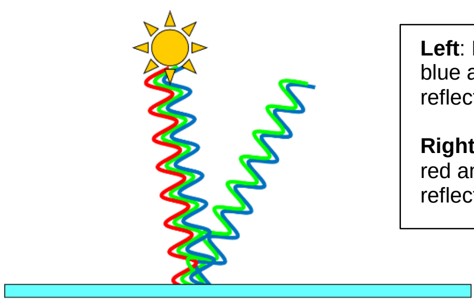
Differential Reflectivity

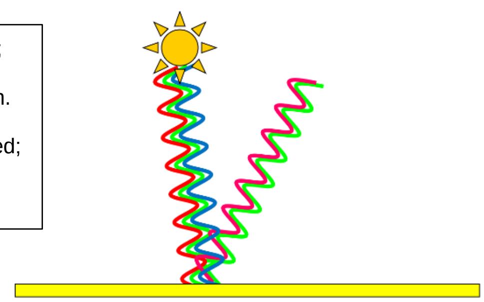
An important idea in remote sensing is that each surface feature and atmospheric component has a unique **spectral signature**. Each is composed of molecules with different atomic arrangements, sizes and shapes, and built with atoms in different combinations of elements. The chemical bonds of each absorb energy of specific wavelengths or wavelength combinations. Other wavelengths either pass through unhindered or are said to be reflected. If it were possible to detect the particular combination of wavelengths reflected from each object, might it also be possible to differentiate one object from another based on those reflections? This is what our eyes do with visible light waves.

Remember, “white” is a combination of equal amounts of the primary colors of visible light: red, green and blue. When “white light” reaches an object that appears cyan (green-blue) in color, we see the green and blue light reflected from the object. The red light is absorbed (not reflected). Most absorbed radiation is converted to heat. Similarly, when something appears yellow (red-green), blue light is absorbed by the object. The first object has a spectral signature we might call “cyan;” the spectral signature of the second might be called “yellow.” Green chlorophyll in plants appears green when most green and some blue wavelengths are reflected while most red wavelengths are absorbed.



Left: Red wavelengths are absorbed; blue and green wavelengths are reflected; surface appears blue-green.

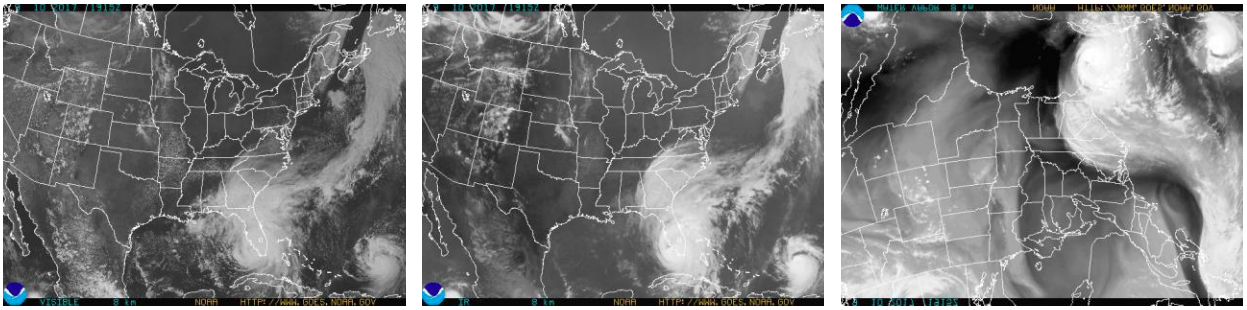
Right: Blue wavelengths are absorbed; red and green wavelengths are reflected; surface appears yellow.



If we had eyes that could “see” various infrared wavelengths in addition to visible light, how differently might things appear? What if those special “eyes” could also sense the intensity of each group of wavelengths detected? Technologies are currently available to do just that. And when those special “eyes” are flown on Earth-orbiting satellites, they produce images of the Earth in a detail we could only imagine a century ago. The concept is reflectivity. The technology is remote sensing.

Remote sensing has to do with detecting just the wavelengths of radiation reflected by various surface features and atmospheric components. Imagine installing filters that allow only selected bands of wavelengths to reach the sensor. Then the sensor “sees” only certain portions of the reflected electromagnetic spectrum.

For example, a typical sensor on many weather satellites works with three filtering mechanisms. One allows only visible light in the waveband that includes red, green and blue wavelengths to reach the sensor. The resulting grey tone image shows the surface and clouds as they would appear in a black and white photograph like the left image below. Another filter allows only reflected thermal infrared wavelengths to reach the sensor producing the center image below in which pixels appearing whiter indicate colder temperatures. The third filter allows only the wavelengths of radiation that reflect from water molecules in the atmosphere. The brighter pixels in right image below indicate greater concentrations of atmospheric water vapor. The imager on geostationary weather satellites orbiting at an altitude of almost 36,000 km (more than 22,000 miles) is such an instrument. It collects data for all three images simultaneously. This GOES imagery array is available every 5 or so making predictions of storm formation and behavior easier and more accurate.

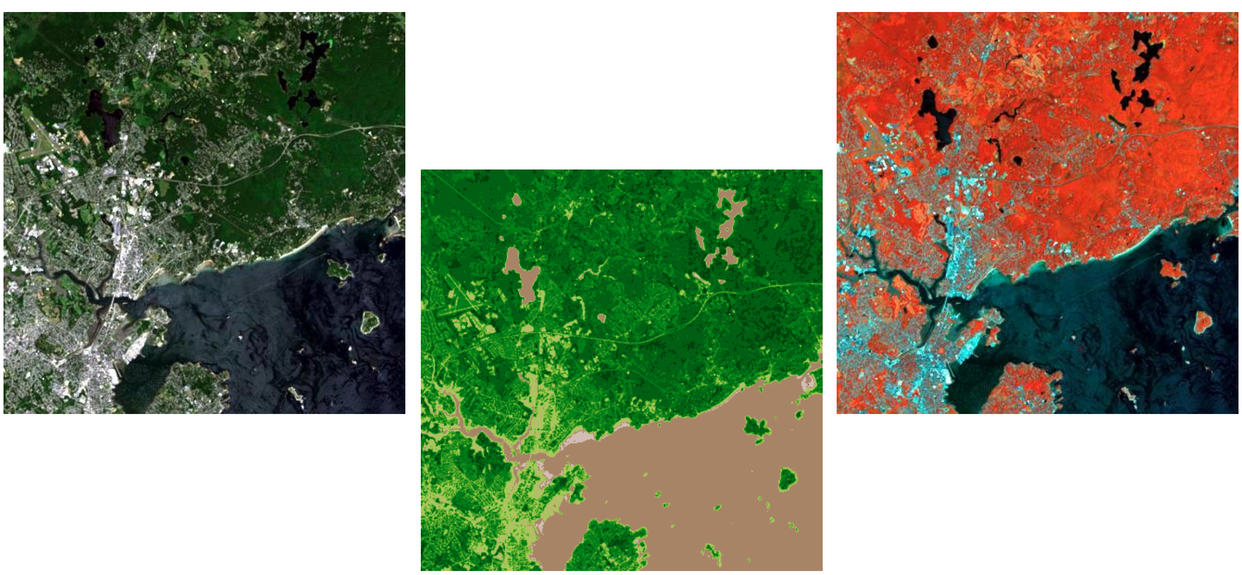


GOES images – Left: Visible light; Center: Thermal infrared; Right: Water vapor

Remote sensors on a host of other environmental satellites provide more detailed information about the atmosphere and properties of various surface features. For example, the newest series of geostationary weather satellites began with GOES-16 launched November 29, 2016, sending a continuous stream of data for not three but 34 baseline products.

Another example is a series of Earth Resources Observation Satellites or Landsat. The Operational Land Imager (OLI) and the Thermal Infrared Sensor (TIRS) on Landsat 8 produce multispectral data sets with eleven wavebands: visible (red, green, blue, deep blue), six infrared, and a panchromatic band. Specialized computer software allows viewing these wavebands three at a time by assigning each to the red, green and blue colors displayed on the computer monitor. The resulting false color images are useful for highlighting and measuring features that may otherwise go unnoticed.

Examine the Landsat images below. The left image is a true color, visible light image where red in the image on the computer screen is red light reflected from surface features, green is green, and blue is blue. In the right image, near infrared (invisible to the human eye) appears red, while visible green still appears green and visible blue appears blue. Reflected visible red light is not shown at all in the right image. Notice that this false color image shows that most of the green plants reflect a great deal of near infrared but rooftops do not. In the center image, software algorithms are employed to produce a normalized difference vegetative index (NDVI) image showing chlorophyll reflectivity. The color palette selected for this false color image allows vegetation to appear green and non-vegetation to appear brown. The darker green the pixel appears, the greater the density of green chlorophyll-based vegetation in that pixel.



Landsat images -- Left: True color, RGB (4,3,2); Center: NDVI; Right: False color, RGB (5,3,2);

The chart below shows principal applications of wavebands from Landsat 5 and 7 satellites as well as those of Landsat 8-9. In other words, which surface features typically reflect which specific wavebands.

Band Number		Band	Principal Applications
Landsat 5,7	Landsat 8-9		
	1	Ultra-blue	Useful for mapping water near coasts and in aerosol studies
1	2	Blue visible light	Useful for mapping water near coasts, differentiating deciduous from coniferous vegetation, differentiating between soil from plants, and identifying human made objects such as roads and buildings (cultural features)
2	3	Green visible light	Useful for differentiating types of plants, determining peak vegetation and the health of plants, and identifying cultural features
3	4	Red visible light	Useful for differentiating plant species, differentiation and identification of cultural features
4	5	Near-infrared energy	Useful for determining plant types and plant health and for seeing the boundaries of bodies of water.
5	6	Shortwave-infrared energy 1	Useful for distinguishing snow from clouds, determining vegetation and soil moisture content
6	10-11	Thermal-infrared energy	Useful in determining relative temperature and determining the amount of soil moisture.
7	7	Shortwave-infrared energy 2 (longer wavelength than band 5)	Useful for differentiating between mineral and rock types and telling how much moisture plants are retaining
8	8	Panchromatic	Useful for sharper image definition with higher spatial resolution
	9	Cirrus	Useful for differentiating cirrus clouds from others

Since the first satellite-based television image of the Earth in 1960, the knowledge base about differential reflectivity of the Earth and atmosphere has increased significantly. Technological advances in sensor design during the same period of time have kept pace. Various surface features and atmospheric components reflect unique combinations of electromagnetic spectrum wavelengths called spectral signatures. This is **differential reflectivity**, a concept that augments the task of differentiating one object or area from another in a satellite-based remote sensing image.

Credits:

GOES imagery from NOAA's GOES Server. Retrieved September 21, 2017 from http://www.goes.noaa.gov/

Landsat 8 images from USGS using GloVis

Lillesand, Thomas M. & Kiefer, Ralph W. *Remote Sensing and Image Interpretation.* 2nd edition. New York: John Wiley and Sons, 1987.

"What are the band designations for Landsat satellites?" Landsat Missions, USGS. Retrieved August 2018 from https://landsat.usgs.gov/what-are-band-designations-landsat-satellites