Chapter 18 Study Guide and Case Studies: Anthropogenic Changes - The Atmosphere

Key Concepts

- The global average temperature rose by 1.3 °C between 1860 and 2017.
- While some smaller fluctuations in the 20th century may have been caused by more solar activity and a lack of global volcanism. The sharp increase in the last 30 years has no natural cause.
- Global warming causes mountain glaciers and continental ice sheets to melt. This melt raises global sea level.
- The VEI 6 1991 eruption of Mt. Pinatubo, Philippines temporarily lowered global average temperature by 0.5 °C, thereby offsetting global warming
- The current warming is caused primarily by the increase in atmospheric carbon dioxide which is a greenhouse gas and currently has no significant natural source.
- Anthropogenic increase of atmospheric CO₂ comes from fossil fuel burning (80%), deforestation (17.3%) and cement production (2.7%).
- Secondary contributors are increasing amounts of methane that also has increase exponentially. This increase has natural and well as anthropogenic sources.
- Anthropogenic increase of atmospheric CH₄ comes from cattle farming (29%), waste disposal (28%%), fossil fuel production (27%) and rice paddies (16%).
- Other contributors are nitrous oxides, ozone and CFCs. The latter is exclusively anthropogenic.
- CO₂ levels in the atmosphere has been measured directly since 1958 on Mauna Loa, Hawaii (Keeling curve). For times prior to that, CO₂ levels are estimated from ice cores in Greenland and Antarctica.
- Since the beginning of the industrial age at the end of the 1700s, atmospheric CO₂ has increased by more than 40% from 280 ppm to 400 ppm in 2016.
- Seasonal variations of atmospheric CO_2 are only a few ppm and so much smaller than the overall increase.
- Between 1958 and 2016, atmospheric CO_2 has increased by 26% from 318 ppm to 400 ppm. This means that the increase in CO_2 has accelerated 6-fold from 0.24 ppm/yr before 1958 to 1.41 ppm/yr since 1958.
- Until 2009, the U.S. was the world's largest contributor to anthropogenic CO_2 with 25% of all emissions. In 2009, China surpassed the U.S. as the world's top emitter. In 2014, Indonesia was the 3^{rd} top contributor through deforestation.

- Natural causes of temperature fluctuations are millennial warming, solar warming and volcanism. All of these cannot explain the current warming.
- The melting of glaciers and ice sheets in a warming climate leads to sea level rise.
- In the last 100 years, global sea level has risen by 15 cm
- Contributors to global sea level rise are melting of glaciers (20%), melting of Greenland ice sheet (20%) and thermal expansion of warming oceans (30%). The impact of the melting Antarctic ice sheet is still an area of research and debated. Icebergs and sea ice (e.g. the Arctic sea ice) do not contribute to sea level rise.
- Various climate scenarios including 'business as usual' to drastically reducing anthropogenic CO₂ predict a temperature increase of 2 – 5 °C and a sea level rise by 40 – 100 cm by 2100.
- A sea level rise on the order of 1 m affects many countries around the world.
- The 1997 Kyoto Protocol aimed to stabilize atmospheric CO_2 at 450 ppm. To achieve this goal, anthropogenic emission would have to fall below 1990 levels by 2012. The protocol needed to be ratified by more than half of the emitters to be effective. This was the case in 2004 after Russia joined the protocol.
- The Kyoto Protocol was opposed by oil-producing countries, the fossil fuel industry and major fossil fuel users (U.S., China).
- The U.S. never joined the Kyoto Protocol and was the only industrialized nation not to do so. The argument was that a ratification of the Kyoto Protocol would hurt the U.S. economy.
- The successor to the Kyoto Protocol is the 2015 Paris Agreement. The U.S. has announced to leave the Paris Agreement.
- Ozone in the stratosphere interacts with incoming UV sunlight so that Earth's surface is protected from this harmful UV radiation.
- In the 1980s, a thinning of the ozone layer was detected during the Antarctic spring. The associated reduction in ozone came from the destruction by anthropogenic CFCs that are used in refrigerators and air conditioners.
- In 1987, the Montreal Protocol was established to phase out CFCs. The ozone hole has slowly recovered but other agents that replaced the CFCs still destroy ozone and are greenhouse gases.

Key Terms

- Global average temperature
- Mountain glaciers
- Ice sheets
- Anthropogenic greenhouse
- Fossil fuels
- deforestation
- Industrial era

- Keeling curve
- Seasonal CO₂ variations
- World's top CO₂ emitters
- Sea level rise
- Thermal expansion
- Kyoto Protocol
- Paris Agreement

- Ozone hole
- Stratosphere
- UV radiation

- Antarctic spring
- CFCs
- Montreal Protocol

Questions for Review

- 1. By how much has the average global temperature changed between 1860 and 2017?
- 2. How has the trend changed in the last few decades?
- 3. Which natural processes caused minimal temperature fluctuations?
- 4. Discuss the interplay between temperature fluctuations and sea level change.
- 5. What is the main cause of the recent temperature increase?
- 6. By which processes are anthropogenic CO₂ and CH₄ produced?
- 7. What other greenhouse gases contribute to global warming?
- 8. What is the Keeling curve?
- 9. How do seasonal variations in atmospheric CO_2 compare to the overall change since 1958?
- 10. Why would atmospheric CO₂ change throughout the year?
- 11. How has atmospheric CO_2 changed recently in comparison to earlier in the 20^{th} century?
- 12. Discuss the world's top CO_2 emitters.
- 13. What natural processes could change global average temperature and can they explain the current warming?
- 14. Describe how sea level has changed in the last 100 years. Why is this change occurring?
- 15. What are the predictions for temperature and sea level change for this century?
- 16. What is the Kyoto Protocol? Discuss.

- 17. Discuss the successor to the Kyoto Protocol.
- 18. What is the Ozone hole? What causes it?
- 19. What is the Montreal Protocol? Discuss.

Case Studies

Case Study 1: Projected Consequences of Global Warming for San Diego

On Nov. 19, 2008 the San Diego Union Tribune released a report written by the <u>San Diego Foundation</u> (SDF) to the California Climate Action team to describe the consequences of climate change for the San Diego Region by 2050. The Tribune summarized the main projections:

- sea level will be 12-18 inches higher
- the region will require 37% more water while resources (such as the Colorado River) will be less by at least 20%
- the fire season will start earlier; the number of days with ideal conditions for large wildfires will increase by up to 20%
- peak electricity demand will be 70% higher

The summary of the San Diego Foundation actually goes further and says it more bluntly: In 2050, if current trends continue ...

- sea level will be 12-18 inches higher
- o San Diego's climate will be hotter and drier
- Wildfires will be more frequent and intense
- We will face severe water shortage
- Public health will be at risk, especially among the elderly and children
- Native plant and animal species will be lost forever
- We will not be able to meet our energy needs

The full report is available in pdf format at the SDF website.