Chapter 7
Earth and the Terrestrial Worlds

Guest Lecture by Chris Kelso

Please pick up one notecard of each color (5 total)
Outline

- The Earth’s Interior
- The Earth’s Surface
- The Earth’s Atmosphere

Concept Questions:
A=Green
B=Pink
C=Orange
D=Yellow
E=White
Cross Section of the Earth

Which of the following do you believe is most closely related to what you might see if you cut the Earth in half?

A=Green    B=Pink    C=Orange    D=Yellow    E=White
The Earth’s Interior

Crust: lowest density, Examples: granite and basalt

Mantle: moderate density, mostly minerals that contain silicon and oxygen

Core: highest density, mostly metals like iron and nickel

Lithosphere: relatively cool and rigid rock that “floats” on warmer and softer rock of the mantle
Differentiation

- Process by which gravity pulls more dense objects below less dense objects
- Can produce distinct layers in materials

The Earth’s density increases towards its center.
The Earth’s Heat Sources

For differentiation to produce the layers inside the Earth, the Earth must have once been hot enough for the interior rock to be molten (liquid).

Which of the following are sources of heat inside the Earth? Choose all that apply.
A. Gravitational energy from the Sun
B. Energy from the Earth’s formation
C. Heat energy from the Sun
D. Energy from radioactivity
Collisions
Clapping example
Radioactive Decay

The products have slightly less mass than the parent nucleus. This mass loss is converted to energy through Einstein’s famous formula:

\[ E=mc^2 \]
Half-life for radioactive decay

\begin{align*}
\text{Red} &= {}^{216}_{84}\text{Po} \\
\text{Blue} &= {}^{212}_{82}\text{Pb}
\end{align*}
Convection

Hot, less dense water rises

Water cools, becomes more dense, sinks

Mantle convection: hot rock rises and cooler rock falls.
Convection Example

If the thickness of the mantle is about 3000 km, and if convection in the Earth moves rocks about 3 cm per year, how long would it take for rocks to travel from the bottom of the mantle to the top.

A. 100 thousand years
B. 1 million years
C. 10 million years
D. 100 million years
E. 1 billion years
Cooling of planets

- The amount of heat contained in a planet depends on its volume (more volume, more heat)
- The heat is only lost through the surface of the planet
- The time it takes to lose the internal heat is related to the ratio of the surface area to the volume (larger ratio loses heat faster)
- For spherical planets, the surface area to volume ratio decreases as the radius increases
- This means smaller planets cool more quickly
Cooling of planets (cont.)
An Electromagnet
Earth’s Magnetic Field
The Earth’s Magnetic Field is dynamic and complicated
Magnetosphere
Aurora Borealis

How can we learn about Earth’s Interior?

Which of the following techniques do you think scientists can use to gather evidence about whether the very center of the Earth is mostly a solid, a liquid, or a gas? Choose all that apply.

A. Drilling through the center of the Earth
B. Studying motion caused by earthquakes
C. Analyzing pictures taken by satellites
D. Scientists cannot study the center of the Earth
Earthquakes help us to map out the interior of the earth

- **Primary (P) Waves**
  - These waves travel the fastest and arrive first after an earthquake
  - Particles move in the direction of travel of the wave
  - Can think of pressure or pushing to help remember the P

- **Secondary (S) Waves**
  - These waves travel slower
  - Particles move perpendicular to direction of travel of the wave
  - Can think of shear or side to side to help remember the S
Earthquake animation

- http://www.iris.edu/hq/files/programs/education_and_outreach/aotm/10/4StationSeismoNetwork480.mov
Four Major Processes Produce Surface Features

Nearly all of the surface features on the Earth are produced by four major processes:
1. Surface Impacts
2. Volcanism
3. Tectonics
4. Erosion
Mars’ surface craters
Craters can help us estimate age

More craters indicate older rocks
Source of volcanic material?

On continents, where does most volcanic material come from?

A. Material comes from the Earth’s melted center
B. Material comes from a melted layer near the Earth’s center
C. Material travels from the Earth’s melted center and mixes with a melted layer beneath the Earth’s surface
D. Material comes from a melted layer beneath the Earth’s surface
E. Material comes from pockets of melted material beneath the Earth’s surface

A=Green    B=Pink    C=Orange    D=Yellow    E=White
Volcanism

Molten rock rises because

- It is less dense
- Surrounding solid rock can squeeze it
- Trapped gases expand as they rise and can result in dramatic eruptions
Outgassing in volcanism

- Volcanoes can release gases into the atmosphere during an eruption in a process called outgassing.
- The most common gases released are Carbon dioxide (CO$_2$), Water vapor (H$_2$O), Nitrogen (N$_2$), and sulfur bearing gases (H$_2$S or SO$_2$).
Tectonics
Continental Drift

How far do you think continents move in a single year?
A. A few inches
B. A few hundred feet
C. A few miles
D. We have no way of knowing
E. Continents do not move

A=Green   B=Pink   C=Orange   D=Yellow   E=White
PhET Simulation

Erosion

Erosion is the break down or transport of rock through action of ice, liquid or gas.

- Break down structures
- Build up structures
If you put a fist-sized rock in a room and left it alone for millions of years, what would happen to the rock?

A. The rock would almost completely turn into dirt
B. About half of the rock would turn into dirt
C. The top few inches of the rock would turn into dirt
D. The rock would be essentially unchanged
If the Earth is drawn to scale as the solid black line, which choice shows the thickness of the atmosphere (the thin, dotted line)?

D. On this scale, the atmosphere is so thin you could not see its thickness

A=Green    B=Pink    C=Orange    D=Yellow    E=White
Structure of the atmosphere
What is the ozone layer?

A. A gas layer in the atmosphere that blocks incoming ultraviolet radiation and does not cause warming of the atmosphere.
B. A gas layer in the atmosphere that absorbs incoming ultraviolet radiation and causes warming of the atmosphere.
C. A gas layer in the atmosphere that absorbs pollution and causes warming of the atmosphere.
D. A gas layer in the atmosphere that blocks incoming ultraviolet radiation and causes warming of the atmosphere.
E. A gas layer in the atmosphere that absorbs pollution and does not cause warming of the atmosphere.
Structure of the atmosphere
Why is the sky blue?

Rayleigh scattering gives the atmosphere its blue color.
The Greenhouse effect

What is the major cause of the greenhouse effect?

A. Gases in the atmosphere absorb heat from the Earth's surface.
B. Gases in the atmosphere absorb heat from the Sun.
C. Gases in the ozone layer absorb heat from the Sun.
D. Gases in the ozone layer absorb heat from the Earth's surface.

A=Green    B=Pink    C=Orange    D=Yellow    E=White
THE ELECTROMAGNETIC SPECTRUM

Penetrates Earth Atmosphere?

Wavelength (meters)

<table>
<thead>
<tr>
<th>Spectrum Type</th>
<th>Wavelength (meters)</th>
</tr>
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<tbody>
<tr>
<td>Radio</td>
<td>$10^3$</td>
</tr>
<tr>
<td>Microwave</td>
<td>$10^{-2}$</td>
</tr>
<tr>
<td>Infrared</td>
<td>$10^{-5}$</td>
</tr>
<tr>
<td>Visible</td>
<td>$.5 \times 10^{-6}$</td>
</tr>
<tr>
<td>Ultraviolet</td>
<td>$10^{-8}$</td>
</tr>
<tr>
<td>X-ray</td>
<td>$10^{-10}$</td>
</tr>
<tr>
<td>Gamma Ray</td>
<td>$10^{-12}$</td>
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</tbody>
</table>

About the size of...

- Buildings
- Humans
- Honey Bee
- Pinpoint
- Protozoans
- Molecules
- Atoms
- Atomic Nuclei

Frequency (Hz)

<table>
<thead>
<tr>
<th>Frequency (Hz)</th>
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<tbody>
<tr>
<td>$10^4$</td>
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<tr>
<td>$10^8$</td>
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<td>$10^{12}$</td>
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<tr>
<td>$10^{15}$</td>
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<tr>
<td>$10^{16}$</td>
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<td>$10^{18}$</td>
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<td>$10^{20}$</td>
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Temperature of bodies emitting the wavelength (K)

<table>
<thead>
<tr>
<th>Temperature (K)</th>
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</thead>
<tbody>
<tr>
<td>1 K</td>
</tr>
<tr>
<td>100 K</td>
</tr>
<tr>
<td>10,000 K</td>
</tr>
<tr>
<td>10 Million K</td>
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</table>
The Greenhouse effect

Some of the Greenhouse Gases:
- Carbon dioxide \((\text{CO}_2)\)
- Water vapor \((\text{H}_2\text{O})\)
- Methane \((\text{CH}_4)\)
Greenhouse gases absorb radiation efficiently in the IR
If human civilization had never developed on Earth, would there be a greenhouse effect?

A. Yes, the greenhouse effect is caused by naturally occurring gases
B. Yes, the greenhouse effect is caused by plants giving off gases
C. No, the greenhouse effect is caused by humans burning fossil fuels
D. No, the greenhouse effect is caused by humans depleting ozone
E. No, there is no conclusive evidence that a greenhouse effect exists
How has the amount of carbon dioxide in the atmosphere changed over the past 500 years?

A. No change
B. Linear increase
C. Linear decrease
D. Exponential increase
E. Exponential decrease
Plot of atmospheric CO$_2$ concentration
Is there a scientific consensus?

Which comes closer to your own view?

A. Most scientists think global warming is happening
B. Most scientists think global warming is not happening
C. Scientists generally disagree about whether or not global warming is happening
D. I do not know

A=Green   B=Pink   C=Orange   D=Yellow   E=White
Challenge Question

- If the Earth were formed as a cube (rather than a sphere) with its same volume, would its interior be cooler, warmer, or about the same temperature as it is now?