Global GHG emissions, per year, 1751-2010
(in millions of metric tons of carbon)
Where the Emissions Come From

Global Fossil Carbon Emissions

- Total
- Petroleum
- Coal
- Natural Gas
- Cement Production

source: wikipedia
Greenhouse Gas Concentrations

Concentrations of Greenhouse Gases from 0 to 2005

- **Carbon Dioxide (CO**$_2$**)**
- **Methane (CH**$_4$**)**
- **Nitrous Oxide (N**$_2$O**)**

(Source: IPCC AR4, 2007, WG1, pg135)
The Keeling Curve

Latest CO$_2$ reading 398.77 ppm
November 02, 2015

Carbon dioxide concentration at Mauna Loa Observatory

https://scripps.ucsd.edu/programs/keelingcurve/wp-content/plugins/sio-blueloon/graphs/mlo_full_record.png
Last two years of CO2 data...

Latest CO₂ reading
November 02, 2015
398.77 ppm

Carbon dioxide concentration at Mauna Loa Observatory

Two years ending November 2, 2015

https://scripps.ucsd.edu/programs/keelingcurve/wp-content/plugins/sio-bluemoon/graphs/mlo_two_years.png
And if you zoom right out...

Latest $\text{CO}_2$ reading
November 02, 2015

398.77 ppm


https://scripps.ucsd.edu/programs/keelingcurve/wp-content/plugins/sio-bluemoon/graphs/co2_800k.png
Surface Temperature Record

Emissions Profile for ≤ 2ºC rise

Basic Energy Balance Model

(Source: IPCC AR4, 2007, WG1, pg96)
Some Experiments to try...

1. Stop the rotation of the earth. What happens to the storms? Why?
2. Remove the land-masses. What happens to the gulf stream?
3. Remove the ice at the poles. What happens to polar temperatures? Why?
4. Remove all CO2 from the atmosphere. How much colder is the earth? Why? What happens if you leave it running?
5. Erupt a whole bunch of volcanoes all at once. What happens? Why? How long does the effect last? Does it depend on how many volcanoes?
6. Remove all human activity. How long does it take for the greenhouse gases to return to the levels they were at before the industrial revolution? Why?
8. Move the earth a little closer to the sun. What happens to temperatures? How long do they take to stabilize? Why that long?
9. Burn all the remaining (estimated) reserves of fossil fuels all at once. What happens to temperatures? Sea levels? Polar ice?
10. Set up the earth as it was in the last ice age. How much colder are global temperatures? How much colder are the poles? Why the difference? How much colder is it where you live?
11. Melt all the ice at the poles (by whatever means you can). What happens to the coastlines near where you live? Over the rest of your continent? Which country loses the most land area?
12. Keep CO2 levels constant at the level they were at in 1900, and run a century-long simulation. What happens to temperatures? Now try keeping aerosols constant at 1900 levels instead. What happens? How do these two results compare to what actually happened?
A very simple climate model

\[(1-a)S \pi r^2 = 4\pi r^2 \varepsilon \sigma T^4\]

Incoming solar radiation = Outgoing blackbody radiation

- albedo of the earth
- solar radiation
- radius of the earth
- emissivity of the earth
- Stefan-Boltzmann constant
- temperature of the earth’s surface

Solving for temperature, you get:

\[T = \sqrt[4]{\frac{(1-a)S}{4\varepsilon \sigma}} \approx 12^\circ C\]

Source: http://en.wikipedia.org/wiki/Climate_model
Simple 1 & 2 Layer Models

Note: Assumes “an atmosphere layer” = enough GHG to complete block all infra-red

Source: Dessler, Introduction to Modern Climate Change, chapter 4
Generalizing to more layers

\[ T = 4 \sqrt[4]{\frac{(n + 1)S(1 - \alpha)}{4\sigma}} \]

Source: Dessler, Introduction to Modern Climate Change, chapter 4
How well does the model work?

<table>
<thead>
<tr>
<th>Planet</th>
<th>Solar constant (W/m²)</th>
<th>Albedo</th>
<th>Observed surface temperature (K)</th>
<th>Inferred n</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mercury</td>
<td>10,000</td>
<td>0.1</td>
<td>452</td>
<td>0.052</td>
</tr>
<tr>
<td>Venus</td>
<td>2,650</td>
<td>0.7</td>
<td>735</td>
<td>82</td>
</tr>
<tr>
<td>Earth</td>
<td>1,360</td>
<td>0.3</td>
<td>289</td>
<td>0.65</td>
</tr>
<tr>
<td>Mars</td>
<td>580</td>
<td>0.15</td>
<td>227</td>
<td>0.22</td>
</tr>
</tbody>
</table>

Source: Dessler, Introduction to Modern Climate Change, chapter 4