Expedition Earth and Beyond: An Introduction To Remote Sensing

Dr. William L. Stefanov
Image Science & Analysis Laboratory/ESCG
NASA Johnson Space Center
Houston, TX 77058

Scan for life forms…

We aren't quite there yet, but science fiction uses (fictional) *remote sensing* **- getting information about a material or surface without physically touching it -** quite a bit. What can we really do with remote sensing?

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Geoscientists Use Remote Sensing For…

Geologic Mapping
- bedrock, structure

Resource Assessment
- mineralogy, structure, vegetation

Hazard Assessment
- volcanoes, earthquakes, floods, disease

Land Cover Mapping/Change
- ecology, urbanization, vegetation

Geomorphology/Landscape Characterization
- particle size, mineralogy, topography

Soil Mapping
- agriculture, soil moisture, soil development

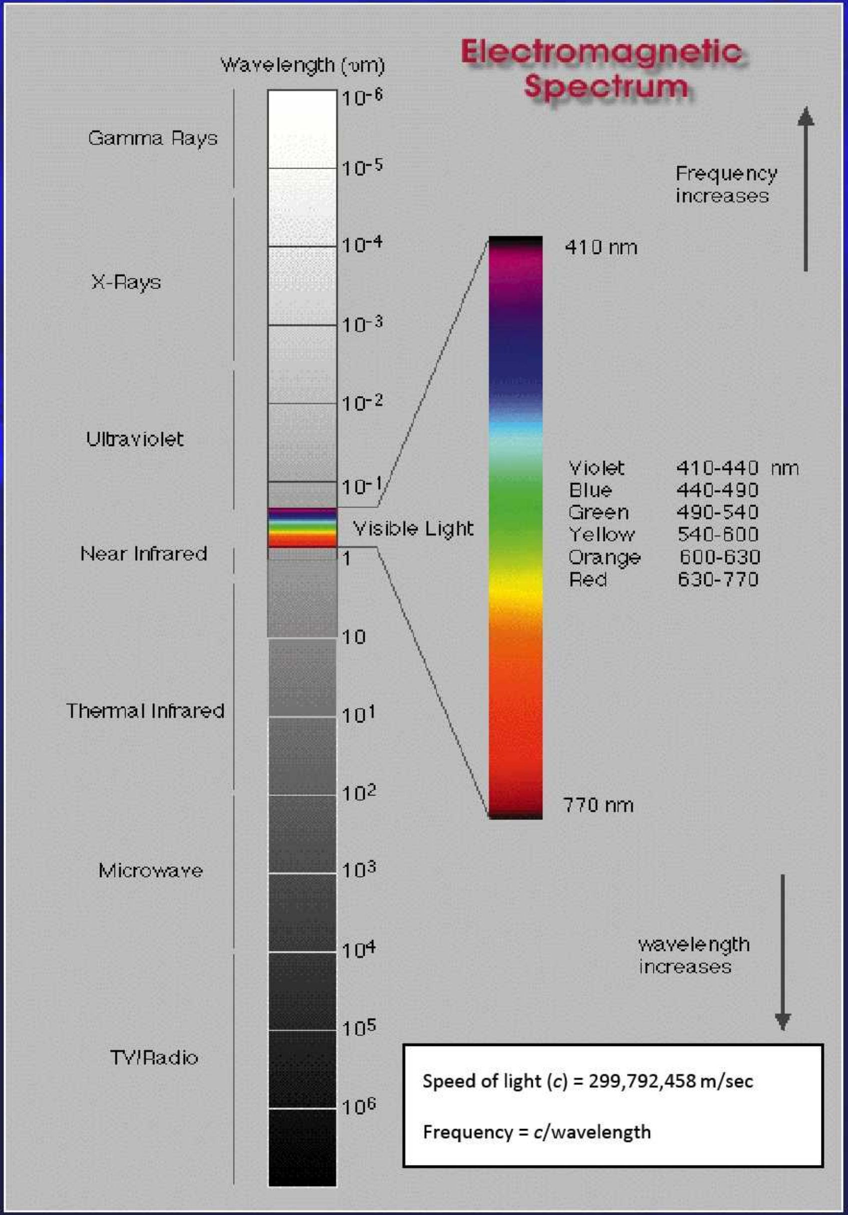
Hydrology
- drainage networks, vegetation, land cover, floods

Climatology
- surface temperature, precipitation, surface energy

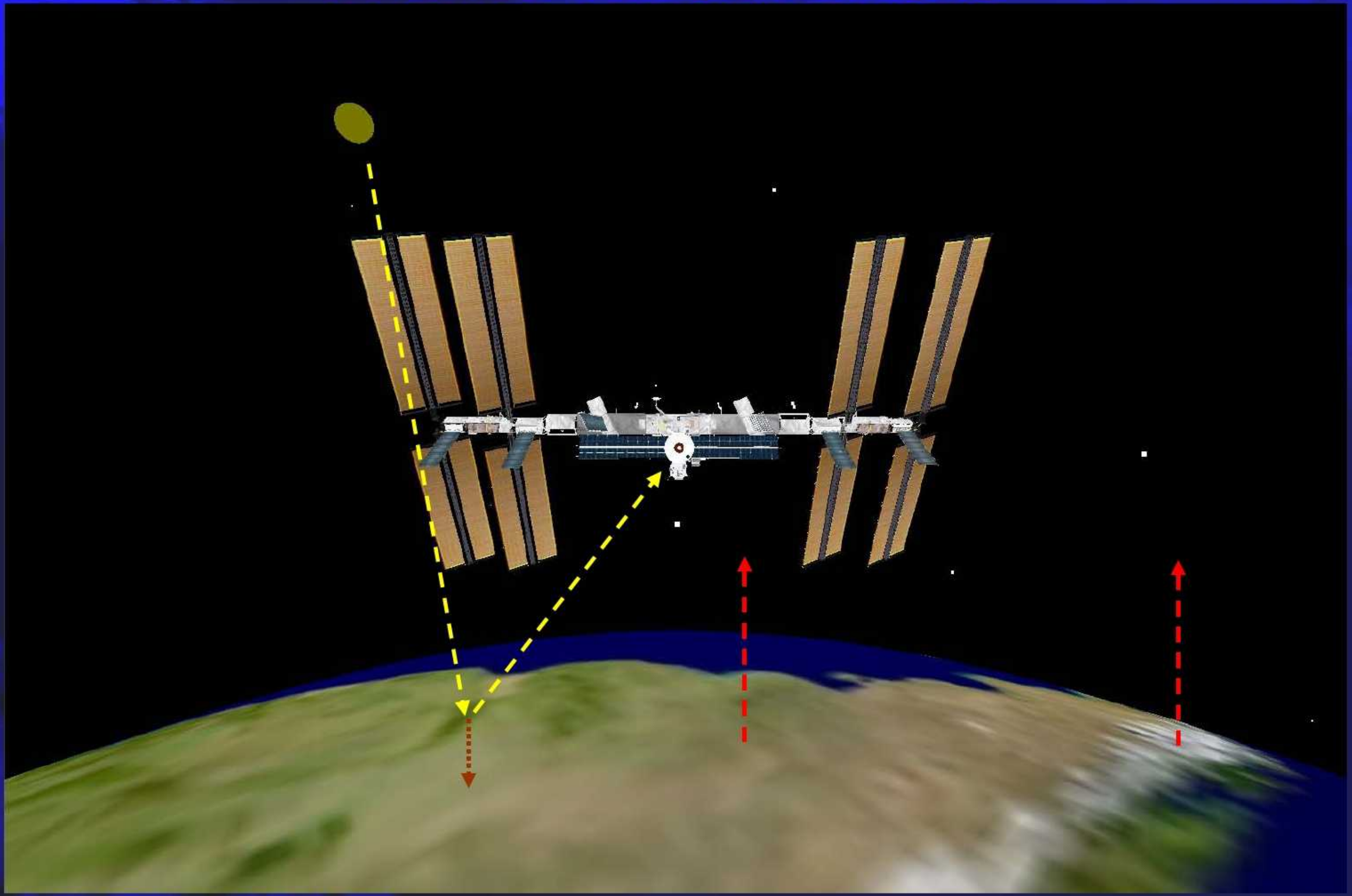
Environmental Monitoring
- air quality, contaminants, subsidence

Science Fundamentals

- Different information is obtained using different wavelengths
- Planet's atmosphere defines "windows" useable for remote sensing
- Most sensors are passive (radar and LIDAR are active)
- Information obtained is directly related to material chemistry and physics – no magic involved.



Science Fundamentals



Incident energy from the Sun is **reflected**, transmitted, or emitted from surficial materials, water, and atmosphere (clouds, dust); sensor sees mixture of energy from multiple surface materials and atmosphere

For passive systems, information is obtained only from the uppermost surface (up to around 130 microns for thermal infrared data); the average thickness of a human hair is 100 microns

Science Fundamentals - Spectra

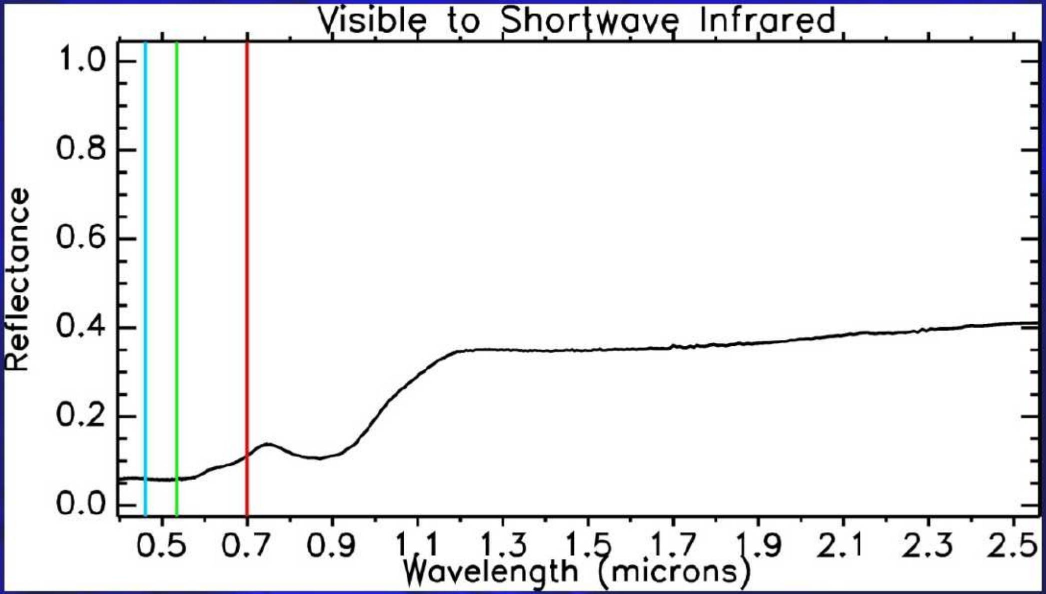
The way solar energy – photons – interacts with a material at different wavelengths determines its *spectrum*.

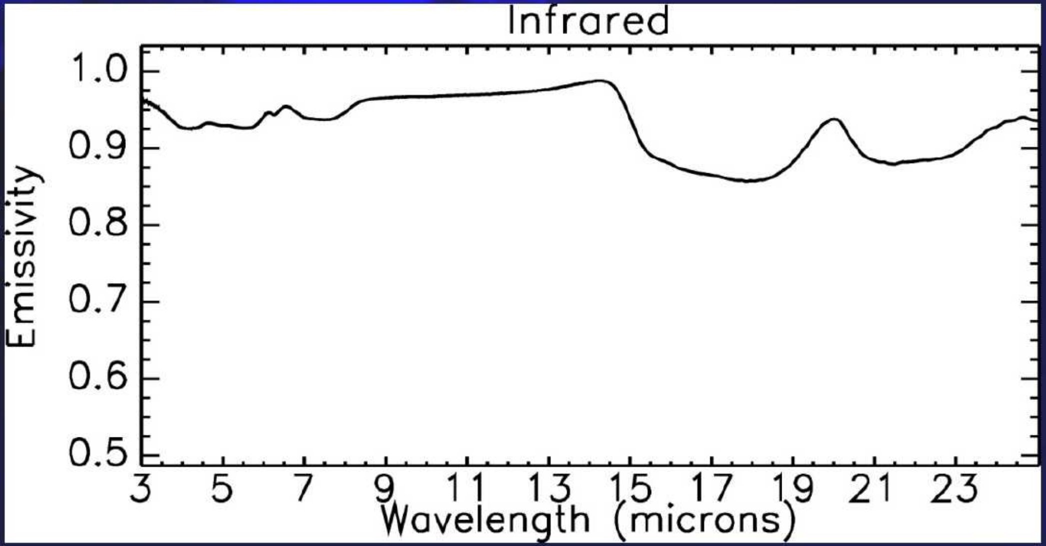
Material spectra in different wavelength regions are much like fingerprints, and can be used to identify different materials using remotely sensed data.

Reflected energy from materials in the red, green, and blue wavelengths are detected by our eyes, and interpreted by our brains as colors.

Hemathite

Fe_2O_3





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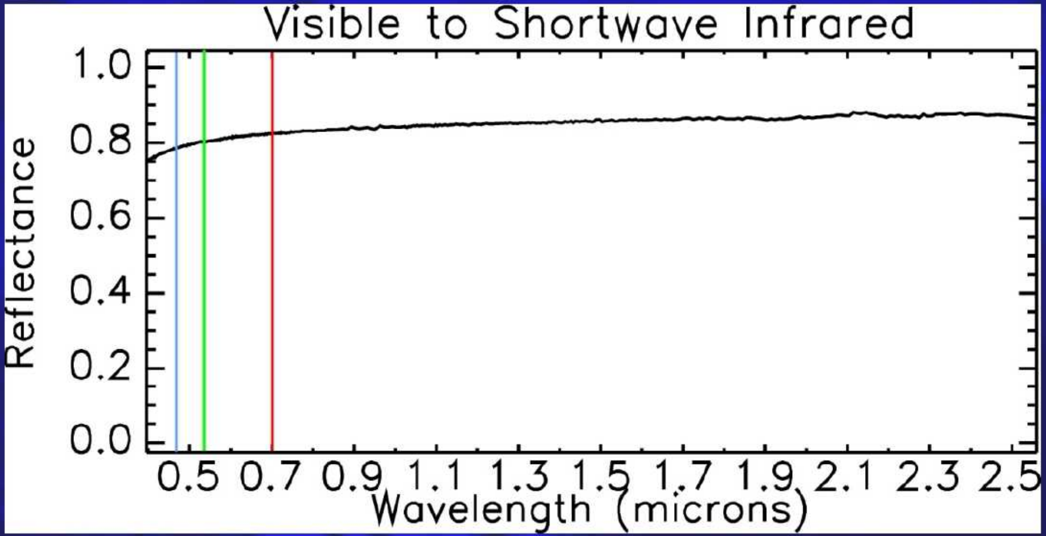
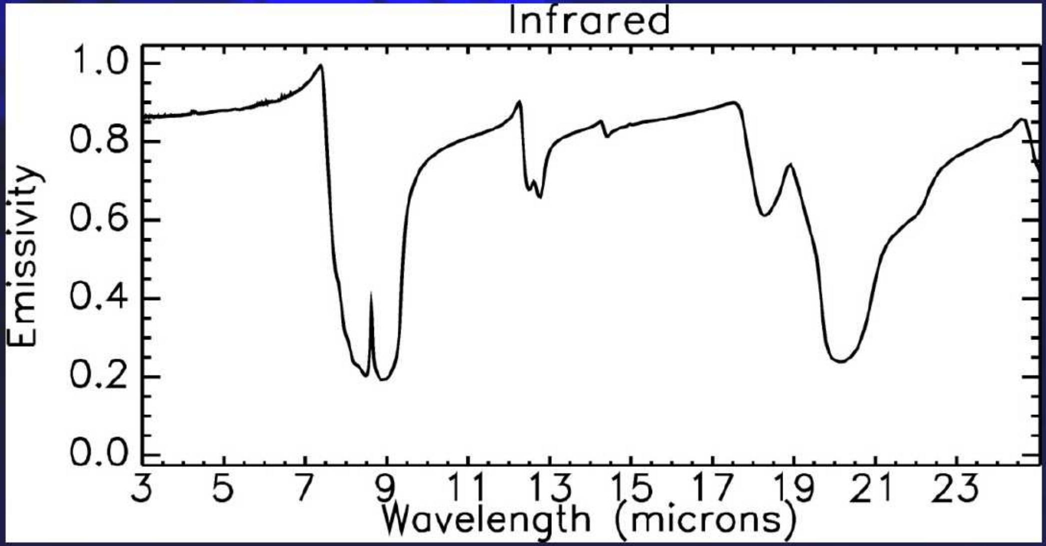
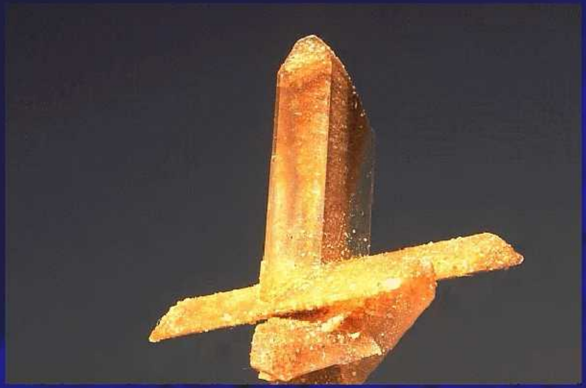
Quartz
SiO_2

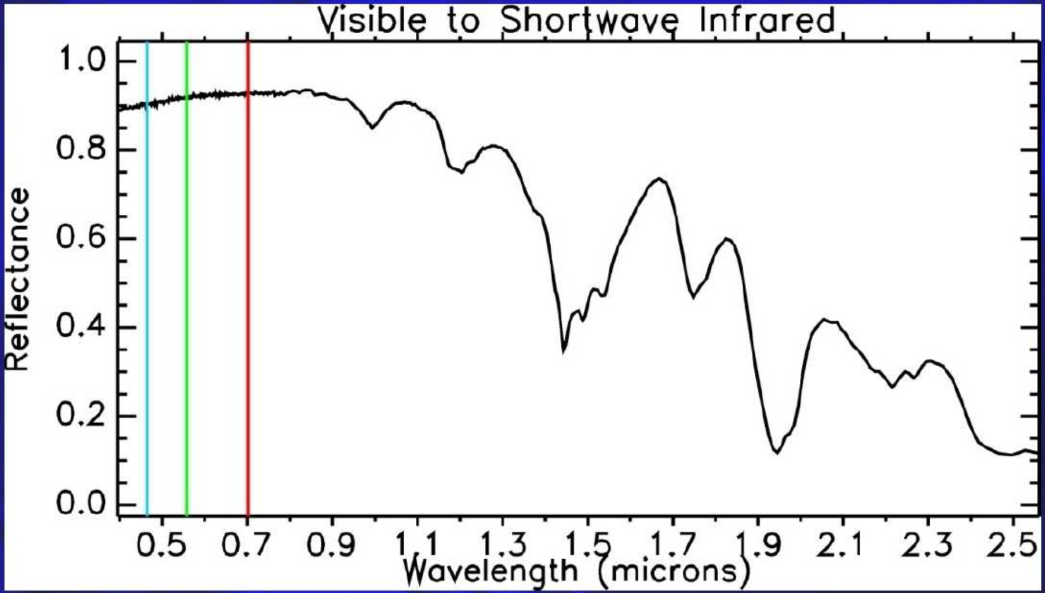

Visible to Shortwave Infrared
Reflectance
1.0
0.8
0.6
0.4
0.2
0.0
0.5 0.7 0.9 1.1 1.3 1.5 1.7 1.9 2.1 2.3 2.5
Wavelength (microns)

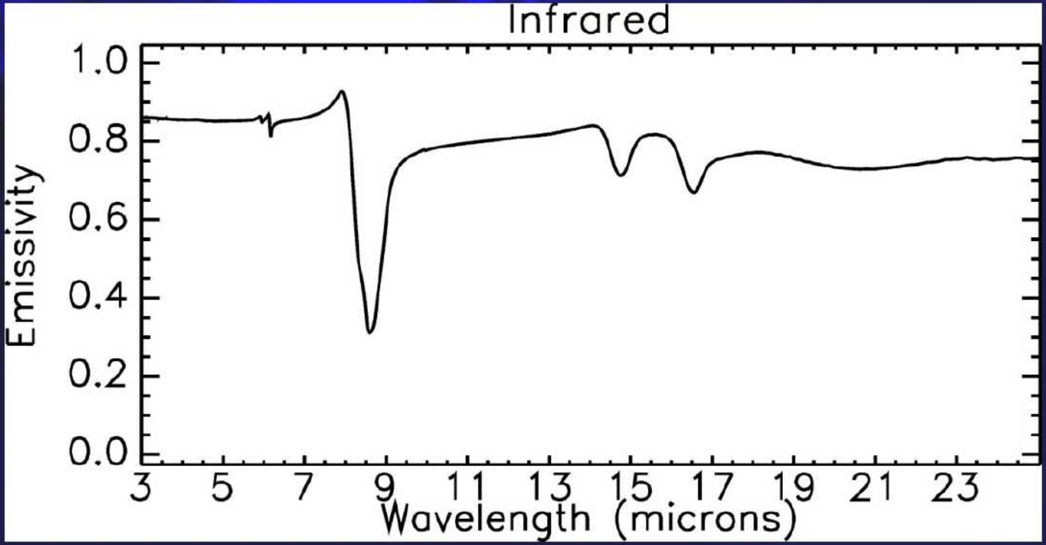

Infrared
Emissivity
1.0
0.8
0.6
0.4
0.2
0.0
3 5 7 9 11 13 15 17 19 21 23
Wavelength (microns)

Gypsum

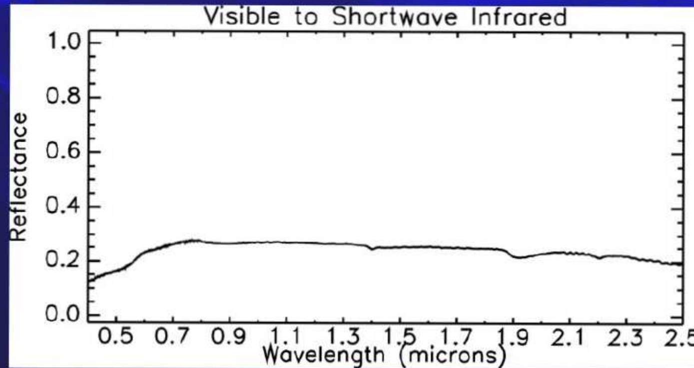
$CaSO_4 \cdot 2H_2O$

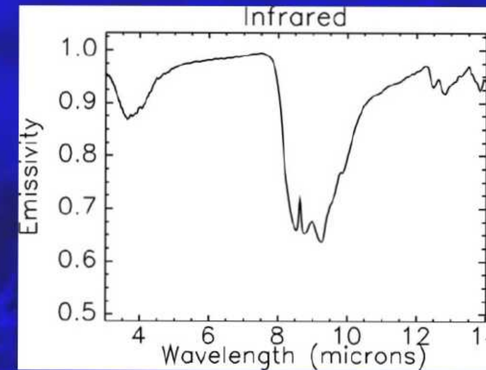




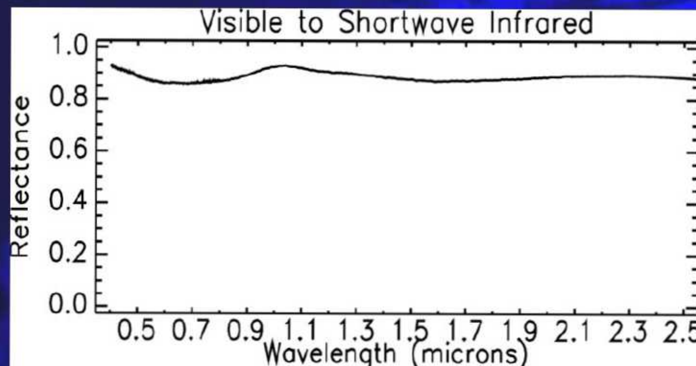


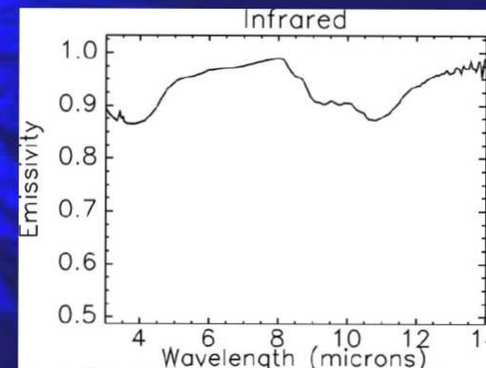
Granite



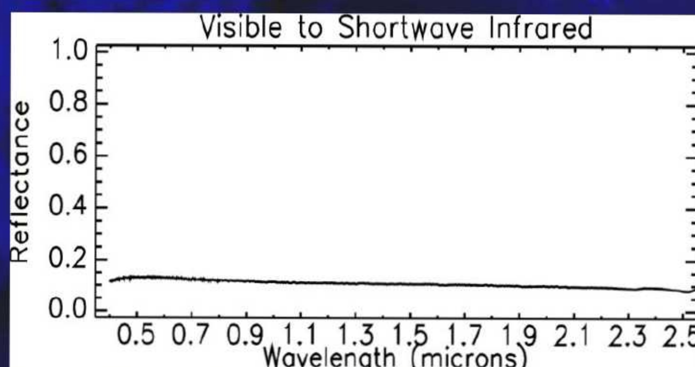


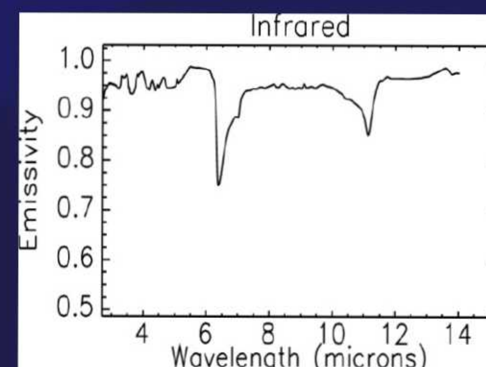
Basalt



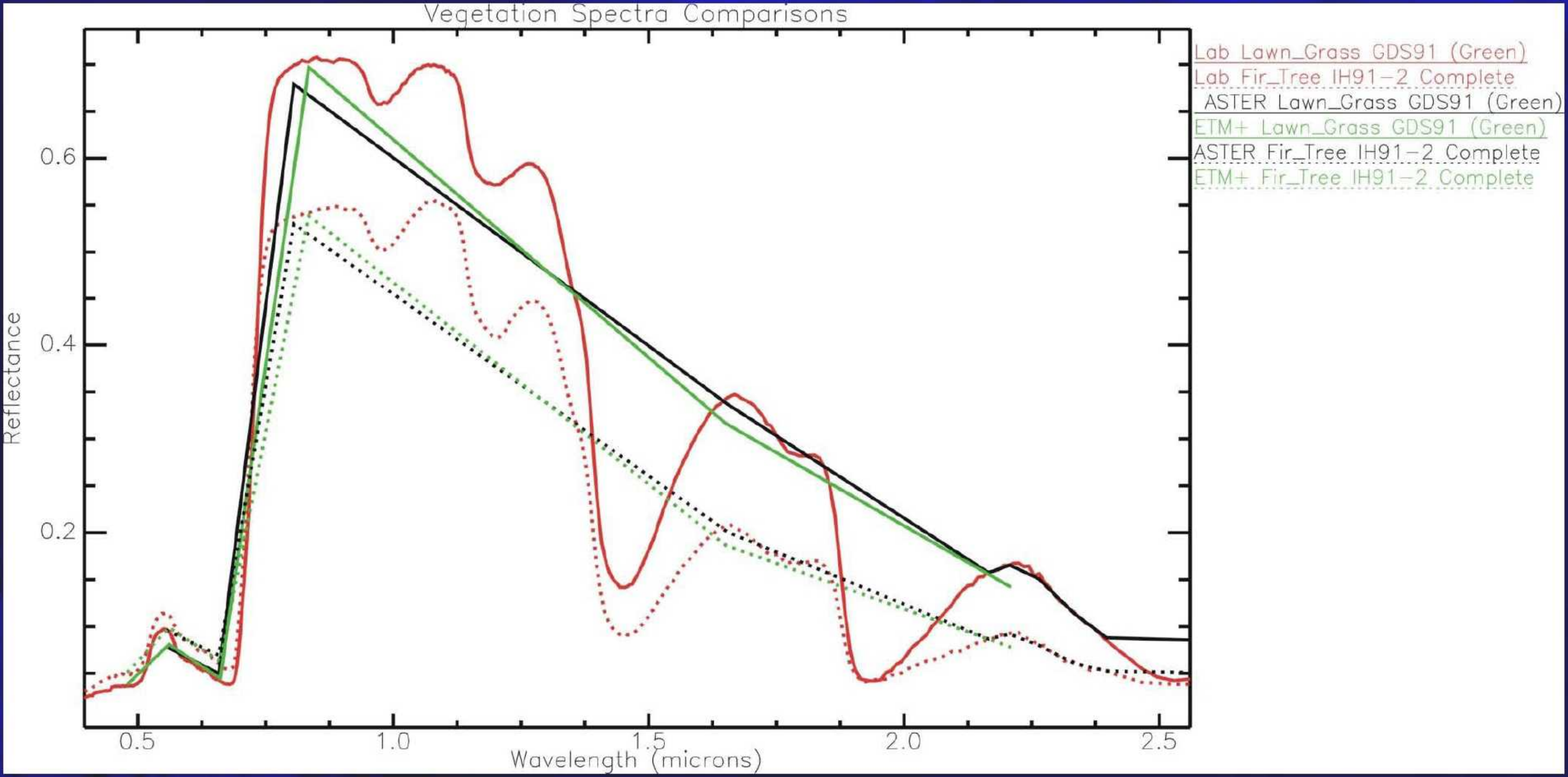


Limestone





Vegetation Spectra



What causes spectral features?

Reflectance

Visible to shortwave infrared (0.4 –3.0 microns)

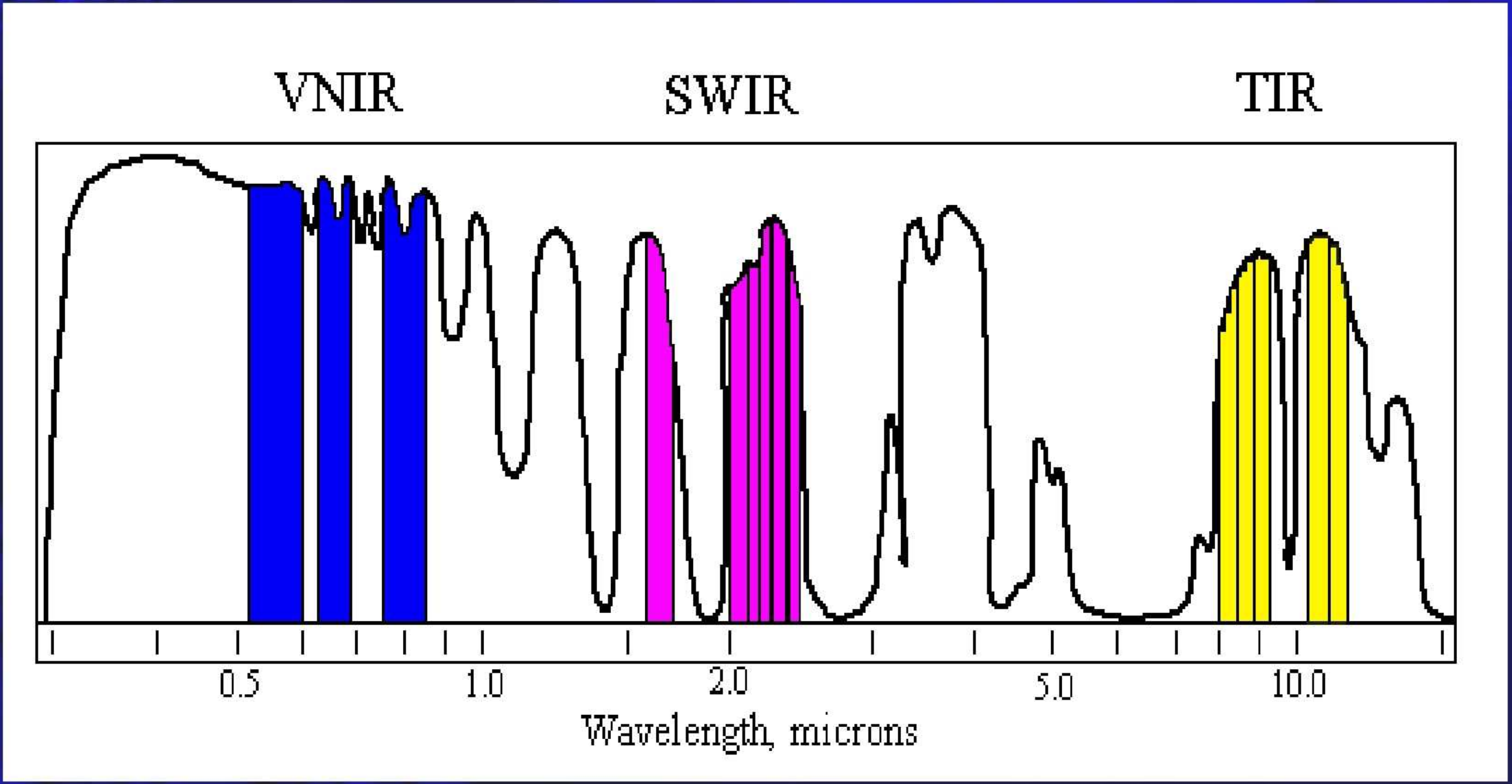
- due to changes in outer shell electron energy states in transition metal ions (Fe, Ni, Zn, Cu, Mn, Cr, Ti, V, Co, Sc) and presence of OH^- and H_2O within crystal lattice as photons are emitted or absorbed
- tells you about the elements present

Emittance

Mid-infrared and longwave infrared (3-5 and 8-25 microns)

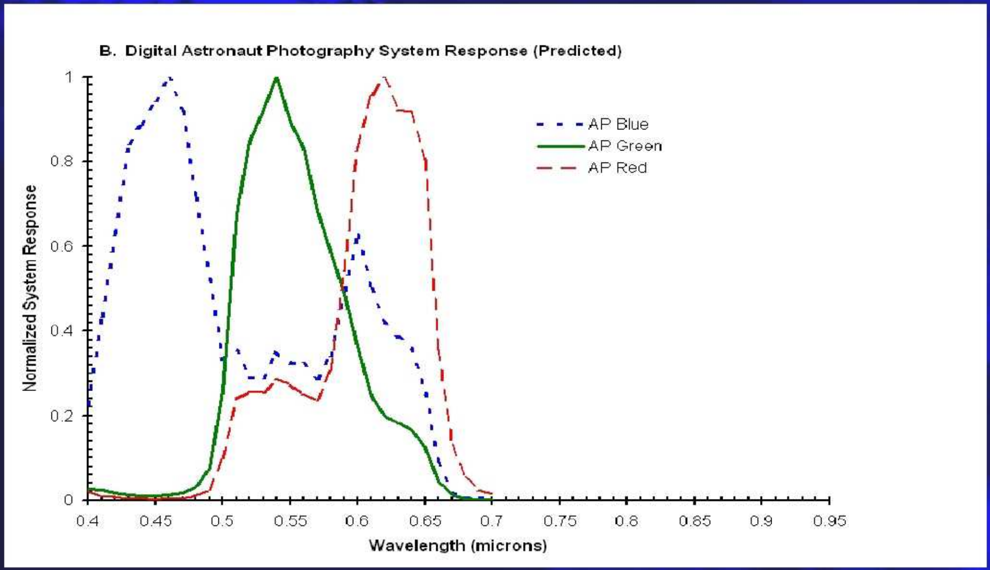
- due to twisting, rotation, and vibration among ions of compounds (Si-O, Al-O, Na-O, Ca-O) that emit or absorb photons
- tells you what kind of molecules/minerals are present

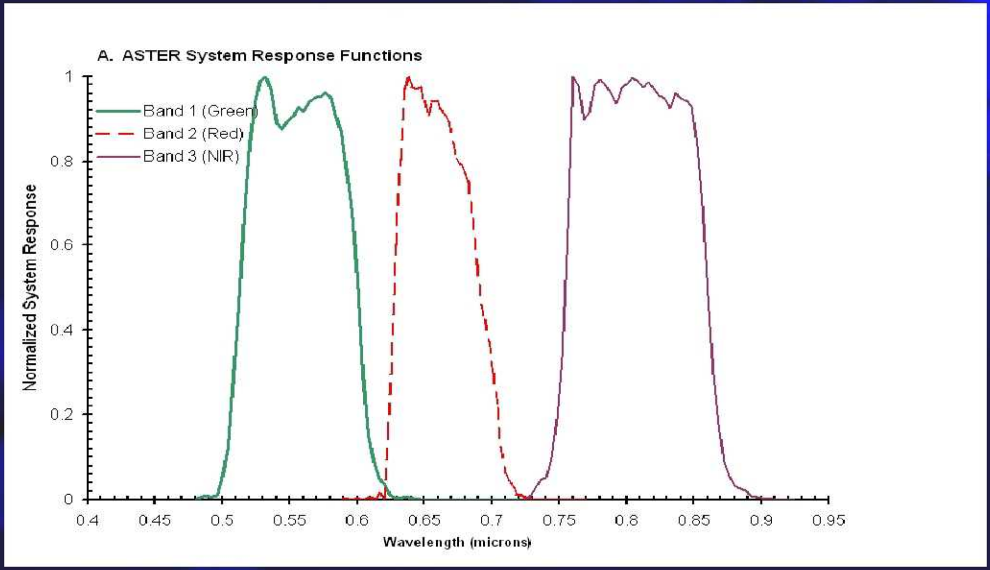
Sensor Fundamentals



Remote sensing instruments are designed with *bands* or channels that are sensitive to different wavelengths – the degree of response to a material in the different bands determines its spectral “fingerprint”

Astronaut Photography

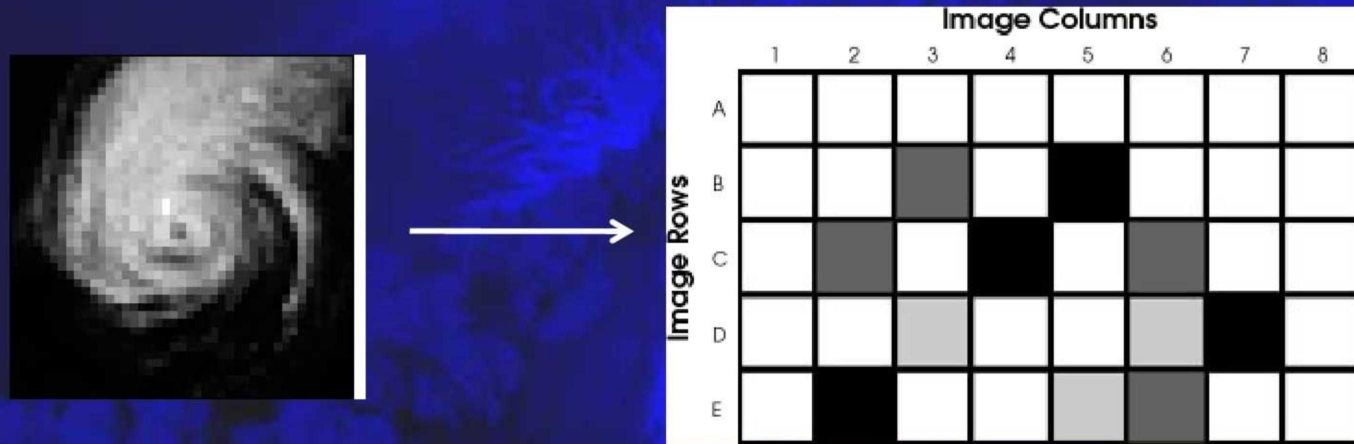




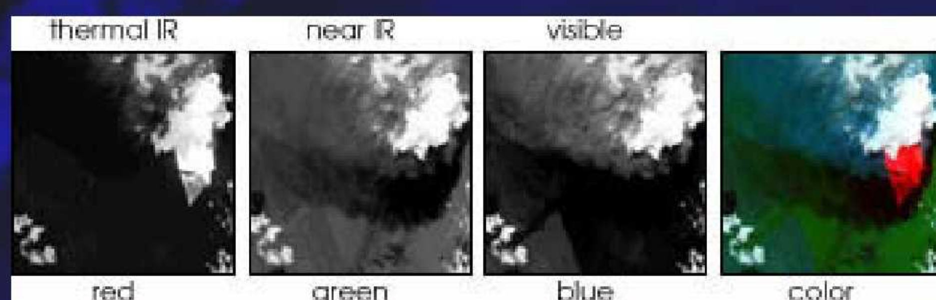
- AP acquired since 1960s as part of Apollo, Skylab, Mir, Shuttle, and ISS missions
- Extensive database of images with variable look angles, spatial resolutions, and repeat times complements automated sensor data archives
- Digital camera AP now approaching commercial spatial resolutions (4 m/pixel) for significantly lower cost
- Nikon high-end digital cameras now in use aboard the ISS

Sensor Fundamentals - Pixels

Digital images are made up of square picture elements, or pixels:



Bright pixels indicate a strong return of energy from the surface in a given band/wavelength; you can merge three bands of information together to form a color image that our eye/brain can understand:

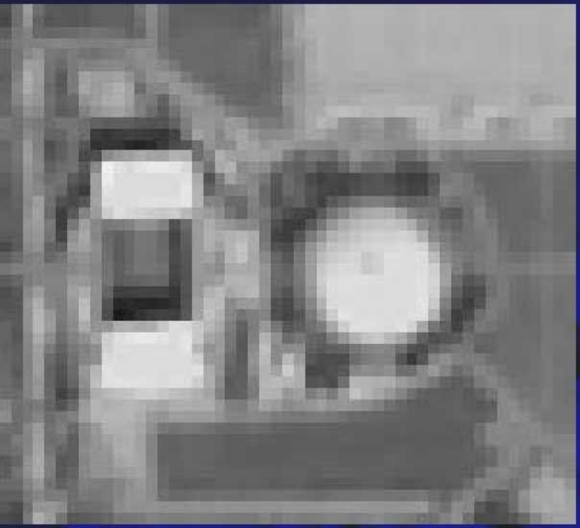


Images courtesy of
NASA Earth Observatory
http://earthobservatory.nasa.gov

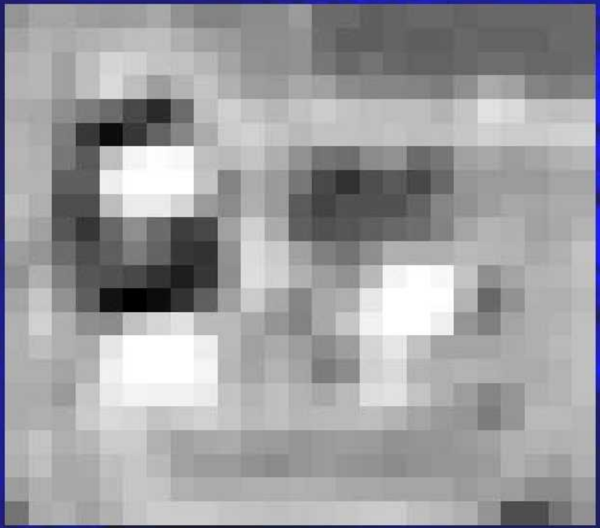
Sensor Fundamentals – Image Resolution

Reliant Stadium, Houston, TX

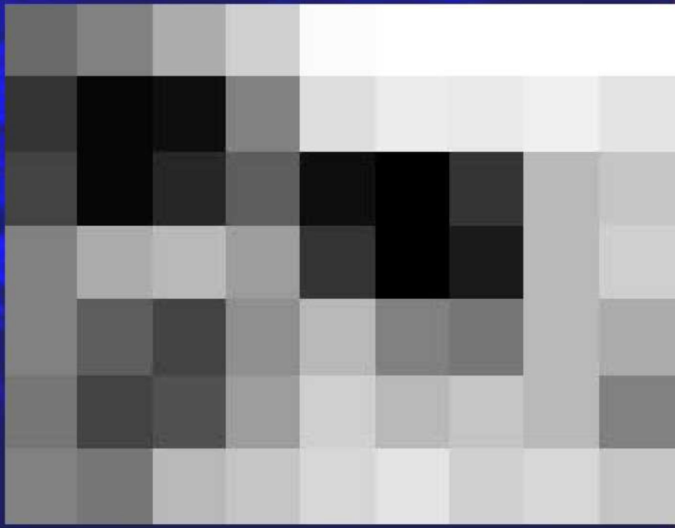
0 200 m



ASTER Band 2 - visible green
15 meters/pixel



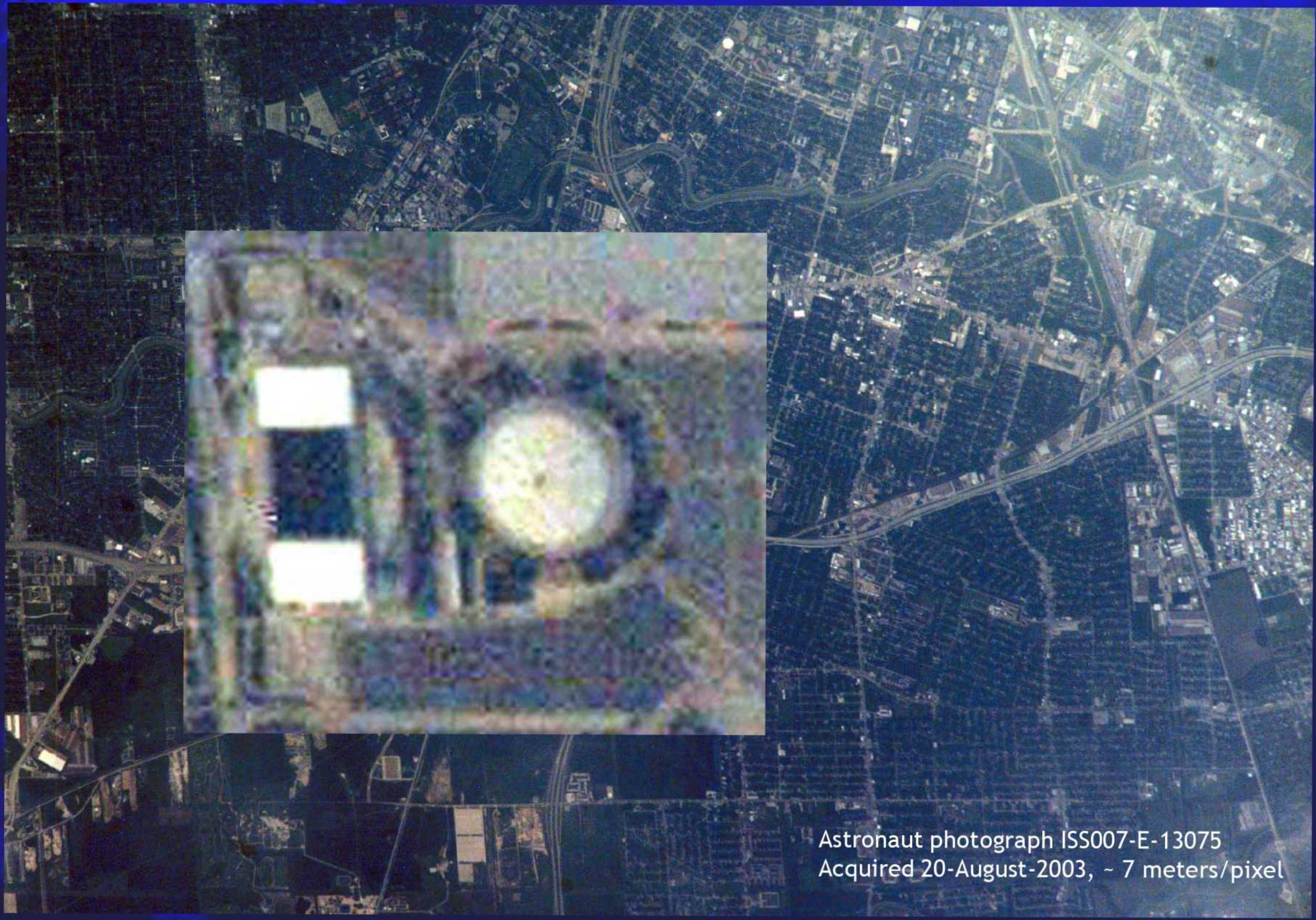
ASTER Band 6 - shortwave IR
30 meters/pixel



ASTER Band 11 - thermal IR
90 meters/pixel

ASTER data acquired 15-October-2003

Reliant Stadium, Houston, TX



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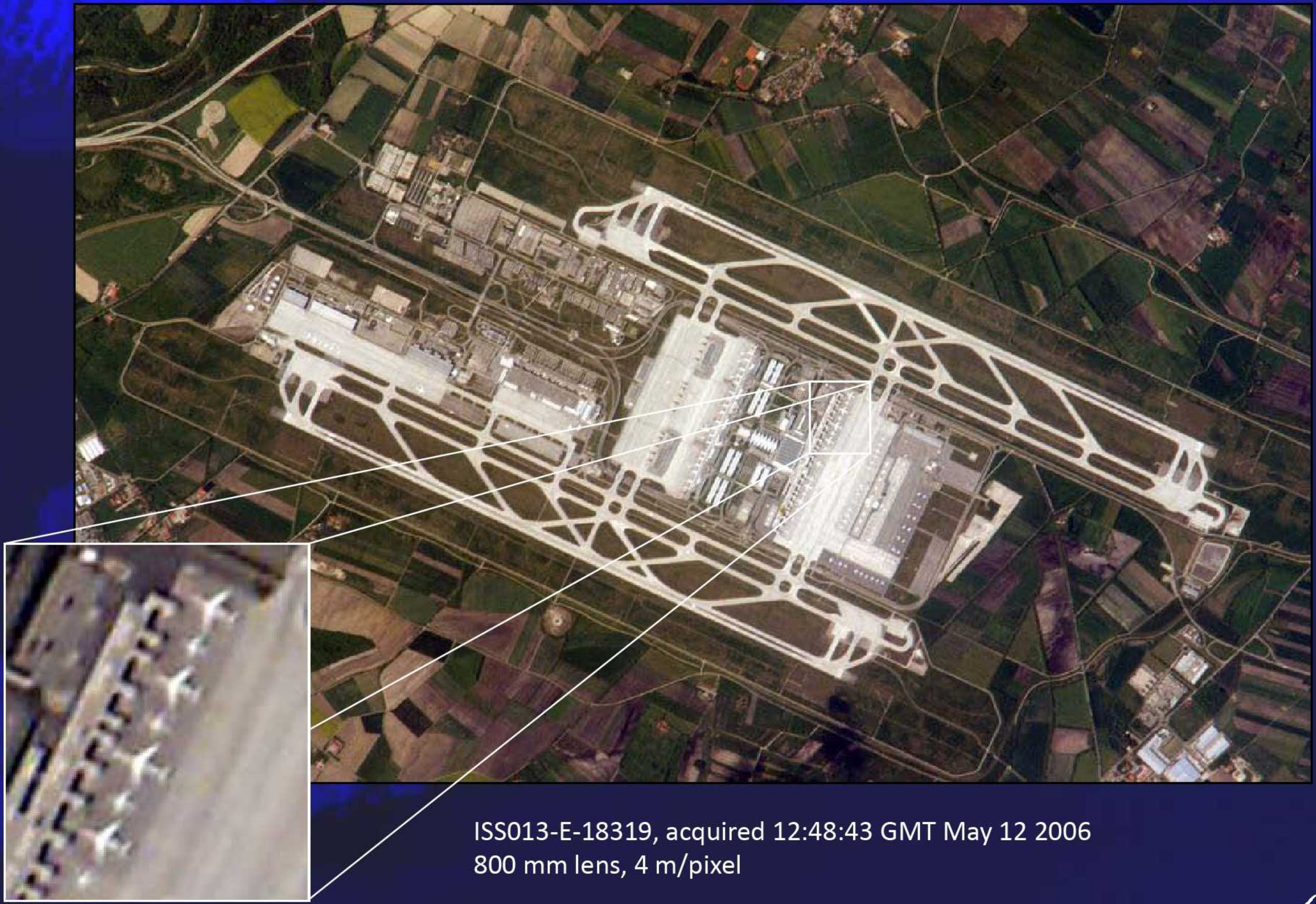
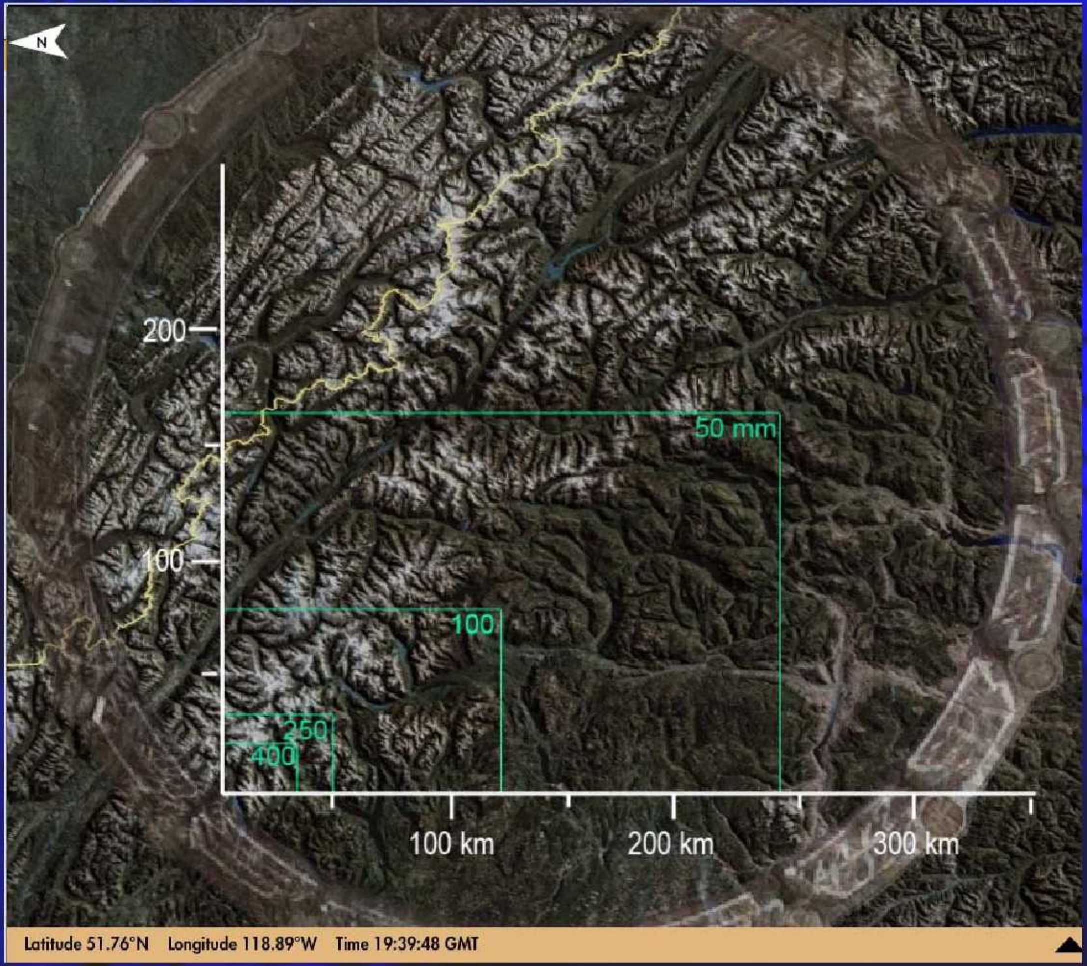
Munich Airport, Germany



ISS013-E-18319, acquired 12:48:43 GMT May 12 2006
800 mm lens, 4 m/pixel

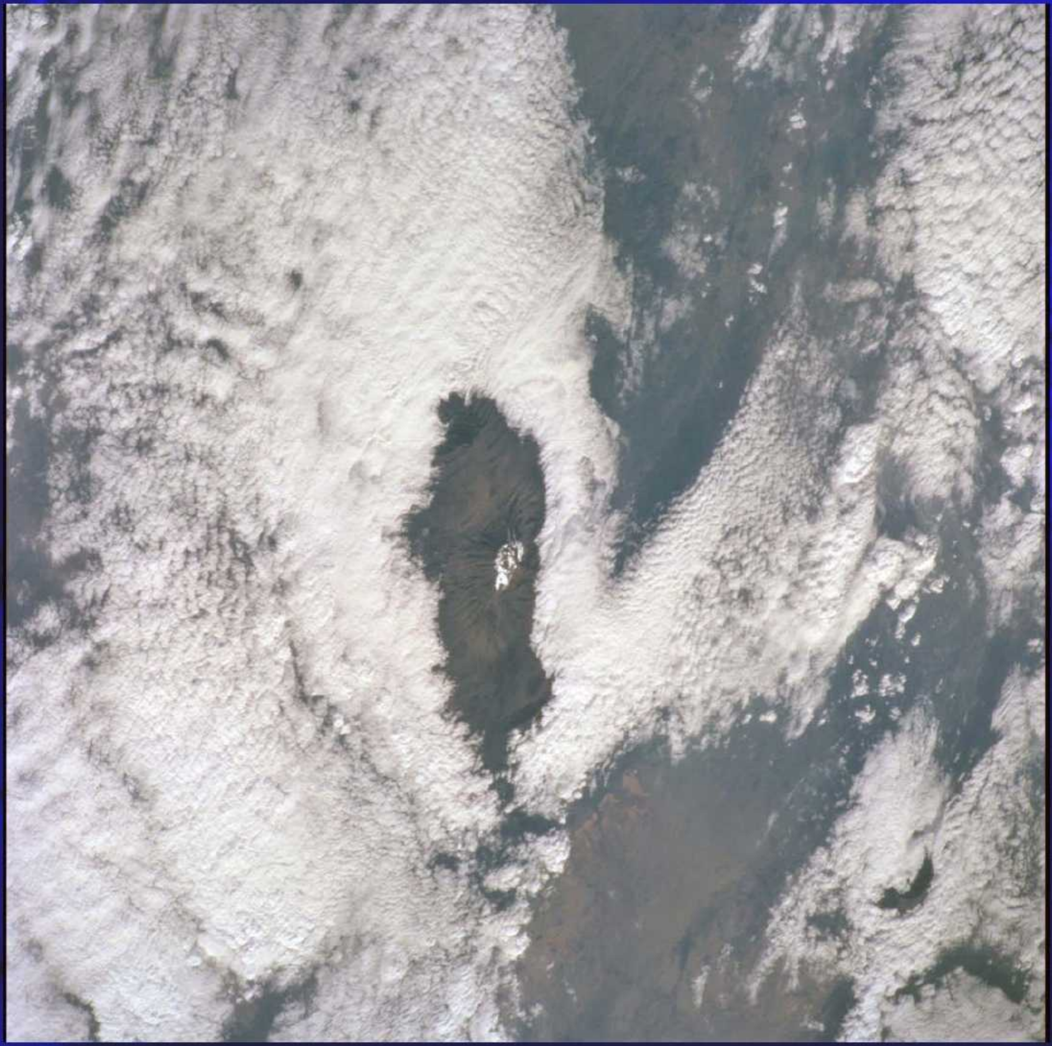
Areal Coverage of Astronaut Photographs



Windows on Earth, http://winearth.terc.edu/

Pixel resolution of image depends on altitude of ISS and camera lens used – longer lens gives more detail but less area coverage

Mount Kilimanjaro, Kenya



ISS002-709-2

50 mm lens

August 8, 2001

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Mount Kilimanjaro, Kenya

ISS017E011744

ISS017-E-11744

180 mm lens

August 23, 2008

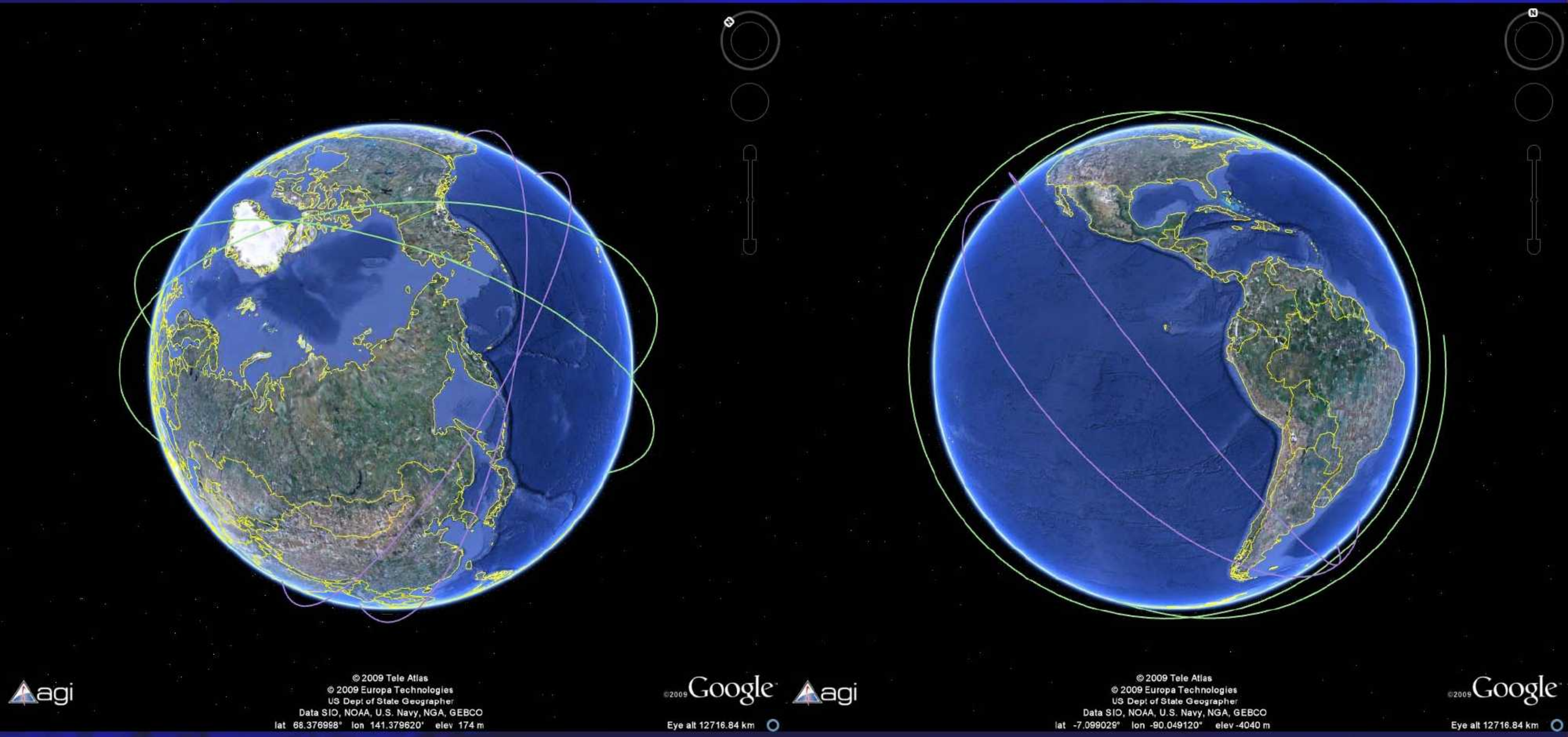
Mount Kilimanjaro, Kenya

ISS014-E-18921

800 mm lens

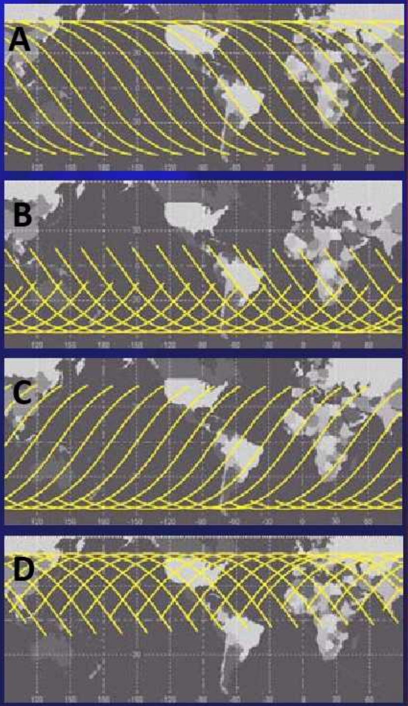
May 3, 2007

Satellite Orbits



Purple – inclined equatorial orbit (ISS) – different viewing angles and illumination over targets
Green – polar orbit (Terra) – same viewing angle and illumination over targets

ISS Orbit = Variable Image Acquisition Times



A – Successive orbit paths, descending ISS passes.
B – Daylight illumination in Southern Hemisphere only.
C – Successive orbit paths, ascending ISS passes.
D – Daylight illumination in Northern Hemisphere only.

Unlike polar-orbiting satellites such as Landsat or Terra, the International Space Station (ISS) has an inclined equatorial orbit that is not sun-synchronous.

This type of orbit limits nadir viewing opportunities to approximately 52N and 52S latitudes, and results in variable ground illumination.

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Scanning For Land Forms – Analyzing Remotely Sensed Data

Broad approaches to doing science with remotely sensed data:

Visualization

- RGB images good for initial discrimination of surficial materials, measurement of features, detection of change over time

Classification

- Classification of image pixels using statistical analysis of variability (numerous techniques) – useful for automated mapping of surficial materials (asphalt vs. bare soil for example)

Spectral Analysis

- Useful for determining components in a single image pixel
- Can extract detailed material identifications from geologic, biologic, and built materials

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Recent Changes, Yellow River Delta, China

Measured unpredictable coastal growth and erosion

ONC, 1976

STS3-09-480, Mar 1982

61A-46-91, Nov 1985

STS28-92-000g, Aug 1989

STS56-157-52, Apr 1993

STS85-726-70, Aug 1997

STS101-718-66, May 2000

ISS006-E-49325, Apr 2003

Images courtesy of C. Evans, NASA-JSC

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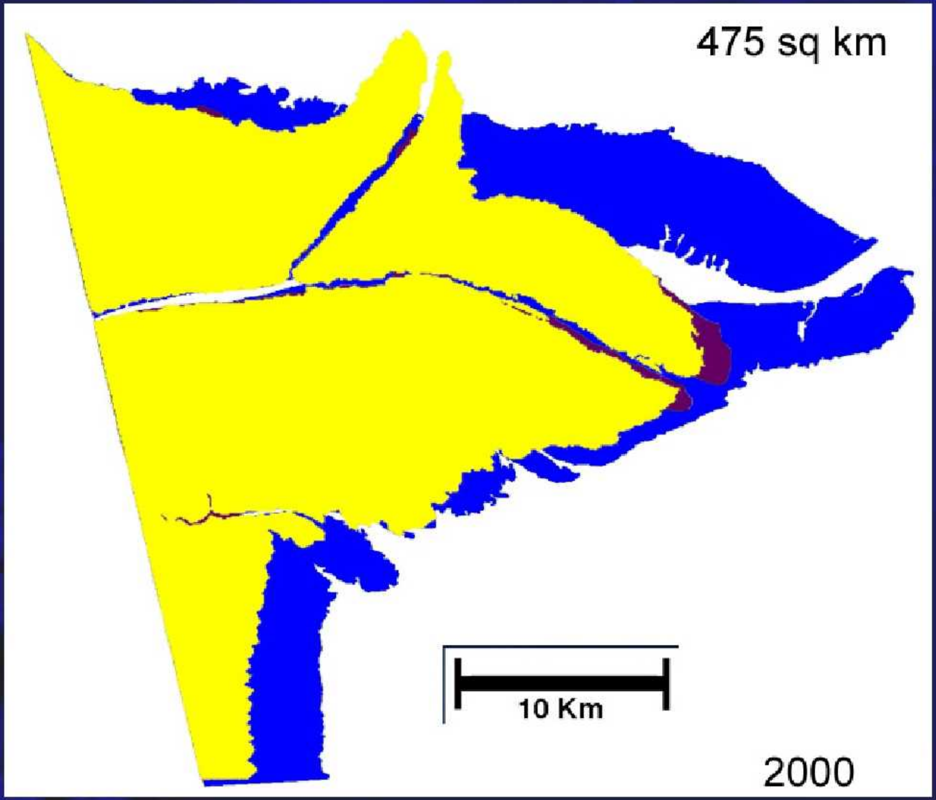
Huang He delta progressive changes 1989-2000

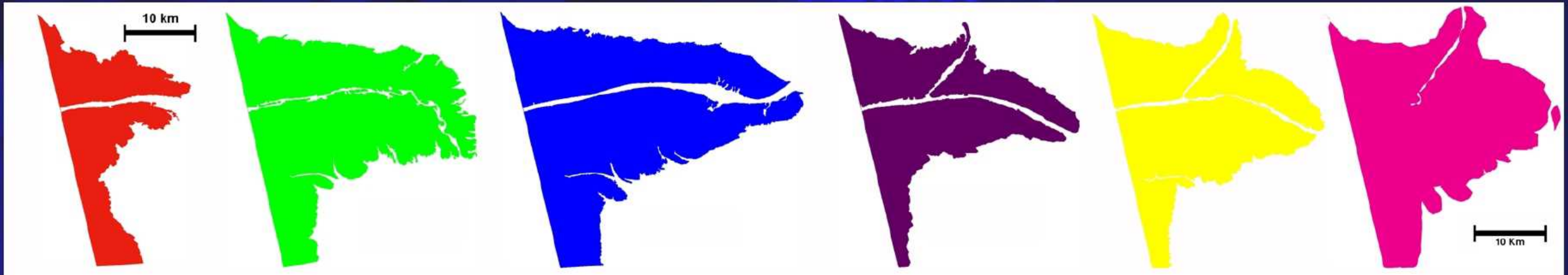
Images courtesy of C. Evans, NASA-JSC



- Rapid build out of nearly 400 sq km
- Rapid erosion of roughly 250 sq km

Masks of the tip of the Yellow River Delta used for calculating area.

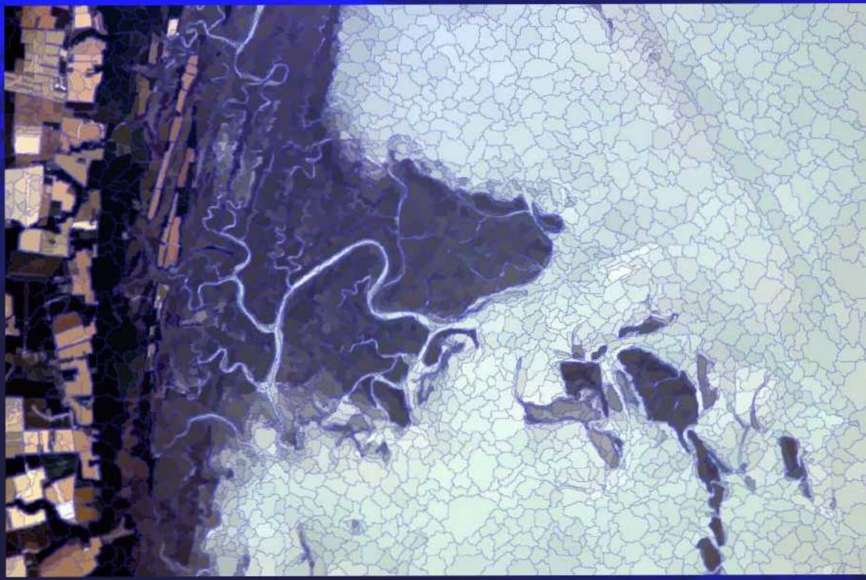
1989-1995: Delta growth = 391 km^2
1995-1997: Delta erosion = 252 km^2
Drought, dam completion, and water over-subscription
1997-2000: Slow delta growth = 86 km^2
In 1996, a new north-facing channel was cut creating new active lobe
Sediment and water flows reduced, little change since 2000



1989	1993	1995	1997	2000	2003
269 sq km	587 sq km	688 sq km	418 sq km	506 sq km	579 sq km

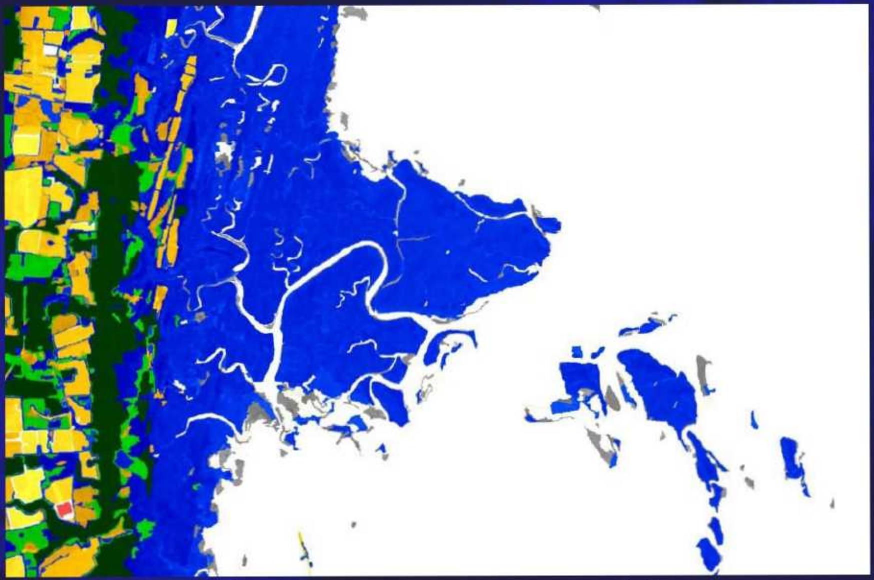
Images courtesy of C. Evans, NASA-JSC

Object-Oriented Classification
Hog Island, VCR LTER Site

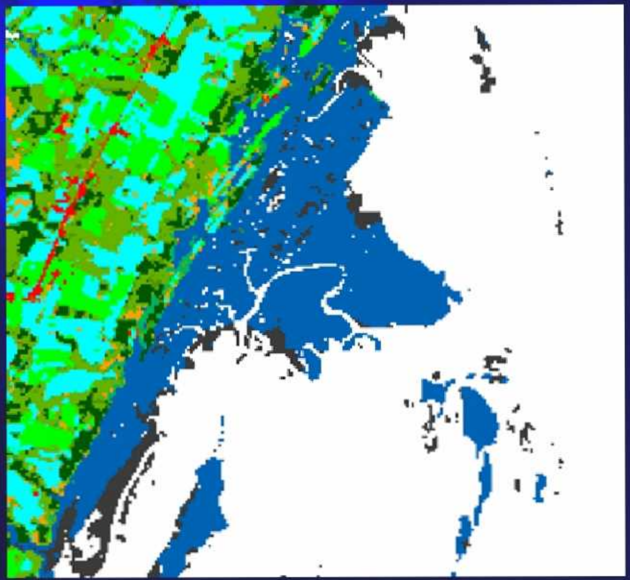


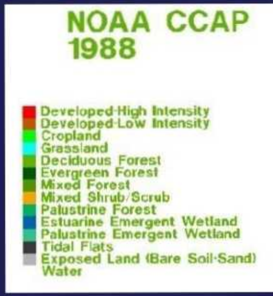
ISS013-E-25378, 800mm, acquired 24-May-06

ensates
ation
of high



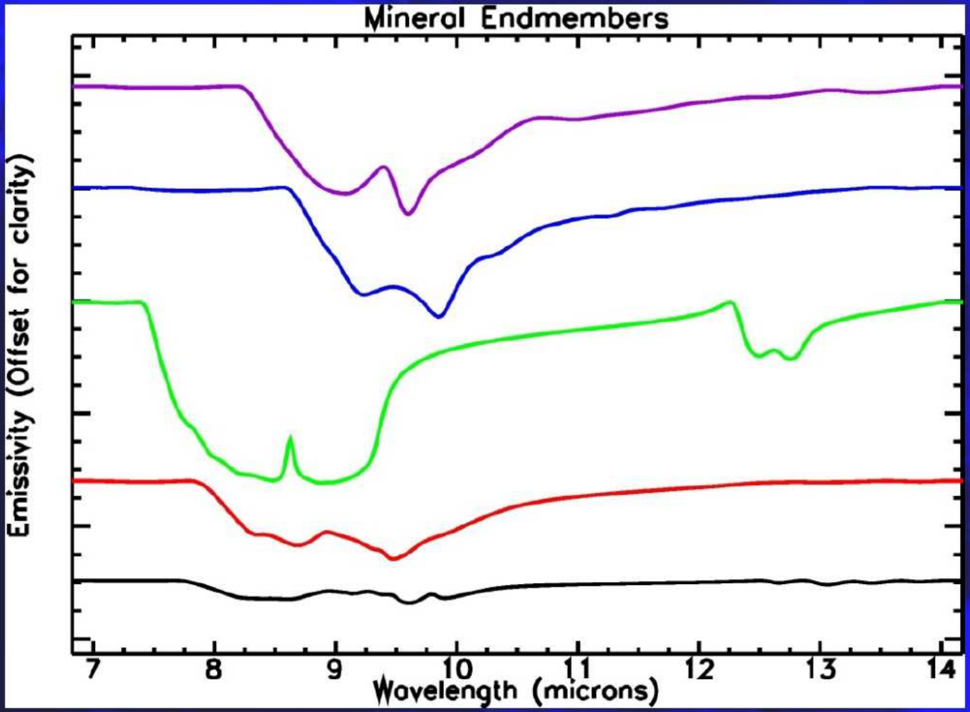
0 6 km

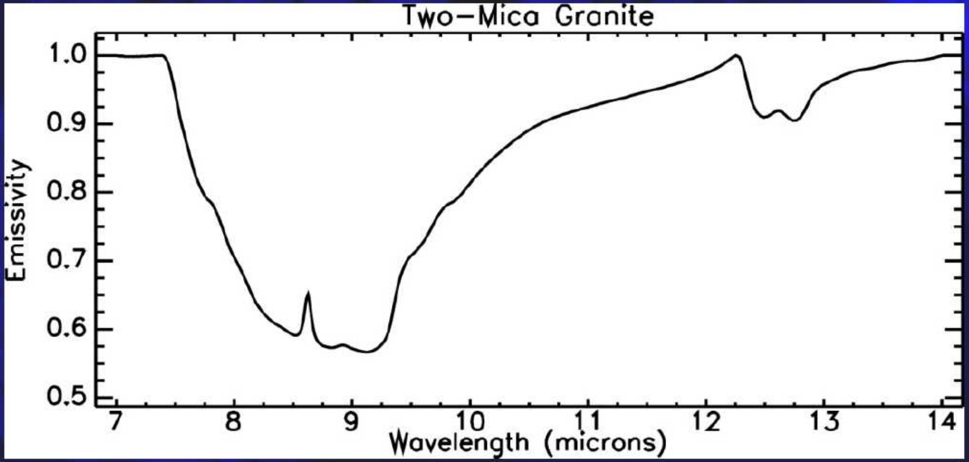




NOAA CCAP data provided by Virginia Coast Reserve LTER project

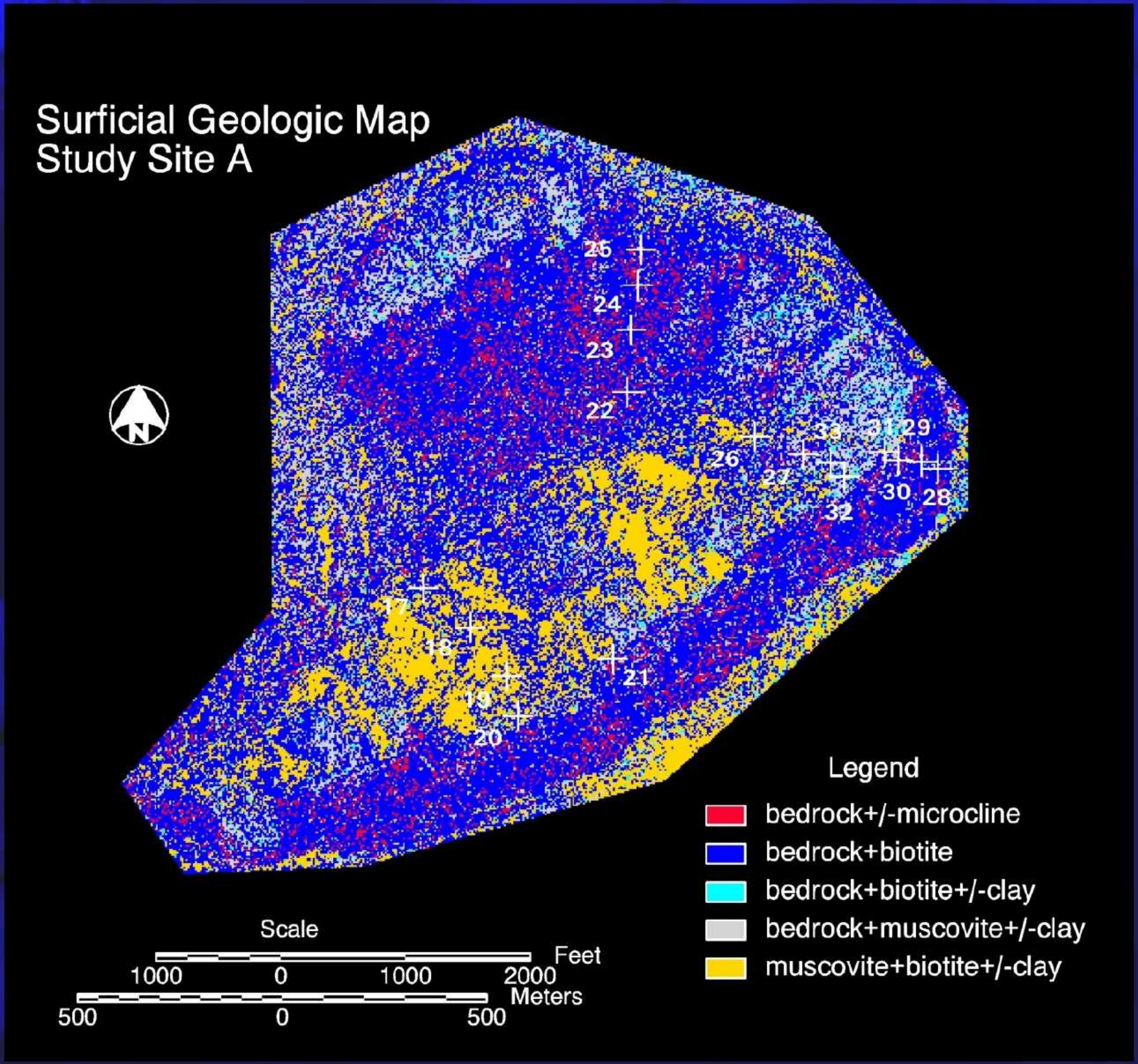
Spectral Analysis
(Pixel Unmixing)



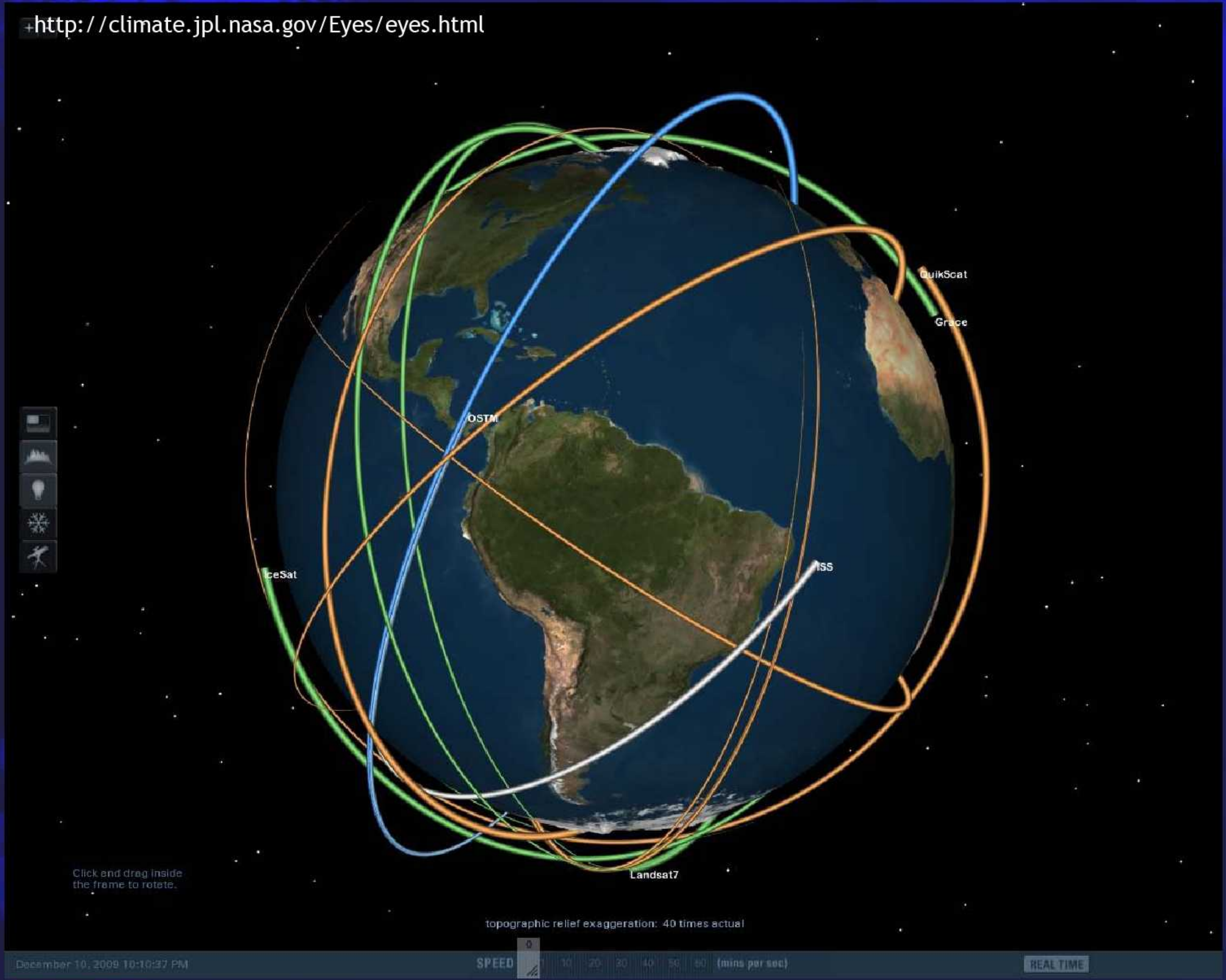


Muscovite	5% +
Biotite	5% +
Quartz	40% +
Orthoclase	30% +
Albite	20%

Soil Mineralogy Mapping Using Spectral Unmixing



Studying Earth Using Remote Sensing



NASA currently has 16 satellites in Earth orbit with sensors collecting data on the atmosphere, oceans, and land

Much of the data is online and freely available

Other planetary bodies in the solar system also have spacecraft collecting data (Moon, Mars, Saturn, Mercury) - can use the tools developed for Earth remote sensing

Online Data Resources

- Astronaut Photography – Gemini to ISS, http://eol.jsc.nasa.gov/
- USGS GLOVIS – graphical tool for searching and ordering ASTER, Landsat, MODIS, EO-1 data, http://glovis.usgs.gov/
- LP DAAC Data Pool – selected ASTER (USA and territories) and MODIS data (global), https://lpdaac.usgs.gov/lpdaac/get_data/data_pool
- Landsat data and visualization software:
  - NASA World Wind software, http://worldwind.arc.nasa.gov/download.html
- MODIS/ASTER Simulator (MASTER) archive - http://masterweb.jpl.nasa.gov/

Image Processing Tools

- Commercial software packages generally provide the widest range of tools and data handling, but also cost $$$ and require top-end desktop/server systems for effective use (ENVI, ERDAS Imagine, and PCI Geomatics are common choices for research and industry)

- Public domain software provides basic functionality for remote sensing work, and is ideal for teaching and visualization purposes:
  - Multispec: http://cobweb.ecn.purdue.edu/~biehl/MultiSpec/
  - ImageJ: http://rsbweb.nih.gov/ij/

Learning More

Remote sensing is usually taught as a 1-2 semester college undergraduate course in natural science, geography, and/or engineering departments; specialized undergraduate/graduate classes are also common. Prior coursework in physics, chemistry, biology, geology, and/or calculus-level math is usually required.

An excellent online tutorial by Dr. Nicholas Short is available at http://rst.gsfc.nasa.gov/

The Canada Centre for Remote Sensing offers a Fundamentals of Remote Sensing tutorial at http://ccrs.nrcan.gc.ca/resource/tutor/fundam/index_e.php