Geology & Earth Science

- **Geology** is the science that pursues an understanding of planet Earth. Traditionally divided into two areas: physical and historical.

- **Earth System Science** is the science that studies the whole Earth as a system of many interacting parts and focuses on the changes within and between them.
THE EARTH SYSTEM

Atmosphere: The mixture of gases that surrounds the Earth (Ex. N, O, Ar, CO₂, and water vapor).

Hydrosphere: The totality of the Earth’s water, except the water vapor in the atmosphere.

Geosphere: The solid Earth, composed principally of rock and regolith.

Biosphere: All of the Earth’s organisms.

Anthroposphere = Human activities.
THE HYDROSPHERE

RESERVOIRS OF THE HYDROLOGIC CYCLE

Water reservoirs in the earth system

- Ocean: 97.5%
- Frozen fresh water (Ice caps and glaciers): 74%
- Groundwater: 99.5%
- Surface water
- Unfrozen fresh water
- Freshwater lakes and streams: 0.1%
- Soil moisture
- Atmosphere
- Biosphere: 0.1%
Drainage Patterns: Dendritic, Trellis, and Rectangular

Drainage Patterns: Parallel, Radial and Centripetal, Annular
Drainage Patterns: Dichotomic, Braided, and Anastomotic

Mississippi River Delta, U.S.        Niger River Delta, Africa
bird’s foot delta                   lobate delta

Nile River Delta, Egypt

Irrawaddy River Delta, Burmah
crenulate delta

Jensen, 2000

Jensen, 2000
RIVER PLUMES DETECTED WITH OCEAN COLOR SENSORS

MISSISSIPPI RIVER DELTA WITH MODIS
CRYOSPHERE

It is the part of the Earth's surface that remains perennially frozen. It includes glaciers (10% of Earth's land surface), sea ice and vast areas of frozen ground (20% of Earth's land surface) that lie beyond the limits of glaciers. Thus, nearly a third of the Earth's land area belongs to the cryosphere.
CONDITION OF THE OZONE LAYER AND TEMPERATURE TRENDS

High Reflection of Light

WHITE SURFACE

THE WORLD OCEAN
**SEA-VIEWING WIDE FIELD-OF-VIEW SENSOR (SEAWIFS)**

<table>
<thead>
<tr>
<th>Banda</th>
<th>Largo de Onda</th>
</tr>
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<tbody>
<tr>
<td>1</td>
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<tr>
<td>2</td>
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<tr>
<td>3</td>
<td>490</td>
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<tr>
<td>4</td>
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<td>7</td>
<td>765</td>
</tr>
<tr>
<td>8</td>
<td>865</td>
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</tbody>
</table>

**Fitoplancton Chl-a**

**CHLOROPHYLL-A AS MEASURED WITH SEAWIFS**

![Chlorophyll-a map](image)
**Advanced Very High Resolution Radiometer (AVHRR)**

<table>
<thead>
<tr>
<th>Banda</th>
<th>Largo de Onda</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.58-0.68</td>
</tr>
<tr>
<td>2</td>
<td>0.72-1.10</td>
</tr>
<tr>
<td>3</td>
<td>3.55-3.93</td>
</tr>
<tr>
<td>4</td>
<td>10.5-11.5</td>
</tr>
<tr>
<td>5</td>
<td>11.5-12.5</td>
</tr>
</tbody>
</table>

**Sea Surface Temperature (SST)**

**Sea Surface Temperature (SST) as Measured by AVHRR**
MODERATE RESOLUTION IMAGING SPECTRORADIOMETER (MODIS)

• 36 bandas del visible al infrarrojo
• Resolucion Espacial
  – 250 m (bandas 1-2)
  – 500 m (bandas 3-7)
  – 1000 m (bandas 8-36)

Temperatura Superficial Del Oceano

Clorofila-a De Fitoplancton
THE ATMOSPHERE

DOPPLER RADAR
ENHANCED LOW-COST MONITORING OF EXTREME WEATHER
AUGUST 9, 2010

OTG radars at UPRM

NWS Nexrad
### ADVANCED VERY HIGH RESOLUTION RADIOMETER (AVHRR)

<table>
<thead>
<tr>
<th>Band</th>
<th>Wavelength (µm)</th>
</tr>
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<tbody>
<tr>
<td>1</td>
<td>0.58-0.68</td>
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<tr>
<td>2</td>
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</tr>
</tbody>
</table>

**L-BAND ANTENNA**

![AVHRR Image]  
**NOAA 12/14**

![Satellite Image]
The GOES Program
Geostationary Operational Environmental Satellite

GOES OBSERVATIONS OF THE CARIBBEAN

http://www.goes.noaa.gov/browsh2.html
Major dust storms are most frequent in arid and semiarid regions that are concentrated in the subtropical high-pressure belts north and south of the equatorial zone. Arrows show the most common trajectories of dust transported during major storms.
EFFECT OF THE SAHARA DUST

SeaWiFS - February 26, 2000
SeaWiFS - March 10, 2000

EFFECT OF THE SAHARA DUST
EFFECT OF THE SAHARA DUST
EFFECT OF THE SAHARA DUST

THE BIOSPHERE
**EVOLUTION OF LIFE**

- 4 BY-simple cells (prokaryotes)
- 3 BY-photosynthesis
- 2 BY-complex cells (eukaryotes)
- 1 BY-multicellular life
- 600 MY-simple animals
- 570 MY-arthropods (ancestors of insects, arachnids and crustaceans)
- 550 MY-complex animals
- 500 MY-fish and proto-amphibians
- 475 MY-land plants
- 400 MY-insects and seeds
- 360 MY-amphibians
- 300 MY-reptiles
- 200 MY-mammals
- 150 MY-birds
- 130 MY-flowers
- 65 MY-since the non-avian dinosaurs died out
- 200,000 years since humans started looking like they do today.

**THE CARBON CYCLE**
Normal Fault Along the Wasatch Mountain Range in Utah as Recorded on Landsat Thematic Band 4 Imagery

SAN ANDREAS FAULT

SPOT Image
Landsat Thematic Mapper Image of the Intersection of the San Andreas and Garlock Faults

Landsat band 4 image

Shaded relief map derived from a digital elevation model
MOVEMENT OF WORLD PLATES ACCORDING TO GPS STUDIES
Using InSAR we are able to map active ground displacements. This geodetic method uses two or more synthetic aperture radar (SAR) images to generate maps of surface deformation or digital elevation, using differences in the phase of the waves returning to the satellite or aircraft.
Detecting Earthquakes with Satellite

Images obtained from satellite radar contained two important information. Information is power transmit beam in the form of phase and amplitude, which is influenced by the number of waves emitted and reflected back. At the time of the wave emitted performed phase measurements. In the images obtained from each pixel, will have two information. The intensity of the signal can be used to determine the characteristics of a material that reflects the wave, while the wave phase is used to determine whether there has been a movement (deformation) on the surface of the reflecting wave.
PLATE BOUNDARIES

SEISMIC ACTIVITY

WORLD’S VOLCANOES

Land Cover Time Sequence of Mount St. Helens, Washington, as seen from Landsat MSS

1979  1983

1988  1996
Cleveland Volcano at Aleutian Arc, Alaska

ISS- Digital Camera

Panchromatic Stereopair of the Menan Butte Tuff Cinder Cone Volcano in Idaho Obtained on June 24, 1960.

Pyroclastic material volcano

Jensen, 2000
Composite Space Shuttle SIR-C/X-SAR image (bands C, X, L) of Kilauea Hawaii volcano on April 12, 1994

SIR-C image overlaid on a digital elevation model. Overland flow of lava on the shield volcano is evident.

Three-dimensional Perspective View of Isla Isabela of the Galapagos Islands Obtained by the Space Shuttle SIR-C/X-SAR (draped over a digital elevation model)

Jensen, 2000
IKONOS IMAGE OF MAUNA KEA

Total Ozone Mapping Spectrometer
Code 916: Atmospheric Chemistry and Dynamics Branch

TOMS

Nimbus 7 Observatory
These false-color images are from the June 16, 1991 eruption of Mt. Pinatubo, Philippines. The gas and ash clouds were tracked by TOMS for several weeks as they encircled the Earth. These satellite observations demonstrate the enormous amounts of gas and ash emitted, as well as details such as differences in peak concentrations and geographic extent. TOMS also detects many smaller volcanic clouds.

-Sulfur Dioxide (SO₂)

-Ash and Aerosols

SOUFRIERE HILLS MONTSERRAT

-Began erupting on July 18, 1995
-Dome collapse on June 25, 1997
-An ash cloud erupted from the Volcano on October 27, 1999
The OMI instrument (onboard Aura Satellite) can distinguish between aerosol types, such as smoke, dust, and sulfates, and measures cloud pressure and coverage, which provides data to derive tropospheric ozone.

Visible: 350 - 500 nm
UV: UV-1 = 270 to 314 nm
UV-2 = 306 to 380 nm

2011 Arctic ozone hole
A combination of extreme cold temperatures, man-made chemicals and a stagnant atmosphere were behind what became known as the Arctic ozone hole of 2011, a new NASA study finds.
On October 22, 2005, one of the six volcanic summits on Isla Isabela in the Galapagos Islands archipelago began erupting. The Sierra Negra Volcano continued to emit ash clouds and lava through the end of the month, before apparently quieting down around October 31. The volcanic emissions contain sulfur dioxide gas, which mixes with water vapor in the air and turns into very reflective sulfate aerosol particles. During large eruptions, volcanoes emit enough sulfur dioxide that the resulting haze of sulfate aerosols can cool the climate by reflecting incoming solar radiation back into space. The Sierra Negra eruption spread a volcanic haze across the Pacific Ocean for several hundred kilometers.
Landsat Thematic Mapper Color Composites of a Portion of the Grand Canyon

TM Bands 4,3,2 (RGB)  TM Bands 7,4,2 (RGB)

Grand Canyon on the Colorado River in Arizona

Landsat TM Band 4  Digital Elevation Model

Shaded Relief Map  Slope Map

Jensen, 2000  Jensen, 2000
GEOLOGICAL MAPPING

• Identify rock types and minerals
• Map concentrations
• Estimate contributions at the sub-pixel scale
• Map physical parameters such as grain size or water content
• Map indicators of soil quality

WHAT KIND OF PARAMETERS/INFORMATION ARE WE LOOKING FOR?

• Mineralogical composition and concentration
• Petrology, identification of rock types
• Physical parameters: grain size, water content, and others
• % cover
HOW DOES THIS INFORMATION APPEAR/TRANSLATE ON THE SPECTRA?

- Composition => Specific absorptions
- Physical parameters => scattering => general shape (continuum), shape of absorptions

GRAIN SIZE - TEXTURE

- Coarse grain= light travels longer
  - Absorption
- Fine grain= multiple reflexions inside grains and at the interfaces
  - Scattering
- BUT scattering intensity depends on the relationship between grain size and wavelength
**GRAIN SIZE - TEXTURE**

![Graph showing reflectance vs wavelength for different grain sizes](image)

**COMPOSITION (MINERALOGY)**

- Well localized specific absorptions

![Graph showing reflectance vs wavelength for different minerals](image)
TETRACORDER

- Developed by the USGS
- Identifies materials by comparing a remotely sensed observed spectrum (the unknown) to a large library of spectra of well-characterized materials

Mineral Maps of Cuprite, NV, Derived from Low Altitude (3.9 km AGL) and High Altitude (20 km AGL) AVIRIS Data obtained on October 11 and June 18, 1998

Hyperspectral data were analyzed using the USGS Tetracorder program.
Read Chapter 18 and answer the review questions 1, 4, and 10 (at the end of the chapter).