What is Climate Change?

Climate change refers to significant, long-term changes in the global climate.

The global climate is the connected system of sun, earth and oceans, wind, rain and snow, forests, deserts and savannas, and everything people do, too. The climate of a place, say New York, can be described as its rainfall, changing temperatures during the year and so on.

But the global climate is more than the “average” of the climates of specific places.

A description of the global climate includes how, for example, the rising temperature of the Pacific feeds typhoons which blow harder, drop more rain and cause more damage, but also shifts global ocean currents that melt Antarctica ice which slowly makes sea level rise until New York will be under water.

It is this systemic connectedness that makes global climate change so important and so complicated.

What is Global Warming?

Global warming is the slow increase in the average temperature of the earth’s atmosphere because an increased amount of the energy (heat) striking the earth from the sun is being trapped in the atmosphere and not radiated out into space.

The earth’s atmosphere has always acted like a greenhouse to capture the sun’s heat, ensuring that the earth has enjoyed temperatures that permitted the emergence of life forms as we know them, including humans.

Without our atmospheric greenhouse the earth would be very cold. Global warming, however, is the equivalent of a greenhouse with high efficiency reflective glass installed the wrong way around.

Ionically, the best evidence of this may come from a terrible cooling event that took place some 1,500 years ago. Two massive volcanic eruptions, one year after another placed so much black dust into the upper atmosphere that little sunlight could penetrate. Temperatures plummeted. Crops failed. People died of starvation and the Black Death started its march. As the dust slowly fell to earth, the sun was again able to warn the world and life returned to normal.
Today, we have the opposite problem. Today, the problem is not that too little sun warmth is reaching the earth, but that too much is being trapped in our atmosphere. So much heat is being kept inside greenhouse earth that the temperature of the earth is going up faster than at any previous time in history. NASA provides an excellent course module on the science of global warming.

How does Global Warming drive Climate Change?

Heat is energy and when you add energy to any system changes occur.

Because all systems in the global climate system are connected, adding heat energy causes the global climate as a whole to change.

Much of the world is covered with ocean which heats up. When the ocean heats up, more water evaporates into clouds.

Where storms like hurricanes and typhoons are forming, the result is more energy-intensive storms. A warmer atmosphere makes glaciers and mountain snow packs, the Polar ice cap, and the great ice shield jutting off of Antarctica melt raising sea levels.

What Causes Global Warming?

There are three positions on global warming: (1) that global warming is not occurring and so neither is climate change; (2) that global warming and climate change are occurring, but these are natural, cyclic events unrelated to human activity; and (3) that global warming is occurring as a result primarily of human activity and so climate change is also the result of human activity.
The claim that nothing is happening is very hard to defend in the face or masses of visual, land-based and satellite data that clearly shows rising average sea and land temperatures and shrinking ice masses.
The claim that the observed global warming is natural or at least not the result of human carbon emissions (see Climate Skeptics below) focuses on data that shows that world temperatures and atmospheric CO_2 levels have been equally high or higher in the past. They also point to the well understood effects of solar activity on the amount of radiation striking the earth and the fact that in recent times the sun has been particularly active.
In general, climate scientists and environmentalists either (1) dispute the data based on, for example, new ice core data or (2) suggest that the timing issue – that is, the rapidity with which the globe has warmed and the climate changed simply do not fit the model of previous natural events. They note also that compared to other stars the sun is actually very stable, varying in energy output by just 0.1% and over a relatively short cycle of 11 to 50 years quite unrelated to global warming as a whole. The data strongly suggests that solar activity affects the global climate in many important ways, but is not a factor in the systemic change over time that we call global warming.
As for the final position that global warming and climate change result from human activity (are "anthropogenic"), scientists attribute current atmospheric warming to human activities that have increased the amount of carbon containing gases in the upper atmosphere and to increased amounts of tiny particles in the lower atmosphere. (NASA offers a good course module on "The Carbon Question.")

Specifically, gases released primarily by the burning of fossil fuels and the tiny particles produced by incomplete burning trap the sun's energy in the atmosphere. Scientists call these gases "greenhouse gases" (GHGs) because they act like the wrong way reflective glass in our global greenhouse.

Scientists call the tiny particles 'black carbon' (you call it soot or smoke) and attribute their warming effect to the fact that the resulting layer of black particles in the lower atmosphere absorbs heat like a black blanket.

Scientists date the beginning of the current warming trend to the end of the 18th or beginning of the 19th century when coal first came into common use.

This warming trend has accelerated as we have increased our use of fossil fuels to include gasoline, diesel, kerosene and natural gas, as well as the petrochemicals (plastics, pharmaceuticals, fertilizers) we now make from oil.

Scientists attribute the current warming trend to the use of fossil fuels because using them releases into the atmosphere stores of carbon that were sequestered (buried) millions of years ago.

The addition of this “old” carbon to the world’s current stock of carbon, scientists have concluded, is what is heating our earth which causes global warming.

What are the most important greenhouse gases(GHGs)?

The most common and most talked about greenhouse gases is CO_2 or carbon dioxide. In fact, because it is so common, scientists use it as the benchmark or measure of things that warm the atmosphere.

Methane, another important GHG, for example, is 28-36 times as warming as CO_2 when in the upper atmosphere (USEPA GWP – Global Warming Potential – estimate over 100 years), therefore, 1 ton of methane = 28-36 tons eCO_2 or CO_2 equivalents.

The most commonly discussed GHGs are:

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  - CO_2 or carbon dioxide is produced any time something is burned. It is the most common GHG, constituting by some measures almost 55% of total long-term GHGs. It is used as a marker by the United States Environmental Protection Agency, for example, because of its ubiquity. Carbon dioxide is assigned a GWP or Global Warming Potential of 1.

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  - Methane or CH_4 is produced in many combustion processes and also by anaerobic decomposition, for example, in flooded rice paddies, pig and cow stomachs, and pig manure ponds. Methane breaks down in approximately 10 years, but is a precursor of ozone, itself an important GHG. CH_4 has a GWP of 28-36.

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  - Nitrous oxide in parean (laughing gas), NO/N_2O or simply NO_x is a byproduct of fertilizer production and use, other industrial processes and the combustion of certain materials. Nitrous oxide lasts a very long time in the atmosphere, but at the 100 year point of comparison to CO_2, its GWP is 265-298.

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  - Fluorinated gases were created as replacements for ozone depleting refrigerants, but have proved to be both extremely long lasting and extremely warming GHGs. They have no natural sources, but are entirely man-made. At the 100 year point of comparison, their GWPs range from 1,800 to 8,000 and some variants top 10,000.

- Sulphur hexafluoride or SF6 is used for specialized medical procedures, but primarily in what are called dielectric materials, especially dielectric liquids. These are used as insulators in high voltage applications such as transformers and grid switching gear. SF6 will last thousands of years in the upper atmosphere and has a GWP of 22,800.

What is black carbon and how does it cause global warming?

Black carbon (BC) is tiny particles of carbon released as a result of the incomplete combustion of fossil fuels, biofuels and biomass. These particles are extremely small, ranging from 10 μm (micrometers, PM10), the size of a single bacterium to less than 2.5 μm (PM2.5), one thirtieth the width of a human hair and small enough to pass through the walls of the human lung and into the bloodstream.

Although BC – think of the plume of smoke from a chimney or a fire – falls out of the lower atmosphere in days, while it is suspended in the air, it absorbs the sun's heat millions of times more effectively than CO2. When wind carries BC over snow, glaciers or ice caps where it falls out onto the white, normally reflective surface, it is particularly damaging because it contributes directly to melting. Overall, BC is considered the second biggest contributor to global warming after CO2.

What are the most important sources of GHGs and black carbon?

Fossil fuel and related uses of coal and petroleum are the most important sources of GHGs and black carbon (power generation, industry, transportation, buildings).

Agriculture is the second most important source (animals – cows and pigs), feed production, chemical intensive food production, and flooded paddy rice production, as well as deforestation driven by the desire to expand cultivated areas.

(New studies suggest that agriculture is the largest contributor of particulate emissions in the US and other developed agricultural countries.)

Natural sources of GHGs and black carbon include forest fires, savanna fires and volcanos.

What evidence do we have of climate change?

The most compelling climate change evidence scientists have of climate change is long term data relating atmospheric CO2 levels and global temperature, sea level, the expanse of ice, the fossil record and the distribution of species.

This data, which goes back millions of years, shows a strong correlation between CO2 levels and temperature. Recent data shows a trend of increasing temperature and rising CO2 levels beginning in the early 19th century.

Because all parts of the global climate are connected, scientists have been able to create models of how changes caused by heating should work their way through the entire system and appear in different areas, for example, sea level, intemperate weather, the movement of fish species in the ocean.

Testing whether or not predicted changes have occurred is an important way to verify underlying theory.

This can be done in two ways.

First, it is possible to load a model with historical data and ask: how well does this model predict what we know happened?

NASA and other scientific agencies have done this and found that the models work well.

A second way to test is to use the model to predict upcoming changes and then to see if emerging reality fits. It is possible to track the rapid retreat of glaciers and observe the summer melting of the Polar Ice Cap. Sea levels are rising measurably, the temperature of the world's oceans is demonstrably rising and consequently many fish species are moving to follow waters that are the right temperature for them.

Correlating these changes to the timing of rises in CO2 levels and temperature suggests relationship. NASA provides a good visual tool for viewing these relational models "in action".

In specific instances, for example, CO2 levels, temperature and ocean pH, the chemical processes are traceable proving direct causal connection.

Visual Impacts of Climate Change Evidence

Melting Glaciers

Climate Change – Scientists View – Do all scientists agree that climate change is occurring and is caused by human activity?

No.

Despite the apparent scientists view consensus among scientists, NGOs, international organizations, policy makers and the media, there are respected scientists who remain "climate sceptics," that is, who doubt that the overall theory of human induced global climate change is correct, or that the observed phenomena demonstrate conclusively that it is, or that the observed phenomena are anything out of the ordinary (viewed in the time frame of "earth history").

It is important to separate these scientists from 'sceptics' who have a financial interest in denying climate change. These people have been important in framing the climate change debate in the United States and the position of the United States government on the issue of climate change. Their success has little to do with alternative science, however, and everything to do with the permeability of the US political process to the influence of such actors.

It is also important to separate these scientists from the ignorant and people who do not understand evidence-based science. Such people are simply uninformed or misinformed, make such ignorant statements as "it's just a theory" or cite isolated facts as if they mattered. Their numbers have made this group politically powerful in the US, but their ignorance sidelines them in the global debate.

Climate sceptics fall into three camps: those like Freeman Dyson, Bjorn Lomborg and Kiminori Itoh who acknowledge climate change, but think that carbon-based theory and current models are too simplistic to capture such a complex process; those like Ivar

Giaever who think that the data is too thin to support such bold claims; and those like Will Happer who contend that the nice analogy of a greenhouse does not apply and that CO2 is too insignificant to be the culprit.

An article prepared to accompany a petition urging the US not to sign global climate accords reviews each of the main contentions of climate change scientists view and presents data suggesting that each is wrong.

The authors of the article cite data, for example, that suggests that the earth's temperature today is essentially at the 3,000-year average global temperature, while during the Medieval period, long before the use of fossil fuels, temperatures were 24^0 C higher.

In a similar vein, they cite data to suggest that glacier shortening began in the early 19th century, 25 years before the start of intensive fossil fuel use. For a more recent web piece by a well-informed, non-scientist sceptic, see David Siegel's "scientists view on global warming"

What has been the result of disagreement among scientists?

Science does not exist in a vacuum.

Scientists have strong beliefs about the world they live in and personal agendas. The people who manage the funding agencies, companies, political action groups, political parties and NGOs that pay for their research also have ideological and organizational agendas.

When talking about disagreements among scientists view, it is therefore important to distinguish between scientific contests between different theories, models and data sets, and the shouting matches among nonscientists who use science for their own purposes.

The key result of disagreements among scientists view has been more science.

Where climate-sceptics have challenged climate scientists' time frames, data and theories, the climate change scientists have re-tested the climate-sceptics' data and claims, re-tested and improved their own data and reworked their models and theories. Every time they return with improved results, the climate-sceptics do the same thing. To date, the ongoing research suggests that the climate change models are better and improving rapidly, but the continued contest demonstrates the living nature of the scientific process.

Outside of the scientific view world, however, ignorance of the facts and of science itself have created a free-for-all. Fringe environmental groups, right-wing internet blogs, politicians of all stripes have spread falsehoods far and wide or distorted the truth to serve their own ends. Beware three particular versions of "science" abuse:

- At the start of "My cause is so critically important that a little exaggeration/a few lies are no sin": This is the most common version indulged in equally by left and right. Environmentalists feel that "life on earth" or whatever is worth any price; the hard right believes that the "climate myth" is simply another internationalist plot to impose government control on free people – whose freedom must be protected at all costs. In both cases, attention to the truth takes a back seat.

- “The sky is falling” – “Oh, give me a break”: Here the divide is between the doomsayers (“Climate Change Impacts Could Collapse Civilization by 2040” report) and the perpetually disengaged (“Americans don’t worry much about climate”). The doomsayers will find any excuse to believe the worst; the “whatevers” see no reason for concern about anything. To put these contending positions in context and observe the misuse of science in action, remember, first, the 1970s and the gloom that surrounded the impending exhaustion of world oil resources that led to a policy of “pump America dry first” and then, second, the “oh, give me a break” reaction to the efforts that ultimately led to the 1970 Clean Air and Water Act.
- “They only believe in/deny climate change because they are [dumb, insane, evil, deluded, godless, terrorists…]”: This is such a common type of “argument” that it must be mentioned, although it is so illogical an “explanation” that it is hard to consider. Most people learned in primary school that such ad homonym attacks do not constitute compelling refutations, but such assertions form such an essential part of what passes for global “public discourse” today that it bears repeating that any such contention only bears tossing out.

Climate change impact

Because the global climate is a connected system climate change impacts are felt everywhere.

Among the most important climate change impacts are:

Rising Sea Levels
Climate change impacts rising sea levels. Average sea level around the world rose about 8 inches (20 cm) in the past 100 years; climate scientists expect it to rise more and more rapidly in the next 100 years as part of climate change impacts.
Coastal cities such as New York are already seeing an increased number of flooding events and by 2050 many such cities may require seawalls to survive. Estimates vary, but conservatively sea levels are expected to rise 1 to 4 feet (30 to 100 cm), enough to flood many small Pacific island states (Vanatu), famous beach resorts (Hilton Head) and coastal cities (Bangkok, Boston).

If the Greenland ice cap and/or the Antarctic ice shelf collapses, sea levels could rise by as much as 20 ft (6 m), inundating, for example, large parts of Florida, the Gulf Coast, New Orleans and Houston.

Projections suggest climate change impacts within the next 100 years, if not sooner, the world’s glaciers will have disappeared, as will the Polar ice cap, and the huge Antarctic ice shelf, Greenland may be green again, and snow will have become a rare phenomenon at what are now the world’s most popular ski resorts.

Torrential downpours and more powerful storms

While the specific conditions that produce rainfall will not change, climate change impacts the amount of water in the atmosphere and will increase producing violent downpours instead of steady showers when it does rain.

Hurricanes and typhoons will increase in power, and flooding will become more common.

Anyone in the United States who has tried to buy storm and flood insurance in the past few years knows that the insurance industry is completely convinced that climate change is raising sea levels and increasing the number of major storms and floods. (To understand the insurance industry's thinking on the subject, consider the chart below compiled by Munich Re-Insurance.)

Heatwaves and droughts

Despite downpours in some places, droughts and prolonged heatwaves will become common.

Rising temperatures are hardly surprising, although they do not mean that some parts of the world will not "enjoy" record cold temperatures and terrible winter storms. (Heating disturbs the entire global weather system and can shift cold upper air currents as well as hot dry ones. Single snowballs and snowstorms do not make climate change refutations.)

Increasingly, however, hot, dry places will get hotter and drier, and places that were once temperate and had regular rainfall will become much hotter and much drier.

The string of record high temperature years and the record number of global droughts of the past decade will become the norm, not the surprise that they have seemed.

Changing ecosystems

As the world warms, entire ecosystems will move.

Already rising temperatures at the equator have pushed such staple crops as rice north into once cooler areas, many fish species have migrated long distances to stay in waters that are the proper temperature for them.

In once colder waters, this may increase fishermen's catches; in warmer waters, it may eliminate fishing; in many places, such as on the East Coast of the US, it will require fishermen to go further to reach fishing grounds.

Farmers in temperate zones are finding drier conditions difficult for crops such as corn and wheat, and once prime growing zones are now threatened.

Some areas may see complete ecological change.

In California and on the East Coast, for example, climate change impacts and warming will soon fundamentally change the forests; in Europe, hundreds of plants species will disappear and hundreds more will move thousands of miles.

Reduced food security

One of the most striking impacts of rising temperatures is felt in global agriculture, although these impacts are felt very differently in the largely temperate developed world and in the more tropical developing world.

Different crops grow best at quite specific temperatures and when those temperatures change, their productivity changes significantly.

In North America, for example, rising temperatures may reduce corn and wheat productivity in the US mid-west, but expand production and productivity north of the border in Canada.

The productivity of rice, the staple food of more than one third of the world's population, declines 10% with every 1^0 C increase in temperature.

Past climate induced problems have been offset by major advances in rice technology and ever larger applications of fertilizer; expectations are that in Thailand, the world's largest exporter of rice, however, future increases in temperatures may reduce production 25% by 2050.

At the same time, global population models suggest that developing world will add 3 billion people by 2050 and that developing world food producers must double staple food crop production by then simply to maintain current levels of food consumption.

(Source: Climate I

Temperatures and Food Production

Pests and Disease

Rising temperatures favor agricultural pests, diseases and disease vectors.

Pest populations are on the rise and illnesses once found only in limited, tropical areas are now becoming endemic in much wider zones.

In Southeast Asia, for example, where malaria had been reduced to a wet season only disease in most areas, it is again endemic almost everywhere year around.

Likewise, dengue fever, once largely confined to tropical areas, has become endemic to the entire region.

Increased temperatures also increase the reproduction rates of microbes and insects, speeding up the rate at which they develop resistance to control measures and drugs (a problem already observed with malaria in Southeast Asia).