Global Nutrient Cycling - Biogeochemical Cycles

Precipitation

Volatile elements

Bioelements in Solution

Uptake

Terrestrial Biomass

Death

Dead Organic Matter

Decomposition

Runoff losses

Ocean

Mean Residence Time (MRT)

= pool size / mean flux in or out of pool

Fractional Turnover = 1 / MRT

= fraction that is removed and replaced per unit time

Useful Conversion Factors

10^{12} g = 1 teragram = 1 Tg

10^9 g = 1 gigaton = 1 gt

10^6 g = 1 metric ton = 1 tonne

Figure by MIT OCW.
**Solar Energy Budget**

Total From Sun: 100%

(1.3 x 10^{21} \text{kcal per year})

- Reflected: 30%
- Absorbed (heat): 47%
- Used in Evaporation: 23%
- Used in Winds & Currents: 0.2%
- Used in Photosynthesis: 0.002%

Energy In = Energy Out

Source of energy to most ecosystems on Earth is Solar Radiation

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**The Geologic Cycle**

Powered by Solar & Geothermal Energy

- **SOLAR**
- **GEOTHERMAL**

- **Igneous (Lava)**
- **Igneous**
- **Magma**

- **Surface Rocks**
- **Weathering Erosion**

- **Uplifting Uncovering**

- **Metamorphic Rocks**

- **Sedimentary Rocks**

**Critical for Driving the Cycle**
The Global Water Cycle

<table>
<thead>
<tr>
<th>Pool (km³)</th>
<th>Flux (km³/yr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ice</td>
<td>33,000,000</td>
</tr>
<tr>
<td>Atmosphere</td>
<td>13,000</td>
</tr>
<tr>
<td>Soil Waters</td>
<td>122,000</td>
</tr>
<tr>
<td>Groundwater</td>
<td>15,300,000</td>
</tr>
<tr>
<td>Oceans</td>
<td>1,350,000,000</td>
</tr>
<tr>
<td>Net transport to land</td>
<td>40,000</td>
</tr>
<tr>
<td>River flow</td>
<td>40,000</td>
</tr>
<tr>
<td>Net transport to the atmosphere</td>
<td>385,000</td>
</tr>
<tr>
<td>Net transport to the ocean</td>
<td>425,000</td>
</tr>
</tbody>
</table>

Reference: Schlesinger, 1997

The Global Phosphorus Cycle

<table>
<thead>
<tr>
<th>Pool (10¹² g P)</th>
<th>Flux (10¹² g P/yr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Land plants</td>
<td>3000</td>
</tr>
<tr>
<td>Crops</td>
<td>60</td>
</tr>
<tr>
<td>Fertilizers &amp; Detergents</td>
<td>12</td>
</tr>
<tr>
<td>P-Mines</td>
<td>21</td>
</tr>
<tr>
<td>Riverflow</td>
<td>21</td>
</tr>
<tr>
<td>Oceans</td>
<td>90,000</td>
</tr>
<tr>
<td>Sediments</td>
<td>4x10⁹</td>
</tr>
<tr>
<td>Soils</td>
<td>200,000</td>
</tr>
<tr>
<td>Mineable rock</td>
<td>10,000</td>
</tr>
<tr>
<td>Dust Transport</td>
<td>1.0</td>
</tr>
</tbody>
</table>

Geologic Time Scales (10⁸ years)

Reference: Schlesinger, 1997
Global Nitrogen Transformations

- Reduced
- Organic - N
  - NH₄⁺
  - Assimilatory Nitrate Reduction
  - Requires Energy
- Oxic
  - NO₂⁻
  - Requires Energy
  - NO₃⁻
  - Releases Energy
- Anoxic
  - N₂O
  - Denitrification (anaerobic respiration)
  - NO
- Nitrogen Fixation
  - N₂

The Global Nitrogen Cycle

- Fluxes (10¹² g N/yr)
  - Industrial N-fixation
  - Fertilized crops
  - Cultivated legumes
  - Land plants
  - N-fixation in lightening <3
  - Biological Fixation 140
  - Denitrification <200
  - Riverflow 36
  - Atmosphere 4x10⁹
  - Denitrification 110
  - Oceans 570,000

- Pools (10¹² g N)
  - Soil organic – N
    - 12,000
  - Groundwater
  - Permanent Burial
    - 10

Reference: Schlesinger, 1997
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The Global Carbon Cycle

See Freeman, Figure 51.1

Ice Core Data Showing Changes in Atmospheric CO₂ Concentrations

Figure by MIT OCW.

Biosphere II Experiment

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Please see:
http://www.bio2.com/index.html
Photosynthesis

Ca(OH)₂ + CO₂ → CaCO₃ + H₂O

Why didn’t CO₂ increase?

Respiration

Understandable only in hindsight

"Biosphere I" Experiment

Falkowski and Tchernov 2004