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.
Book Topics based on geology, geomorphology and soil science

- Photogeology
- Drainage Patterns
- Lineaments
- Geobotany
- Direct Multispectral Observations of Rocks and Minerals
- Photoclinometry
- Band Ratios
- Soil and Landscape Mapping
- Integrated Terrain Units
- Wetlands Inventory
- Radar Imagery for Exploration
BUT, THE EARTH SYSTEM IS MUCH MORE...

**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

Fresh water 2.5%

Ocean 97.5%

Unfrozen fresh water

Frozen fresh water (Ice caps and glaciers) 74%

Surface water

Ground-water 98.5%

Biosphere

Atmosphere

Soil moisture

Surface fresh water (Lakes, streams)

Water reservoirs in the earth system
Drainage Patterns: Dendritic, Trellis, and Rectangular

Jensen, 2000
Drainage Patterns: Parallel, Radial and Centripetal, Annular

Parallel

Radial and Centripetal

Annular

a. b. c.

Jensen, 2000
Drainage Patterns: Dichotomic, Braided, and Anastomotic

Jensen, 2000
Deltas

Mississippi River Delta, U.S.

Irrawaddy River Delta, Burmah

Niger River Delta, Africa

Nile River Delta, Egypt

Irrawaddy River Delta, Burmah

bird’s foot delta

lobate delta

lobate delta

Jensen, 2000
RIVER PLUMES DETECTED WITH OCEAN COLOR SENSORS

SeaWiFS Sensor
August 2004

Orinoco River

Amazon River
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.
Himalayas from ASTER
CONDITION OF THE OZONE LAYER AND TEMPERATURE TRENDS

High Reflection of Light

WHITE SURFACE
THE WORLD OCEAN

Atlantic Ocean
Caribbean Sea
Gulf of Mexico
Southern Ocean
Indian Ocean
Pacific Ocean
Arctic Ocean
Arabian Sea
Mediterranean Sea
Persian Gulf
Baltic Sea
Black Sea
North Sea
Bering Sea
Hudson Bay
North Atlantic
Norwegian Sea
East China Sea
Sea of Okhotsk
Sea of Japan
Bering Sea
Gulf of Mexico
Atlantic Ocean
Caribbean Sea
## SEA-VIEWING WIDE FIELD-OF-VIEW SENSOR (SEAWIFS)

<table>
<thead>
<tr>
<th>Banda</th>
<th>Largo de Onda</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>412</td>
</tr>
<tr>
<td>2</td>
<td>443</td>
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<tr>
<td>3</td>
<td>490</td>
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<tr>
<td>4</td>
<td>510</td>
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<td>5</td>
<td>555</td>
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<td>6</td>
<td>670</td>
</tr>
<tr>
<td>7</td>
<td>765</td>
</tr>
<tr>
<td>8</td>
<td>865</td>
</tr>
</tbody>
</table>

![Image of SEAWIFS sensor]

**Fitoplancton Chl-a**
CHLOROPHYLL-A AS MEASURED WITH SEAWIFS
SEA SURFACE TEMPERATURE (SST)
SEA SURFACE TEMPERATURE (SST) AS MEASURED BY AVHRR
• 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

EN TODAS NUESTRAS EDICIONES

El radar Doppler más poderoso de la TV
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>
</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>

**L-BAND ANTENNA**
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
A massive sandstorm blowing off the northwest African desert has blanketed hundreds of thousands of square miles of the eastern Atlantic Ocean with a dense cloud of Saharan sand. The massive nature of this particular storm was first seen in this SeaWIFS image acquired on Saturday, 26 February 2000 when it reached over 1000 miles into the Atlantic. These storms and the rising warm air can lift dust 15,000 feet or so above the African deserts and then out across the Atlantic, many times reaching as far as the Caribbean where they often require the local weather services to issue air pollution alerts as was recently the case in San Juan, Puerto Rico. Recent studies by the U.S.G.S. have linked the decline of the coral reefs in the Caribbean to the increasing frequency and intensity of Saharan Dust events. Additionally, other studies suggest that Saharan Dust may play a role in determining the frequency and intensity of hurricanes formed in the eastern Atlantic Ocean.
EFFECT OF THE SAHARA DUST
EFFECT OF THE SAHARA DUST
THE BIOSPHERE
<table>
<thead>
<tr>
<th>Era</th>
<th>Time (Millions of Years Ago)</th>
<th>Important Events</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre cambrian</td>
<td>2,100</td>
<td>Oldest eukaryotic fossils</td>
</tr>
<tr>
<td></td>
<td>2,500</td>
<td>Oxygen begins to accumulate in atmosphere</td>
</tr>
<tr>
<td></td>
<td>3,500</td>
<td>Oldest prokaryotic fossils</td>
</tr>
<tr>
<td>Paleozoic</td>
<td>340</td>
<td>Reptiles appear</td>
</tr>
<tr>
<td></td>
<td>360</td>
<td>First insects</td>
</tr>
<tr>
<td></td>
<td>370</td>
<td>Amphibians appear</td>
</tr>
<tr>
<td></td>
<td>420</td>
<td>Plants colonize land</td>
</tr>
<tr>
<td>Mesozoic</td>
<td>280</td>
<td>Mass extinction</td>
</tr>
<tr>
<td></td>
<td>195</td>
<td>Birds evolve from reptiles</td>
</tr>
<tr>
<td></td>
<td>230</td>
<td>First dinosaurs and mammals</td>
</tr>
<tr>
<td></td>
<td>66.4</td>
<td>Mass extinction</td>
</tr>
<tr>
<td>Cenozoic</td>
<td>2.4</td>
<td>Ice age</td>
</tr>
<tr>
<td></td>
<td>Present time</td>
<td>Advent of modern humans</td>
</tr>
<tr>
<td></td>
<td>Less than 0.1</td>
<td>Simple animals</td>
</tr>
<tr>
<td></td>
<td>0.0</td>
<td>Present time</td>
</tr>
</tbody>
</table>

1 BY-multipcellular life
2 BY-complex cells (eukaryotes)
3 BY-photosynthesis
4 BY-simple cells (prokaryotes)

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-Birds
65 MY-Since the non-avian dinosaurs died out

200,000 years since humans started looking like they do today.
THE CARBON CYCLE

Carbon dioxide (CO₂) is a greenhouse gas that is released during the burning of fossil fuels. This CO₂ is then absorbed by the ocean and plants through photosynthesis. Eventually, this carbon is released back into the atmosphere as CO₂ and O₂, completing the cycle.
PHOTOSYNTHESIS

Carbon dioxide + water + energy \[\text{Photosynthesis by plants}\] \rightarrow \text{Carbohydrates + Oxygen}

Light rays from the sun

Carbon dioxide (CO$_2$) from the atmosphere

Oxygen (O$_2$) given off to the atmosphere

Carbohydrates

Water (H$_2$O) from the soil

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VEGETATION INDEX
EARTH'S PRODUCTIVITY
THE GEOSPHERE
Normal Fault Along the Wasatch Mountain Range in Utah as Recorded on Landsat Thematic Band 4 Imagery

Jensen, 2000
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
PLATES BOUNDARIES

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

Extruded lava dome (shield) volcano

Jensen, 2000
Total Ozone Mapping Spectrometer
Code 916: Atmospheric Chemistry and Dynamics Branch

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.
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.
SO2 concentration over the Sierra Negra Volcano from October 23-November 1 measured by OMI

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.
IKONOS IMAGE
OF GRAND CANYON
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
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
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 versus wavelength for different grain sizes of pyroxene.](image-url)
COMPOSITION (MINERALOGY)

- Well localized specific absorptions
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).