hazy periods. Cameras, radiometers, spectrometers, and spectroradiometers are some examples of passive sensors. *Active sensors* emit the energy to scan or to illuminate the objects and surfaces. They send a pulse of energy from the sensor to the object, and measure the radiation that is reflected or backscattered. Active sensors measure the time delay between emission and backscattered pulses to determine the distance to the object. Data from active sensors can be used to measure location, height, speed, and direction of movement of an object or surface. LIDAR (Light Detection and Ranging) and RADAR (Radio Detection and Ranging), Scatterometer, and Laser Altimeters are examples of active sensors. For instance, LIDAR can determine the properties of clouds, and some of the constituents of atmosphere and atmospheric profiles through which the laser beam passes. Laser altimeters use LIDAR to determine the topography of the underlying surface.

When discussing and comparing remote sensing systems and the images produced, there are least four measures that need to be considered, including spatial resolution, spectral response, spectral resolution, and frequency of coverage (temporal resolution). The first measure, *spatial resolution* refers to size of smallest object that can be distinguished in an image produced by remote sensing. The *spectral response* refers to the ability of a remote sensing system to respond to incoming radiation, and to collect radiation measurements within a particular wave length band that will correspond to a meaningful property. For instance, some sensors produce *panchromatic* images created from radiation sensed within a spectral band that extends from 0.45 to 0.90 nm, in other words black and white images that sense radiation across all wave-lengths of visible light. The blue, green, red and near-infrared wave-length bands lie within or near the panchromatic band and are of particular interest in sensing agricultural crop production. *Spectral resolution* refers to the number of different intensities of radiation the sensor is able to distinguish. Typically, this ranges from 8 to 14 bits, corresponding to 256 levels of the gray scale and up to 16,384 shades of color, in each band. The last measure, *frequency of coverage*, is a measure of "how often" a remote sensing system can be available to collect data from a particular site on the ground.

There are several airborne and satellite remote sensing systems that are operational or under development providing data on land surface, weather, oceans and other features of earth. A number of factors including spectral range, price, availability, reliability and flexibility are important in deciding between aerial and satellite images. Aerial images are the main source of coordinate and attribute data, and provide more detailed information than satellite images. National, state, and local governments are the main source of aerial images. For example, the *National Aerial Photography Program* (NAPP) provides full coverage of the lower 48 United States at 1:40,000 scale (color infrared aerial photographs with stereographic coverage) at 5 to 10 year return intervals.

Satellite systems provide a broader range of spatial, spectral and temporal data relative to aerial images, and cover large areas. Satellite images are often used to create or update landcover classification, and to detect and monitor change over large areas. *LANDSAT*, the first land remote sensing system, is a series of satellites put into orbit around the earth to collect environmental data about the earth's surface. The LANDSAT program was initiated by the U.S. Department of Interior and NASA under the name ERTS, Earth Resources Technology Satellites. ERTS-1 (later renamed to Landsat) was launched on July 23, 1972, and was the first unmanned satellite designed solely to acquire earth resources data on a systematic, repetitive, and multispectral basis. The most recent Landsat satellite, Landsat 7, was launched on April 15, 1999, and added a 15m resolution panchromatic band, and an enhanced resolution of the thermal band (at 60 m resolution), as compared to Landsat 6. Landsat data have been used widely to study agriculture, geology, forestry, regional planning and mapping, and global change. The US Geological Survey (USGS) is the distributor for the data. The USGS now offers, at no cost, Orthorectified Landsat 4, 5 and 7 satellite data. The data is available for free download from the Global Visualization Viewer (GloVis) at http://glovis.usgs.gov and Earth Explorer at http://earthexplorer.usgs.gov. One disadvantage of landsat data is limited availability of usable images. The return interval to any one location is every 16 days, but cloud cover may result in the interval between usable images being significantly more than this.

Other satellites such as SPOT, Terra, AVHRR, Ikonos, Quickbird, and many more have been developed over the years. SPOT and Terra are two widely used satellites providing coarse resolution data. The *Moderate Resolution Imaging Sensor* (MODIS) is a NASA instrument aboard the Terra (EOS AM) and Aqua (EOS PM) satellites. The Terra satellite passes from north to south across the equator in the morning. The Aqua satellite passes south to north over the equator in the afternoon. Terra MODIS and Aqua MODIS view the entire Earth's surface every 1 to 2 days, acquiring data in 36 spectral bands, ranging from 0.4 to 14.4 microns. The spatial resolution of MODIS data depends on each band, and varies from 250 meters (the red and infrared portion of light spectrum) to 1 kilometer. The VEGETATION instrument on SPOT was launched by French national space agency (CNES), and provides daily coverage of data since 1996. The data comes in the blue, red, near-infrared, and short wave infrared portion of the spectrum, and has been used to study changes in crop yields and forests, and their interaction with climate.