Atmospheric Evolution and Climate Change

11-4-2005

Opening Discussion

- Do you have any questions about the quiz?
- What did we talk about last class?
- Have you seen anything interesting in the news?
- Apology for late appearance of slides.
- Why does air want to travel from the pole to the equator and the other way around?
- What do I think will end life on Earth?
- Are Mike and I related?
- Applying the math formulas.
- Could you feel the spin on a planet like Jupiter?

More Minute Essays

- No hurricane has ever been seen to cross the equator. In fact, they typically don't form within 5 degrees of the equator because the Coriolis forces are too small in that region.
- The sky is blue because you are “seeing” the blue of the scattering atoms. Sunset is red because the blue either hit the Earth or went out to space before getting to you.
- Can you have greenhouse gases that don't heat up a planet?
- I couldn't find anything on “meteorological retrograde motion”.

Atmospheric Gain

- Outgassing – erupting volcanoes release volatiles.
- Evaporation/sublimation – if a planet warms, liquids or ices on the surface can turn to gas and become part of the atmosphere.
- Impacts – rare impacts of volatile rich bodies can add extra material to the atmosphere. This doesn't account for much after the heavy bombardment.
- Bombardment – if the planet has no significant atmosphere, micrometeorites and high energy particles can vaporize surface materials.

Atmospheric Loss

- Condensation – if the planet cools materials can go from the atmosphere back to liquid or solids on the surface.
- Chemical reactions – gases can be dissolved in liquids or bound to solids.
- Solar wind stripping – only hits exosphere, a magnetosphere prevents this.
- Impacts – large impacts can blow sections of the atmosphere into space.
- Thermal escape – particles in exosphere can occasionally get enough energy to achieve escape velocity.

Details of Thermal Escape

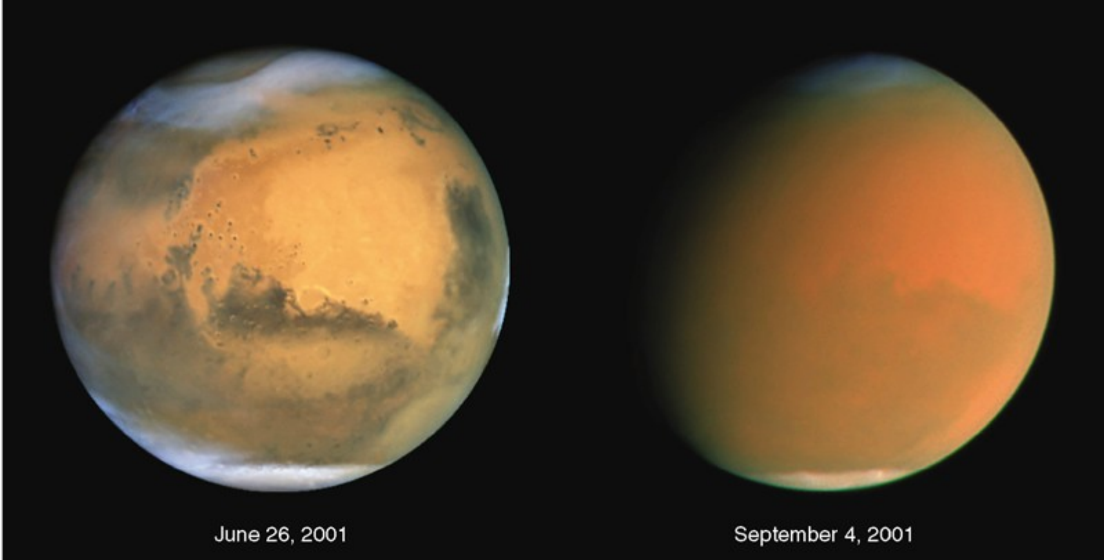
- When we talked about gravity we talked about the escape velocities of various objects. Small planets don't retain atmospheres because atoms are able to attain escape velocity.
- The actual velocities of gas atoms is a distribution that covers lots of speeds, but the average of that distribution is given by the following equation. Note how it varies with temperature and the mass of the particles.

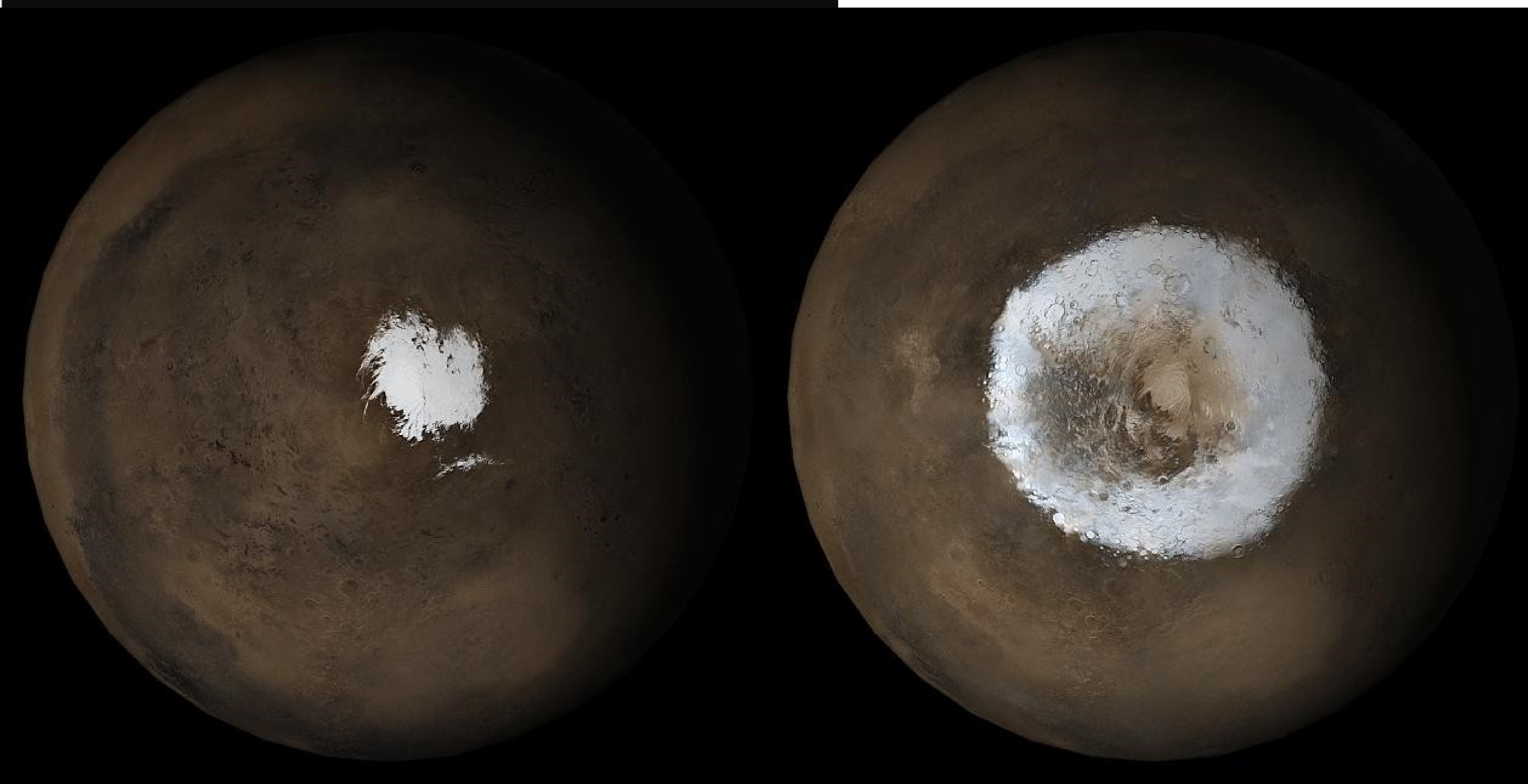
$$v_{thermal} = \sqrt{\frac{2kT}{m}}$$

Mars Weather

- The weather on Mars is quite interesting. The seasons there are more extreme than on the Earth because the orbit is more elliptical. Also, the primary component of the atmosphere can condense out at the poles in the winter.
- The result of this is that there are large scale motions of the atmosphere as air condenses at one pole and sublimates at the other, then switches back the other direction.
- These global movements of air can kick up extremely large dust storms that can cover the whole planet.

Pictures





How Mars Got This Way

- We have evidence that Mars was once much warmer and wetter. The huge volcanoes on Mars should have outgassed significant amounts of CO_2 and water. The water should have been sufficient to form a reasonable ocean on the planet and the greenhouse effect would have kept things warm enough for liquid water to be stable.
- Once volcanism stopped loss processes could remove the atmosphere. The solidifying of the interior would also have removed the magnet field and let the solar wind strip away the atmosphere more quickly.
- Water dissociation leads to hydrogen escape.

Venus Weather

- Venus has no significant weather at ground level. There aren't significant winds or precipitation.
- Sulfuric acid clouds are blown about by strong winds in the upper atmosphere. The presence of sulfuric acid indicates that there most be some fairly recent volcanism as the sulfur dioxide needed to produce it isn't stable over geological timescales.
- Venus is extremely dry, even the upper atmosphere lacks water. Venus should have had as much water at the Earth, but photo dissociation effectively removed it.

How Venus Got This Way

- So why is Venus so different from Earth given the similar size and distance from the Sun? The answer lies in the minor difference in distance to the Sun.
- When a planet warms more water evaporates. Since water is a greenhouse gas, having more in the atmosphere warms the planet further. This positive feedback loop can lead to a runaway greenhouse effect if the planet is a bit closer to the Sun than the Earth.
- Because the Sun was dimmer in the past Venus might have been habitable though we are unlikely to ever know.

Implications for the Earth

- The Earth's atmosphere has been remarkably stable over the age of the Solar System. We owe this to the stabilizing influence of our Moon, the size of our planet, and our distance from the Sun.
- Judging from the other terrestrial planets in our Solar System, this stability is the exception, not the rule.
- The greatest fear of those who worry about global warming is the possibility of a runaway greenhouse on Earth. It is almost inevitable in 1 billion years as the Sun gets brighter. Our current activities could speed up the process.

Minute Essay

- What do you think will lead to the end of life on Earth? Why do you feel that way?