EARTH (⊕)

Atmosphere

Composition:
- Nitrogen (N₂) 78.09%
- Oxygen (O₂) 20.95%
- Argon (Ar) 0.93%
- Carbon Dioxide (CO₂) 0.035% (rising)
- Water Vapor (H₂O) varies (≤ 0.4%)

But, atmospheres of Venus and Mars
CO₂ = 95% - 96%!!

Where is all the CO₂ on Earth??
Why is there so much N₂, O₂, H₂O on Earth??

Recycled Air

Earth’s atm. has changed since formation

Action of Volcanoes:
- Outgassing
  - water vapor, N₂, CO₂, Ar
- Primary source of Earth’s Water
  - water is predominant surface

Action of water, rain:
- dissolves CO₂, settles into rocks
  - Examples: Limestone, Coca-Cola, Pepsi

Action of Plant Life: (algae)
- releases O₂, absorbs CO₂

http://www.nasa.gov/vision/universe/newworlds/ets_breath.html
Environmental Issues

Ozone ($O_3$) Depletion

Ground Level Ozone - near surface
- pollutant (crop & respiratory problems)

Ozone Layer - in middle layer (10 - 35 km high)
- absorbs and blocks UV from sun

Depletion of Ozone Layer
- manmade Chloroflourocarbons (CFC)
  - reacts with and destroys $O_3$

The Ozone Hole
- sharp drop in ozone over South Pole
- hole is dramatically larger since 1980

Effects of Ozone Depletion (increase UV)
- can induce skin cancer, cataracts, affect plants, animals

2006: Tied record - largest ozone hole
Set record - least amount of ozone

http://ozonewatch.gsfc.nasa.gov/
Montreal Protocol, 1987 (ratified by 191 countries)

“Perhaps the single most successful international agreement to date has been the Montreal Protocol.”
Kofi Annan, Former Secretary General of the United Nations

- phaseout of CFC by 1995 in developed countries
- total phaseout of other compounds by 2015
- but CFC takes years to reach O₃ layer
- CFC levels in stratosphere reducing very slowly.
  - full recovery not expected until year 2050 – 2070

The Greenhouse Effect

What is it?
Refers to energy (heat) gained versus energy (heat) lost

Primary energy source for Earth

- most of Sun's energy is in the form of visible light
- atmosphere is transparent to visible Light

Earth’s surface absorbs most of the energy
- heats up and reradiates energy
- emits infrared (IR) energy

Atmosphere is not transparent to IR
- “greenhouse” gases absorb IR, heat up
- slows down heat loss to space
  - "greenhouse effect" does not generate heat
  - like a blanket slows heat loss from Body

Greenhouse Gases:
- H₂O, CO₂, Ozone (O₃), methane (CH₄), nitrous oxide (N₂O)
- avg T of Earth is 35°C (63 °F) warmer than it would be with no atmosphere.
  - avg T of Earth = 60 °F
But, all forms of combustion release CO\textsubscript{2}.
- CO\textsubscript{2} levels are highest in 800,000 yrs
- Oct. 2016, level is 404.93 ppm

Consequences:

**Global Temperature Rise:**
- 16 warmest yrs on record all 1998-2015
- Hottest year ever: 2015 (2016 ?)
- 2\textsuperscript{nd} hottest year: 2014
  [Link]

**Shrinking ice sheets:**
- Antarctica: -147 billion tons ice per year
- Greenland: -258 billion tons ice per year

**Sea level rise:**
- rose 6.7 inches in 20\textsuperscript{th} century
- rose 1.3 inches from 2000-2010

**Changes of Ocean chemistry:**
- Oceans becoming more acidic as more CO\textsubscript{2} absorbed (+30% in past 100 yrs)

**30 indicators of climate:**
- All show long term trend to warmer climate

**Other Worlds**

**Moon, Mercury**
- worlds with no atmosphere

**Both have much less mass than Earth**
- less surface gravity than Earth

<table>
<thead>
<tr>
<th>Mass (M\textsubscript{E})</th>
<th>Gravity (m/s\textsuperscript{2})</th>
</tr>
</thead>
<tbody>
<tr>
<td>Earth</td>
<td>1.0</td>
</tr>
<tr>
<td>Mercury</td>
<td>0.055</td>
</tr>
<tr>
<td>Moon</td>
<td>0.012</td>
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</tbody>
</table>

- weaker gravity cannot contain atmosphere

**With no greenhouse gases:**
- Both experience rapid heat loss during night time

<table>
<thead>
<tr>
<th></th>
<th>T\textsubscript{Daytime}</th>
<th>T\textsubscript{Nighttime}</th>
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</thead>
<tbody>
<tr>
<td>Mercury</td>
<td>800 °F</td>
<td>-280 °F</td>
</tr>
<tr>
<td>Moon</td>
<td>260 °F</td>
<td>-280 °F</td>
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</tbody>
</table>
**Venus**
- "Earth’s Twin"
- very similar mass, density, surface gravity as Earth

Venus has a very thick atmosphere
- 92 times the pressure of Earth's
  - same pressure as 1 km (3000 ft) under water
  - completely covered by clouds
    - composed of sulfuric acid droplets!

Atmosphere:

<p>| | |</p>
<table>
<thead>
<tr>
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<tbody>
<tr>
<td>CO₂</td>
<td>96.5%</td>
</tr>
<tr>
<td>N₂</td>
<td>3.5%</td>
</tr>
<tr>
<td>Argon, Water</td>
<td>trace amounts</td>
</tr>
</tbody>
</table>

Surface Temps: \(890 \, ^\circ\text{F}!!\)
- hottest surface in the solar system!
- very little difference from day to night or from equator to pole

Thick Carbon Dioxide "blanket"
- absorbs 99% of emitted IR from surface
  - “Runaway Greenhouse”
  - no mechanism to remove CO₂ from atmosphere

**MARS**
Smaller mass, surface gravity then Earth

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<table>
<thead>
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<tbody>
<tr>
<td>Mass:</td>
<td>0.107 (M_\oplus)</td>
</tr>
<tr>
<td>Surface Gravity:</td>
<td>3.73 (m/s^2)</td>
</tr>
</tbody>
</table>

Does not have enough gravity to keep thick atmosphere
- has thin atmosphere
  - 150 times less pressure than Earth's
  - clouds: mostly frozen CO₂ (dry ice)

Atmosphere:

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<table>
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</thead>
<tbody>
<tr>
<td>CO₂</td>
<td>95.3%</td>
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<tr>
<td>N₂</td>
<td>2.7%</td>
</tr>
<tr>
<td>Argon, Water</td>
<td>1.7 %</td>
</tr>
</tbody>
</table>

Total amount of CO₂ is less than on Earth

Very weak greenhouse effect:
- Average surface temp: \(-75 \, ^\circ\text{F}\)
- Daytime (Summer): \(+80 \, ^\circ\text{F}\)
- Nighttime: \(-200 \, ^\circ\text{F}\)

BUT, evidence of liquid water on surface in past!
- surface temp must have been warmer
  - above 32 \(^\circ\text{F}\) for liquid water
- atm pressure must have been greater
  - otherwise water "boils" away

**MARS: “Missed Opportunity”**

Evidence of past Volcanic Activity

Environment must have been Earth-like
- higher pressure, temp for liquid water

Due to smaller mass, surface gravity
- most of atmosphere lost to space
  - after first 1 - 2 billion years
- possibly CO₂ removed by ancient waters
- with colder temps, any remaining water would freeze

"Runaway" Scenario:  
- as temperatures decrease
- ability to warm itself decreases