GEOL 437: Global Climate Change
1/30/18: Radiation balance, atmospheric composition and the natural greenhouse effect

- What is a “greenhouse” gas?
- The “natural greenhouse effect”
- See for yourself!
Atmospheric composition and the natural greenhouse effect:

Key concepts

- Stefan Boltzmann Law
- Radiative Flux
- Radiative balance
- Wien's Displacement Law
- Greenhouse gas
- The “natural greenhouse effect”
How warm would the Earth's surface be without an atmosphere?

Stefan-Boltzmann Law
(black body radiation)

Flux of radiation from a black body
is proportional to
the fourth power of its temperature.
If the Earth is not heating up or cooling down, then

\[
\text{Radiative flux from Sun (in)} = \text{Radiative flux from Earth (out)}
\]
What if we add an atmosphere?

Major constituents of today's atmosphere (% by volume)

- Nitrogen ($\text{N}_2$) 78%
- Oxygen ($\text{O}_2$) 21%
- Argon (Ar) 0.9%
- Water Vapor ($\text{H}_2\text{O}$) 0.00001% (South Pole) – 4% (tropics)
What makes a greenhouse gas?

*absorption and re-radiation of terrestrial radiation: stretch, bending, rotation of asymmetric molecules*

http://www1.lsbu.ac.uk/water/vibrat.html

Martin Chaplin, Water Absorption Spectrum,
http://www1.lsbu.ac.uk/water/vibrat.html, accessed 1/29/18
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Important greenhouse gases (partial list; % by volume)

- Water Vapor ($H_2O$) 0.00001% (South Pole) – 4% (tropics)
- Carbon dioxide ($CO_2$) 0.0370%
- Methane ($CH_4$) 0.00017%
- Nitrous Oxide ($N_2O$) 0.00003%
Wien's Displacement Law

The flux of radiation emitted by a black body is greatest at a wavelength which depends inversely on the temperature of the black body.
Wien's Displacement Law:

\[ \lambda_{\text{max}} = 2.9 \times 10^{-3} \text{ m} \cdot \text{K} / \text{Temperature} \]

Spectral curves for blackbody radiators

Temperature of Sun's surface

Wien's Displacement Law

Flux

Increasing flux

\[ 1 \times 10^{-7} \text{ to } 3 \times 10^{-6} \text{ m} \]

Wavelength (m)

(Short) - (Long)

Ultraviolet - Visible - Infrared
Role of greenhouse gases in Earth's radiative balance

- Which gases absorb strongly in the visible wavelength range?
- Which gases absorb strongly in the infrared wavelength range?

Diagram from Skinner et al., The Blue Planet (1999)
NOTE: wavelength scale is reversed
See for yourself
Summary

- The atmosphere is mostly transparent to visible radiation from the Sun.
- Trace amounts of greenhouse gases absorb and reradiate the infrared radiation emitted by Earth strongly. This keeps the planet's surface at about 15°C (288K) – much warmer than the -18°C (255K) we calculated for Earth without an atmosphere – and is the basis of the natural greenhouse effect.
- Next: the climatological annual cycle and interannual radiative forcing.
  - Reading: Hansen et al (1992)

HW2
E.C.: what's wrong in this figure?

Source: https://commons.wikimedia.org/wiki/File:Atmospheric_Transmission.png, acc 1/29/18