Earth's Atmosphere, Oceans, and the Carbon Cycle

11-28-2005

Opening Discussion

- Have you seen anything interesting in the news?
- Why aren't we looking for comets? It is not lack of a threat, but lack of ability to detect. Composition means almost nothing for a 10 km body. There are FAR more comets than asteroids. Each one is much less likely to come into the inner solar system, but there are so many more it balanced out. The single best comet finder has been SOHO.
- Breakdown of extinctions from KT impact. How do we know that? Evolution and mass extinctions.

More Minute Essays

- Crocodiles are older than dinosaurs, but birds did evolve from dinosaurs.
- Teacher telling story about an asteroid that would have a close approach to the Earth.
- Pecan pie is my favorite holiday pie.

Earth's Oceans

- Earth, Venus, and Mars likely all outgassed large amounts of water. Only the Earth has it sitting on the surface in liquid form thanks to a stable climate and low CO_2 levels.
- Mars certainly did have significant surface water at one time, but it has either been lost or is now frozen at the poles and under the surface.
- Venus might have had water early in its history. It is likely we will never know. After the runaway greenhouse effect all the water was in the atmosphere and over time the hydrogen was lost through photodissociation and escape.

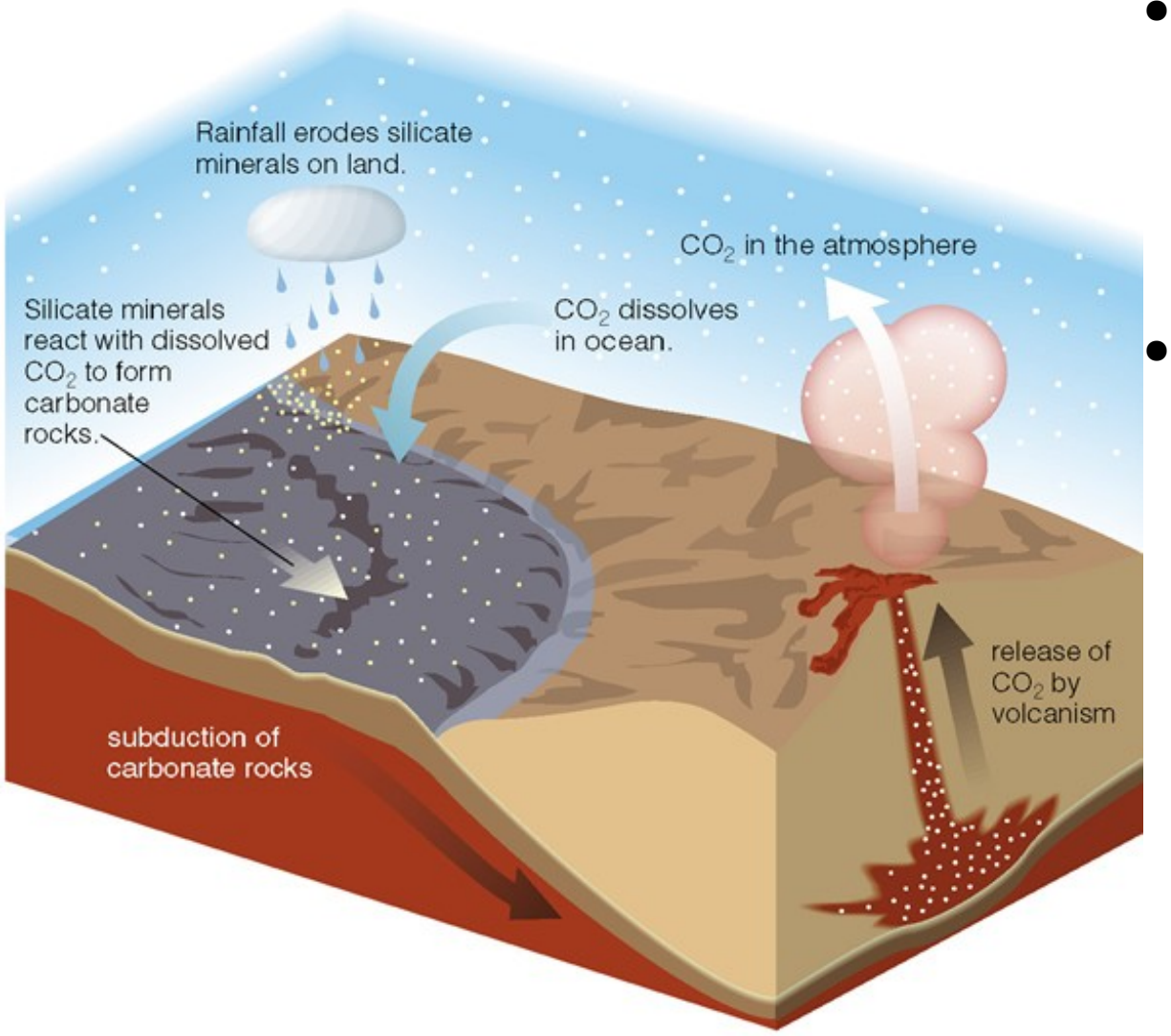
Missing CO_2?

- Venus's atmosphere has large amounts of CO_2. It is also the primary component of Mars's atmosphere though the atmosphere of Mars is much thinner. A lot of CO_2 has been outgassed on the Earth, just like Venus. Where is it?
- The answer is that it is trapped in the oceans and rocks. The Earth has as much CO_2 as Venus, but only a small fraction is in the atmosphere at any given time.

Oxygen and Ozone

- The Earth is the only body in our Solar System with significant atmospheric oxygen. The reason for this is life.
- Oxygen is highly reactive and if it weren't replenished we would lose all of it in a few million years to various chemical reactions.
- Photosynthesis not only put O_2 into our atmosphere, when that O_2 gets to the stratosphere it becomes ozone (O_3) through photodissociation of the O_2. This forms the stratosphere and protects surface life from UV radiation.

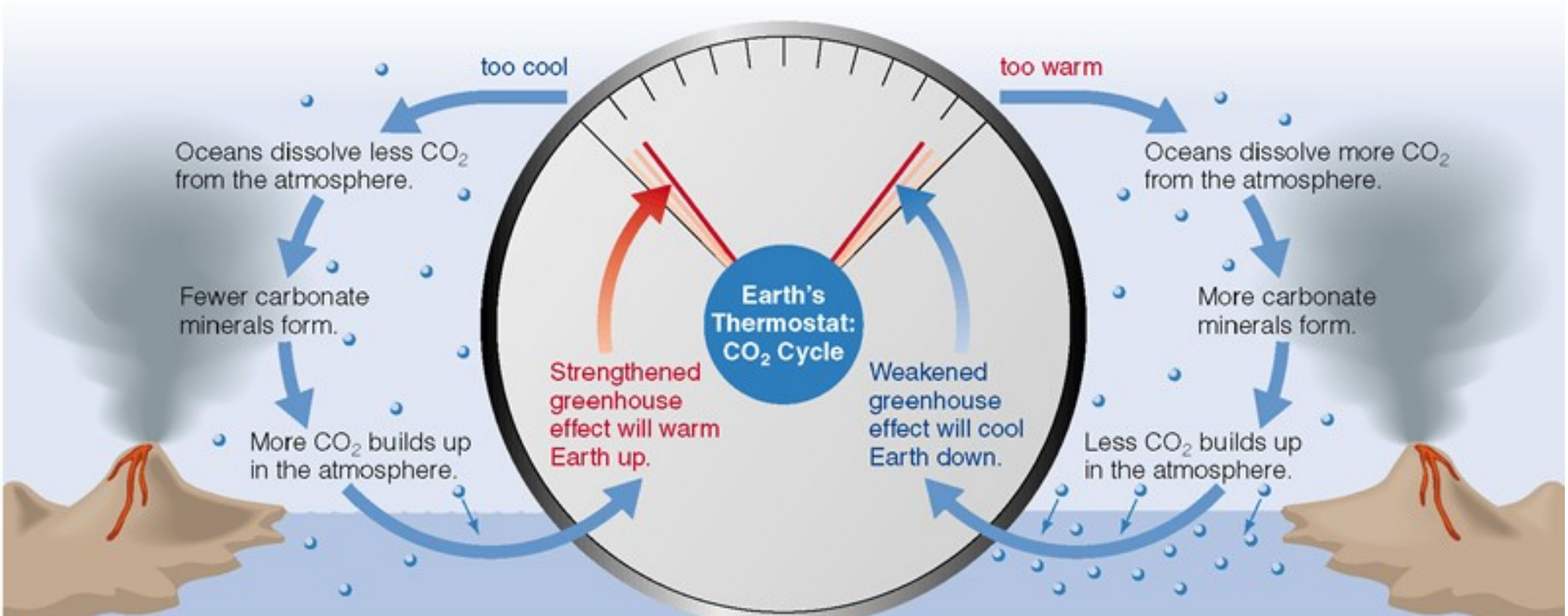
The Carbon Dioxide Cycle



- CO_2 is constantly recycled from the atmosphere to the oceans and into rocks.
- This process requires surface water because the CO_2 bearing rocks only form from CO_2 dissolved in water. In present times it also forms from shells of sea animals, but life isn't required.

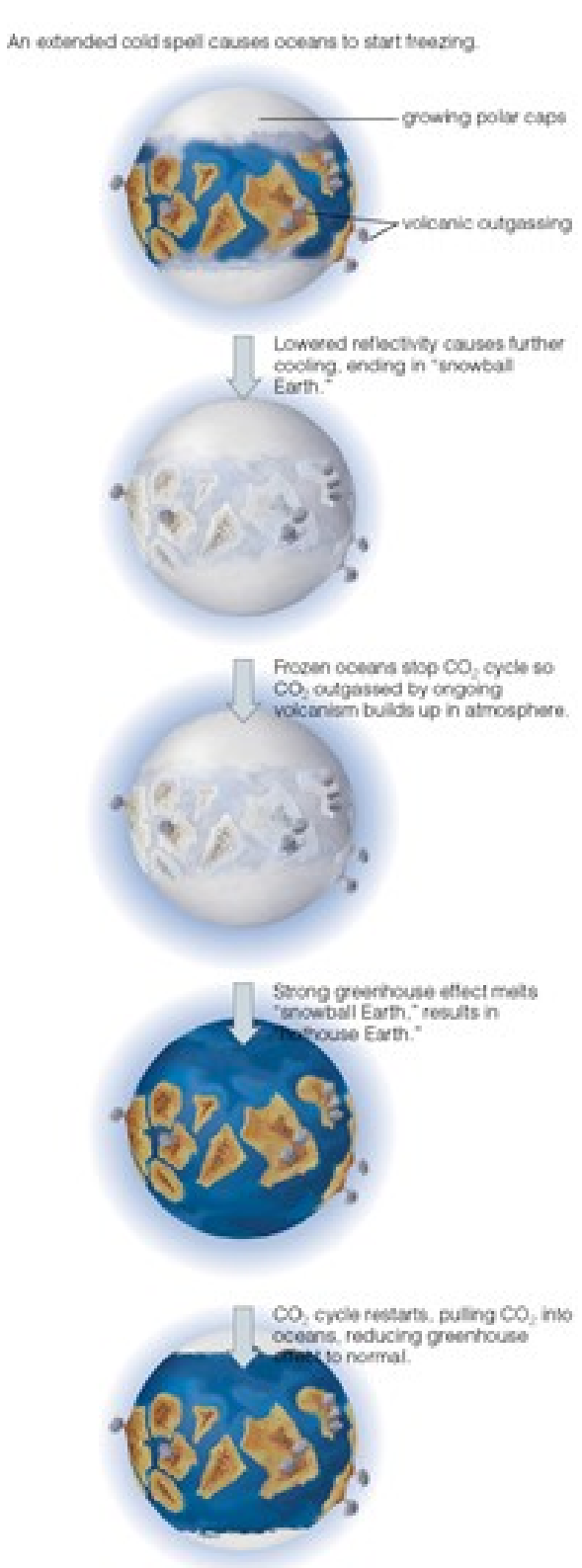
Negative Feedback Stability

- Carbonate minerals form more quickly when the temperature is hotter and less quickly when it is cold. This is a negative feedback that stabilizes our climate. This cycle can stabilize things on a timescale of roughly 400,000 years.



Ice Ages

- Water tends to lead to positive feedback loops which send temperatures to extremes. We have already discussed the positive feedback of a runaway greenhouse. Ice freezing or melting produces another positive feedback.
- When small variations in solar brightness, continent locations, axis tilt, or orbit cause the poles to be a bit colder, more ice freezes. Ice is highly reflective which further reduces temperatures. This leads to ice ages where ice can extend well down into the mid-latitudes.
- What causes and stops ice ages is not very well understood.



Snowball Earth

- Recently geologists have found evidence that there could have been extreme ice ages in the distant history of the Earth where the temperatures got so low that all the oceans froze over.
- This has no impact on the internal temperature of the Earth and outgassing continues. Without surface water, CO_2 builds up in the atmosphere and eventually produces a strong enough greenhouse effect to melt the ice.
- This likely leads to a period of extreme heat that lasts for hundreds of thousands of years.

Long Term Climate and Stability

- In the longer term, the brightening of the Sun will definitely make the Earth uninhabitable between 1 billion and 4 billion years from now.
- Obviously, the relative stability of the climate of our planet has been critical to the survival of life over the last 4 billion years. It is even more important to complex life such as humans.
- Plate tectonics appear to be significant in keeping our climate so stable. Unfortunately, we don't know how common plate tectonics are or how likely other stabilizing effects are. Answers to those questions will help us understand how rare the Earth really is.

Minute Essay

- Today we talked about the natural mechanisms that the Earth has for removing CO_2 from the atmosphere. What impact does that have on the issue of global warming? Have the Earth's natural regulation mechanisms help us out?