A Primer on Climate Science

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Climate science is a very complex topic. Most people learn about things like this through the news, their knowledge is fragmentary and unstructured. My friends (who helped write this) are very fortunate to have been trained in science.

The first thing to do is put some structure on the questions we are trying to answer. We propose dividing our knowledge into Causes, Mechanisms, Observed Effects, and Predicted Effects. Within this structure, this is what we know about our climate.

Causes

1. CO_2 is produced by burning fossil fuels (basic chemistry).
2. The Carbon in this CO_2 has been sequestered in the ground for millions of years.
3. We have burned it at a very rapid and increasing rate starting in the 1800s.
4. We predict that this should increase the CO_2 concentration in the atmosphere.
5. We observe the increase through direct measurement (for example at Mauna Loa) and also through ice core samples and other mechanisms.
6. Preindustrial CO_2 was about 270 ppm. It's currently 408 and increasing 3 ppm per year, so 30 ppm per decade.
7. If there is no economic growth and we keep doing what we're doing, in 30 years, we'll be at 500 ppm. If the world continues to develop, perhaps 600 ppm.

Mechanisms

The Basics:

1. The Earth maintains its temperature through a heat balance. Light comes from the sun and heats the Earth, primarily by the light being absorbed by the ground.
2. Some of the light is also absorbed by the atmosphere.
3. Some light is reflected from the surface of the earth back into space.
4. The light that is absorbed heats the ground. Because the ground is hot, it emits infrared light, cooling it.
5. This sets up an equilibrium. The hotter the ground gets, the more infrared light it emits.
6. Because of the configuration of the electrons in the various types of molecules in the atmosphere, infrared light coming from the ground is more likely to be absorbed by the atmosphere.
7. CO_2 and H_2O are the main constituents of the atmosphere that absorb a lot of infrared light.
8. More CO_2 in the atmosphere means more absorption of infrared light by the atmosphere.

9. If the atmosphere absorbs more infrared light, it gets hotter, and heat that would have gone out into space goes into the atmosphere.

The Complicated Parts:

1. There are numerous feedback mechanisms in the system of the Earth, some tending to stabilize temperatures, some tending to amplify disturbances and cause instability. Examples:
2. (Positive feedback, destabilizing) Ice is white and is a good reflector. If the earth gets a little colder, there will be a little more ice. This causes more light to be reflected back into space, which causes the earth to get a little colder. Run this cycle a bunch of times, and you're in an ice age. Increase the temperature a little bit, and the reverse happens, you come out of an ice age.
3. (Negative feedback, stabilizing) If the Earth gets hotter, it evaporates more water. Water vapor forms clouds. Clouds are white and reflect light back into space. If it gets hotter, there are more clouds, which makes the Earth cooler.
4. (Positive feedback, possibly catastrophically destabilizing) The Earth contains large stores of frozen methane (CH_4), both in permafrost in Siberia, Canada, and Alaska, as well as at the bottom of the ocean, as methane hydrates. As the earth gets hotter, these melt and the methane is released. Methane is also a greenhouse gas like CO_2.
5. Climate models attempt to simulate this. Unfortunately we cannot run a controlled experiment with the entire earth to validate these models, and so there will always be uncertainty in their outputs, but they have been shown to provide reasonably accurate predictions.

Observed Effects:

1. From ice core samples, we see an increase in average temperatures since the industrial revolution.
2. From ground level temperature measurements, we see an increase in average temperatures.
3. From satellite measurements of surface temperature, we see an increase in average temperature.
4. Everywhere we see glaciers receding.
5. Extremely large quantities of ice are melting and being shed in the arctic and the antarctic into the sea.

Predicted Effects:

1. It is very hard to know what will happen to the Earth and human civilization as many effects will occur.
2. Melting ice will increase sea levels, causing coastlines to change. A large part of Earth's population and economic infrastructure lives very close to sea level.
3. Increases in temperatures will change the species that can survive in any given area. Crops that grow in one region may have to be grown further north (or south in the southern hemisphere). This will tend to cause huge ecological instability as species die off in one area but potentially gain a foothold in another. Species that cannot move will die. The overall effects on ecosystems are unpredictable overall, but there will likely be large disruptions as parts of food chains and vital symbiotic relationships are severed when one species does not make the move.
4. More heat in the atmosphere means more energy. It is this heat energy that creates thunderstorms, hurricanes, and tornadoes. There will be more of all of these.
5. All of these things are likely to cause challenges for food production, at least in some parts of the world.
6. Food and economic disruptions may lead to civil unrest and large refugee flows.