CLIMATE CHANGE

Course - Third Class

By

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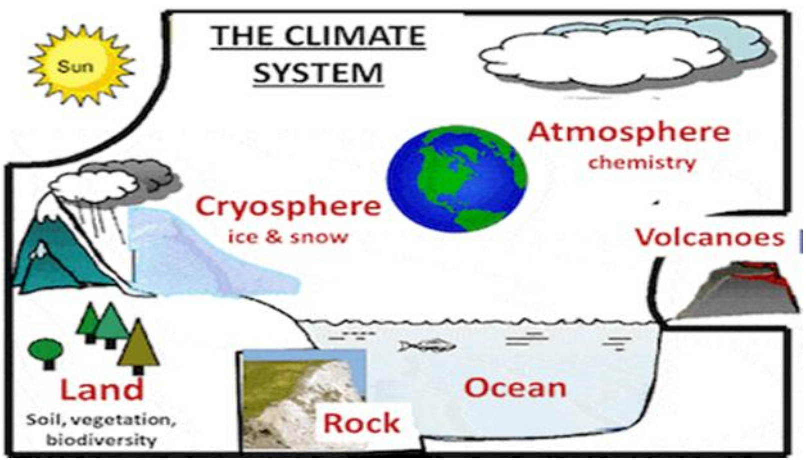
What is Climate Change?

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?

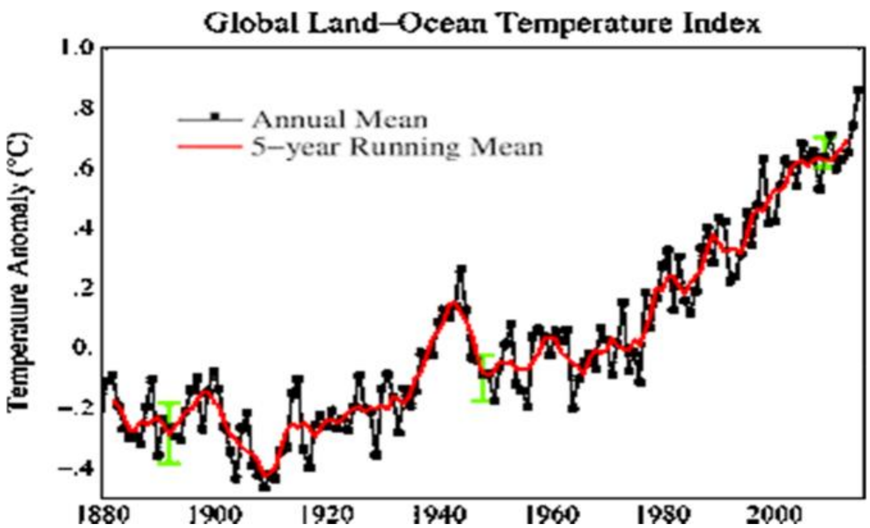
Global warming is the slow increase in the average temperature of the earth's atmosphere because an increased amount of the energy (heat) striking the earth from the sun is being trapped in the atmosphere and not radiated out into space.

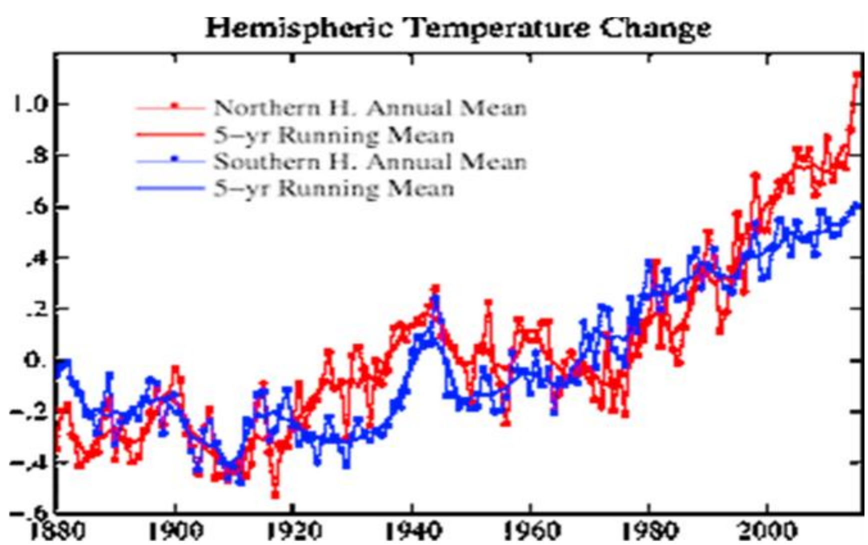
The earth's atmosphere has always acted like a greenhouse to capture the sun's heat, ensuring that the earth has enjoyed temperatures that permitted the emergence of life forms as we know them, including humans. Without our atmospheric greenhouse the earth would be very cold. Global warming, however, is the equivalent of a greenhouse with high efficiency reflective glass installed the wrong way around.

Ionic ally, 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.

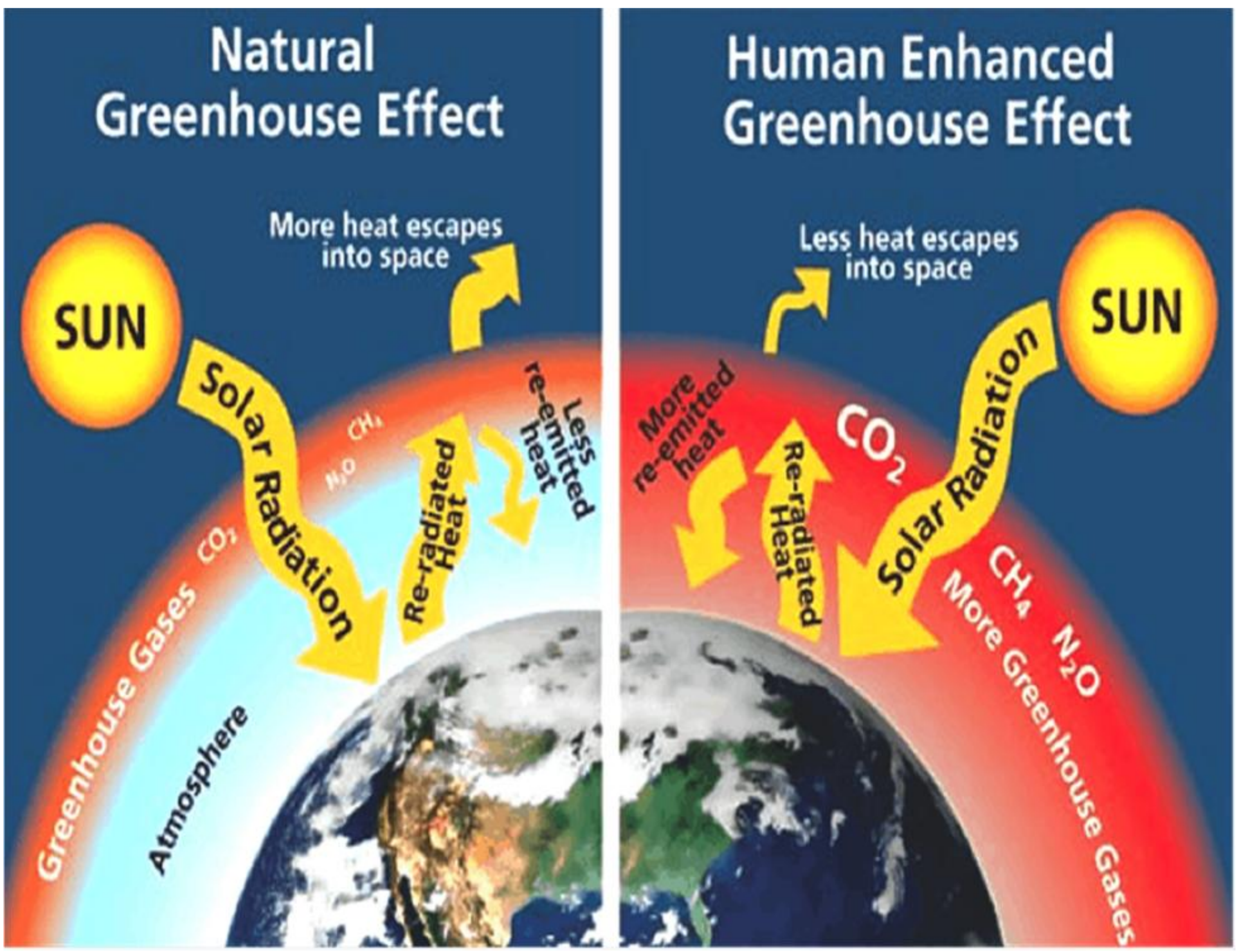
So much heat is being kept inside greenhouse earth that the temperature of the earth is going up faster than at any previous time in history. NASA provides an excellent course module on the science of global warming.





Global Warming and Climate Change

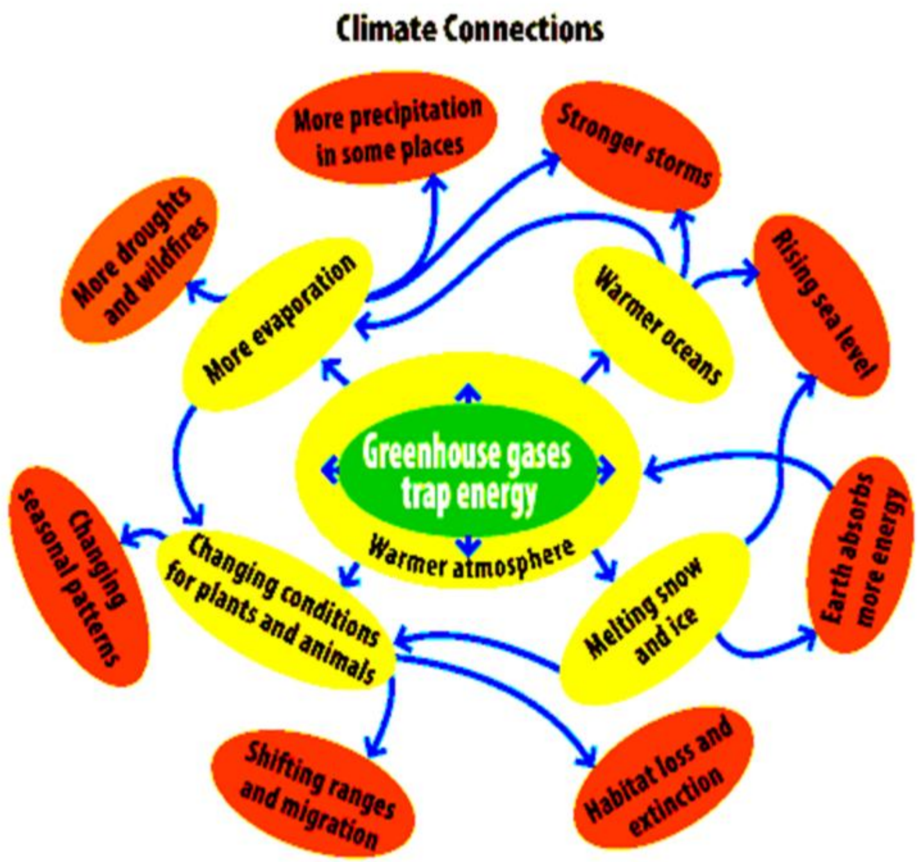
Global climate change is a huge topic, and a difficult one to make students fully grasp the importance of. In this lecture, start with the oxygen catastrophe and Earth's first ice age as an illustration of how changing the atmosphere can completely alter the climate of the Earth (and the life it supports). A set of data and graphs, taken from NASA's global warming key indicators website is shown to give a sense of the evidence behind our understanding of climate change. Finally, try to cover all of the major impacts that climate change is having, or is expected to have. A student notes outline is also available for this lecture.
Essential concepts: Global warming, global climate change, hurricanes, El Nino, La Nina, carbon dioxide, greenhouse gases, methane, greenhouse effect, weather, climate, atmosphere, stratosphere, troposphere, IPCC, proxies, average temperature, Hurricane Katrina, great ocean conveyor, glaciers, ice caps, sea ice, water cycle, hydrologic cycle, stratoshield.



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.



Changes in temperature change the great patterns of wind that bring the monsoons in Asia and rain and snow around the world, making drought and unpredictable weather more common. This is why scientists have stopped focusing just on global warming and now focus on the larger topic of climate change.

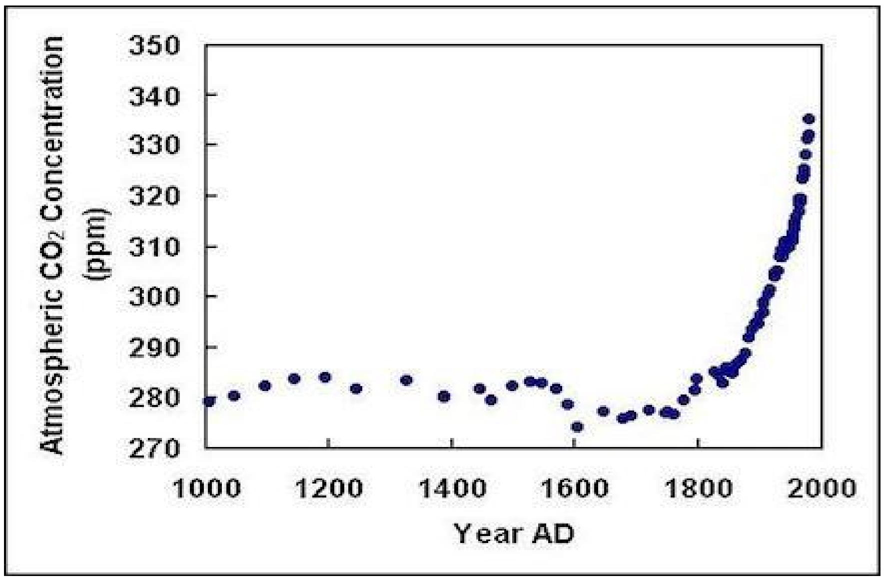
What Causes Global Warming?

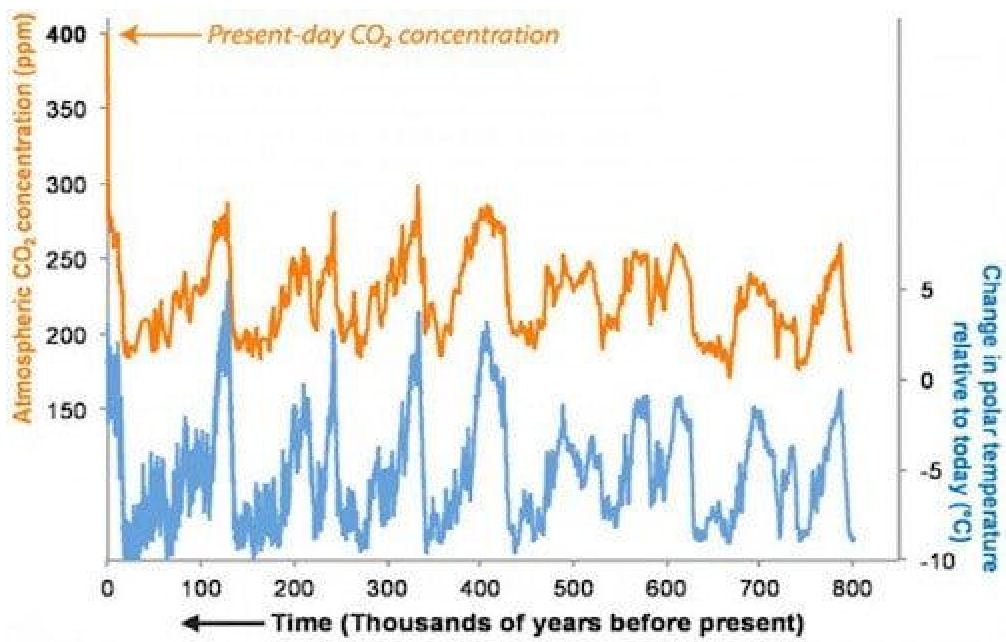
There are three positions on global warming: (1) that global warming is not occurring and so neither is climate change; (2) that global warming and climate change are occurring, but these are natural, cyclic events unrelated to human activity; and (3) that global warming is occurring as a result primarily 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 CO2 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 CO2 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 CO2 when in the upper atmosphere (USEPA GWP – Global Warming Potential – estimate over 100 years), therefore, 1 ton of methane = 28-36 tons eCO2 or CO2 equivalents.

The most commonly discussed GHGs are:

- CO2 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.

- Methane or CH4 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. CH4 has a GWP of 28-36.

- Nitrous oxide in parean (laughing gas), NO/N2O or simply NOx 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 CO2, its GWP is 265-298.

- 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.

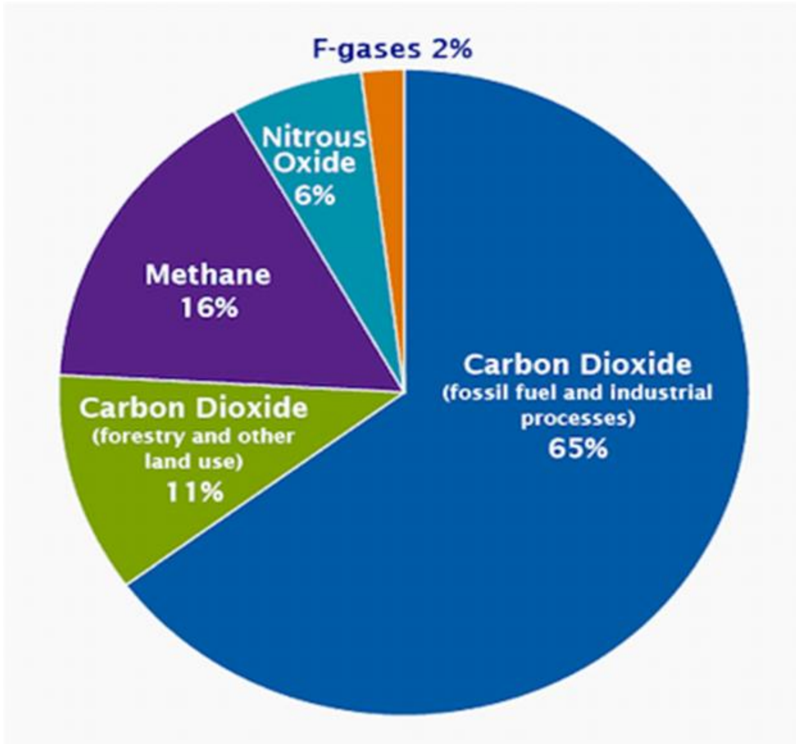
What is black carbon and how does it cause global warming?

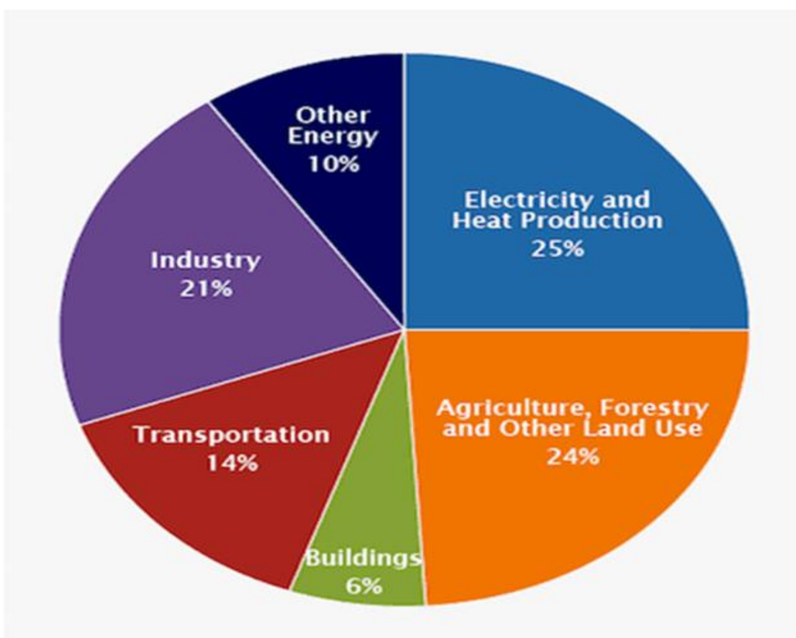
Black carbon (BC) is tiny particles of carbon released as a result of the incomplete combustion of fossil fuels, biofuels and biomass. These particles are extremely small, ranging from 10 µm (micrometers, PM10), the size of a single bacterium to less than 2.5 µm (PM2.5), one thirtieth the width of a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

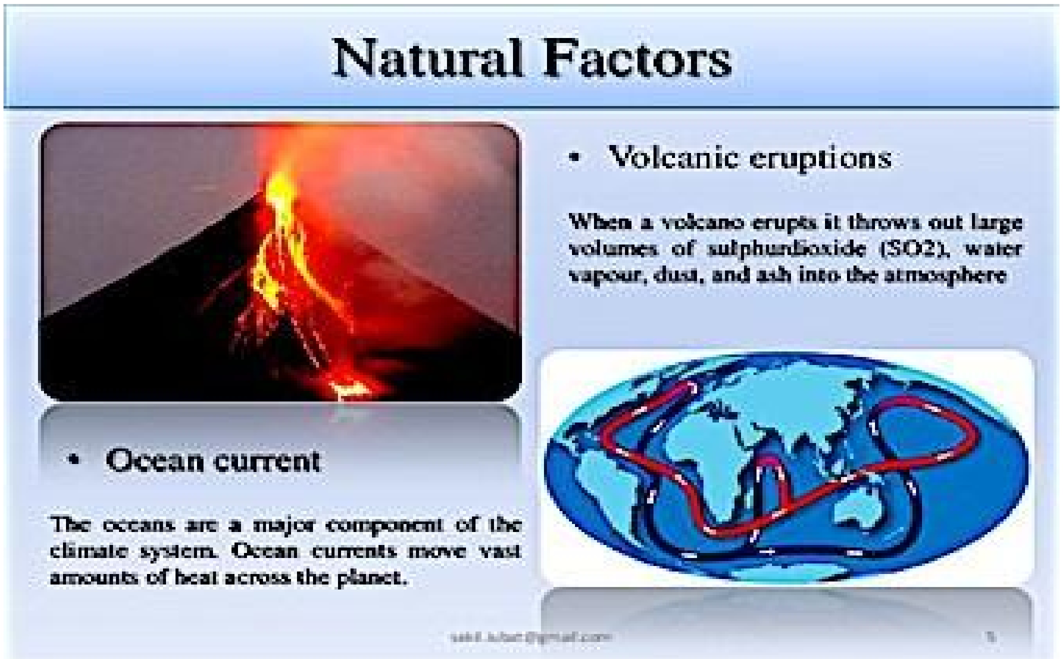
What are the most important sources of GHGs and black carbon?

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.


F-gases 2%
Nitrous Oxide 6%
Methane 16%
Carbon Dioxide (fossil fuel and industrial processes) 65%
Carbon Dioxide (forestry and other land use) 11%


Other Energy 10%
Electricity and Heat Production 25%
Industry 21%
Agriculture, Forestry and Other Land Use 24%
Transportation 14%
Buildings 6%



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 CO_2 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 CO_2 levels and temperature. Recent data shows a trend of increasing temperature and rising CO_2 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?

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

Flooding

Supercell Storms

Rising Sea Levels

Worsening Droughts

Increasing Tornados

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.

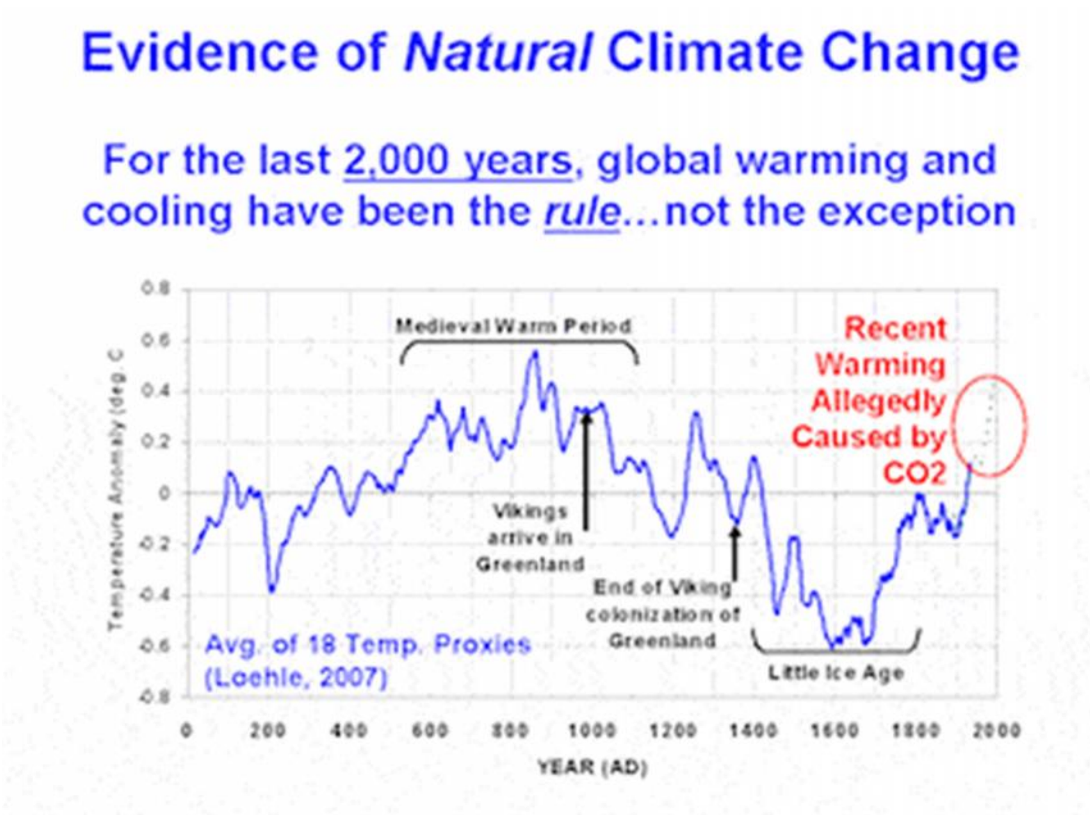
It is also important to separate these scientists from the ignorant and people who do not understand evidence-based science. Such people are simply uninformed or misinformed, make such ignorant statements as "it's just a theory" or cite isolated facts as if they mattered. Their numbers have made this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

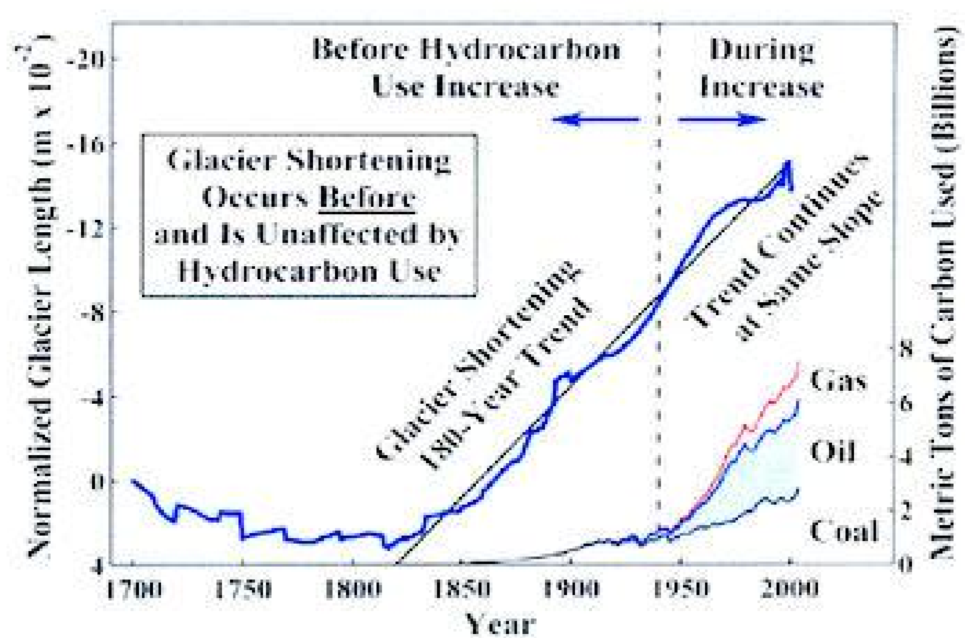
Climate sceptics fall into three camps: those like Freeman Dyson, Bjorn Lomborg and Kiminori Itoh who acknowledge climate change, but think that carbon-based theory and current models are too simplistic to capture such a complex process; those like Ivar Giaever who think that the data is too thin to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


Evidence of Natural Climate Change
For the last 2,000 years, global warming and cooling have been the rule…not the exception
Medieval Warm Period
Recent Warming Allegedly Caused by CO2
Vikings arrive in Greenland
End of Viking colonization of Greenland
Little Ice Age
Avg. of 18 Temp. Proxies (Loehle, 2007)
Temperature Anomaly (deg. C)
YEAR (AD)


Before Hydrocarbon Use Increase
During Increase
Glacier Shortening Occurs Before and Is Unaffected by Hydrocarbon Use
Glacier Shortening 180-Year Trend
Trend Continues at Same Slope
Gas
Oil
Coal
Normalized Glacier Length (m x 10³)
Metric Tons of Carbon Used (Billions)
Year

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

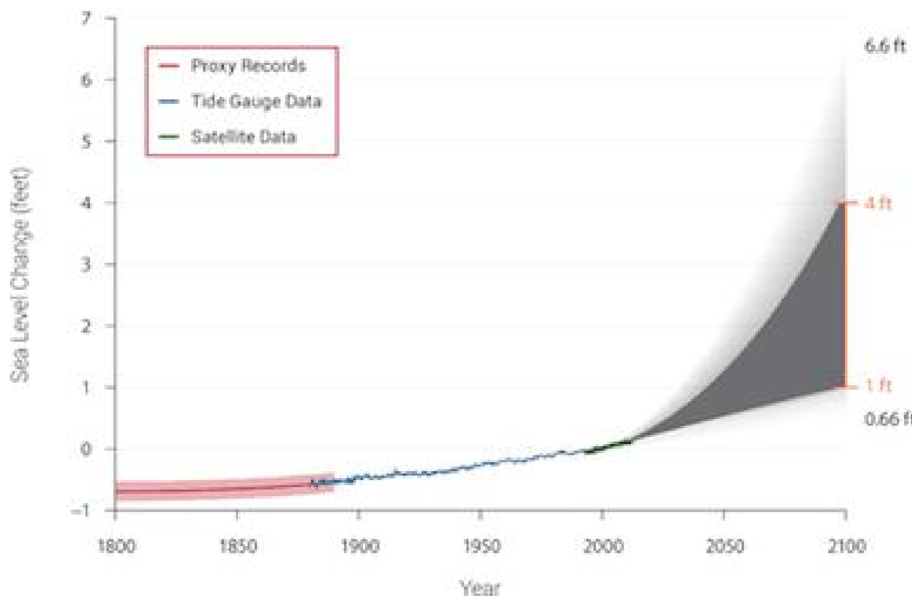
Because the global climate is a connected system climate change impacts are felt everywhere.

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.

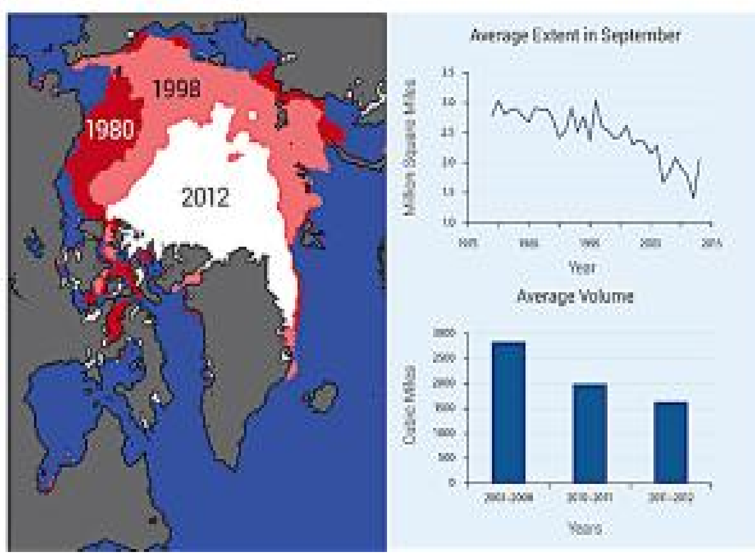
Past and Projected Changes in Global Sea Level



Melting Ice

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.

Arctic Sea Ice Loss



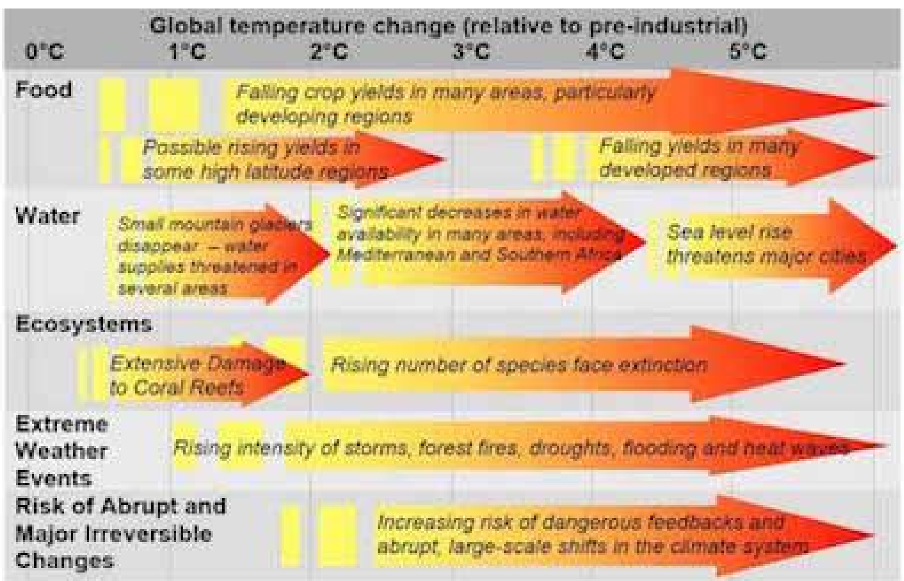
To view an interactive map of changing polar ice coverage, 1979 to 2015

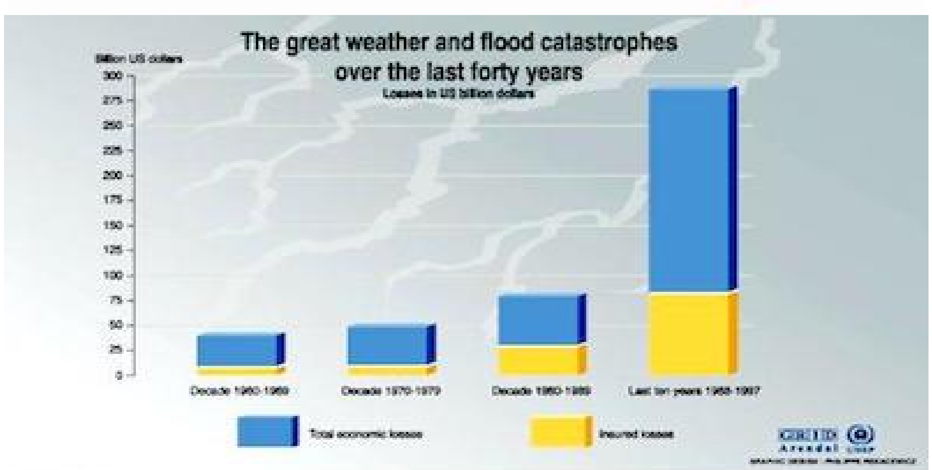
Torrential downpours and more powerful storms

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.)





Source: Munich Re Group, 1999

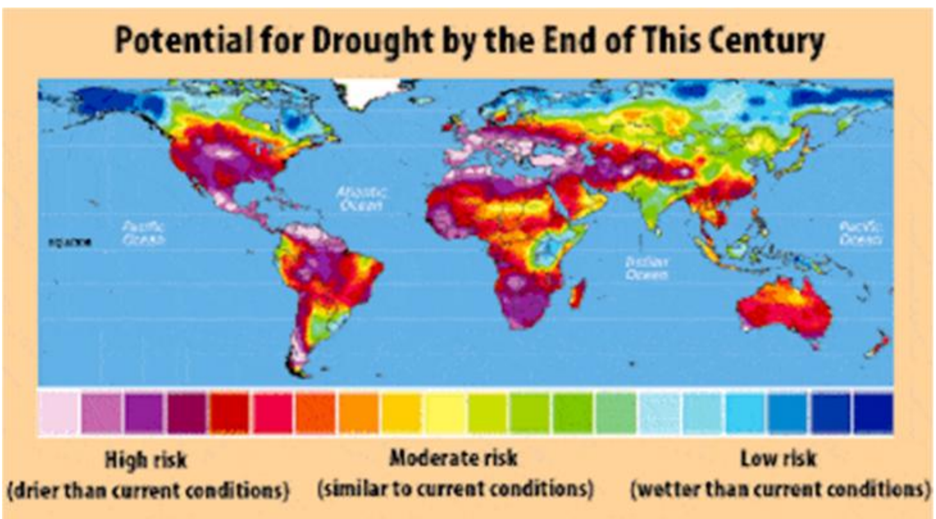
Heat waves and droughts

Despite downpours in some places, droughts and prolonged heat waves 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.

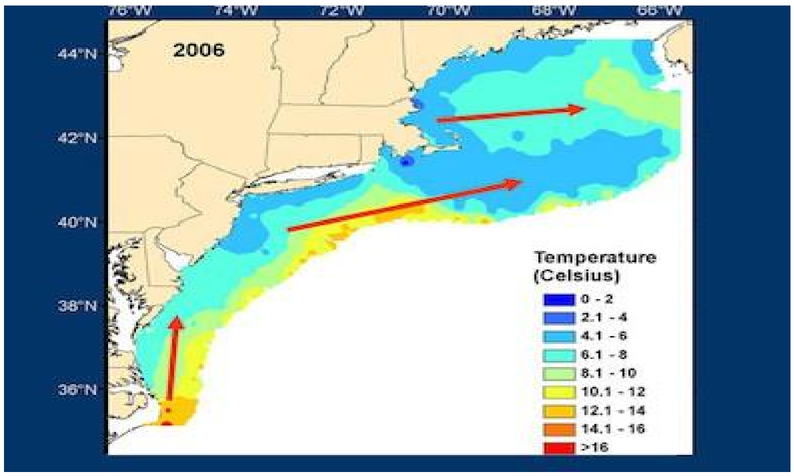
Already rising temperatures at the equator have pushed such staple crops as rice north into once cooler areas, many fish species have migrated long distances to stay in waters that are the proper temperature for them. In once colder waters, this may increase fishermen's catches; in warmer waters, it 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.

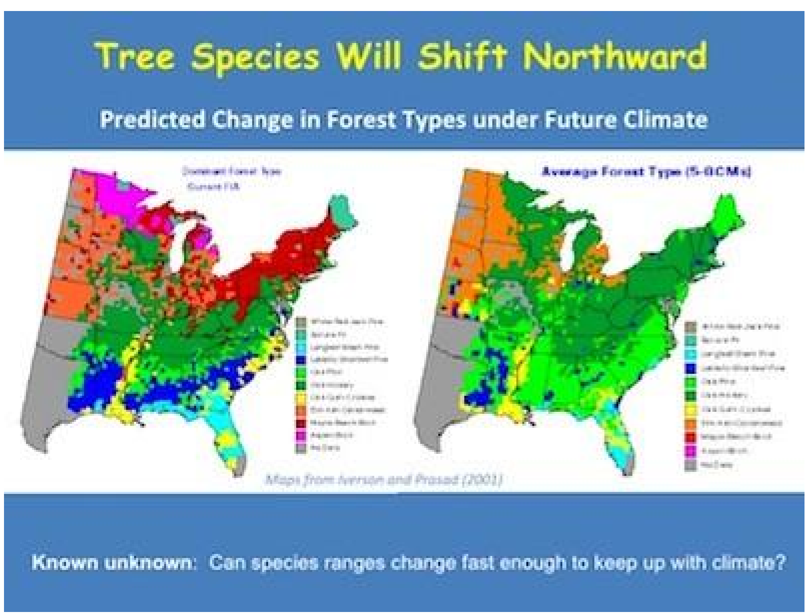
Some areas may see complete ecological change.

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.

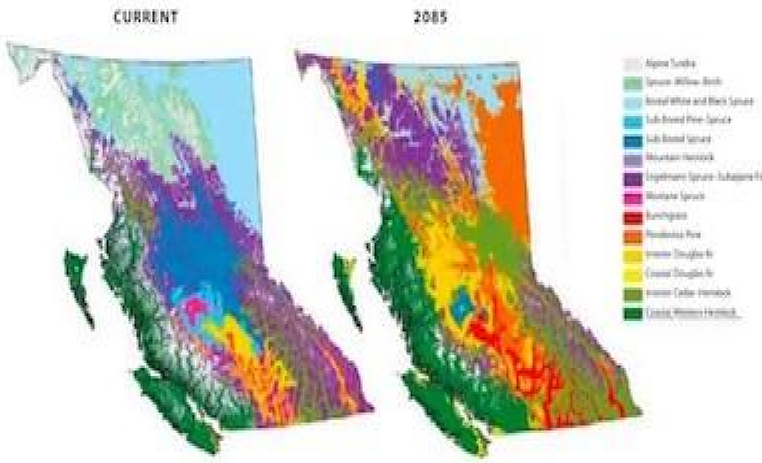
Changing Fisheries



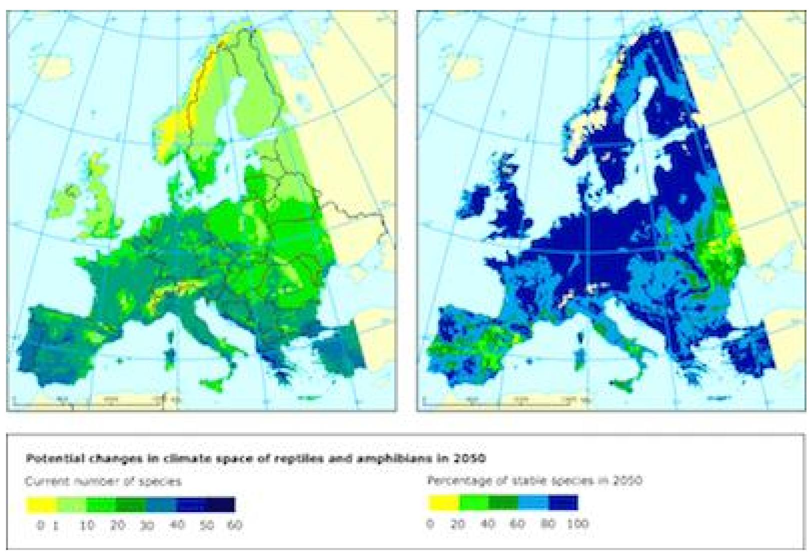
Shift in Forest Types



California Tree Species Changes



European Species Changes



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.

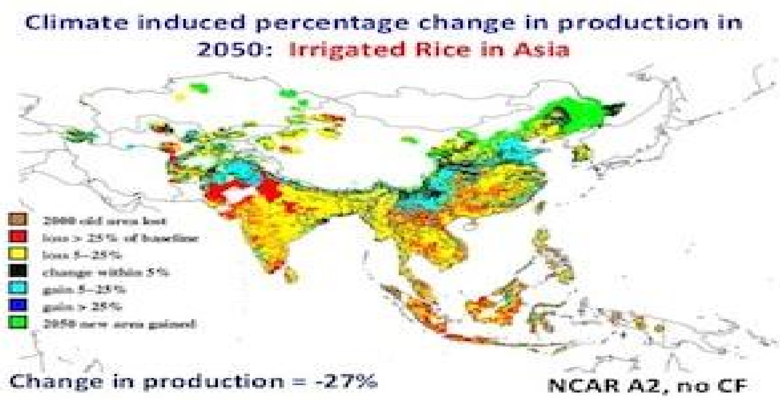
In North America, for example, rising temperatures may reduce corn and wheat productivity in the US mid-west, but expand production and productivity north of the border in Canada.

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.

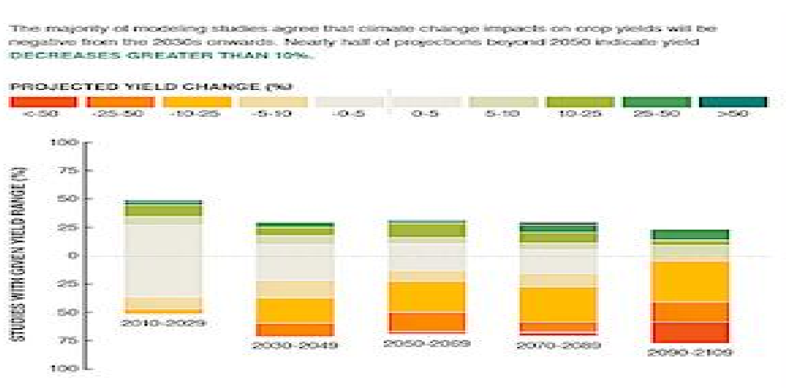
Past climate induced problems have been offset by major advances in rice technology and ever larger applications of fertilizer; expectations are that in Thailand, the world's largest exporter of rice, however, future increases in temperatures may reduce production 25% by 2050.

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.

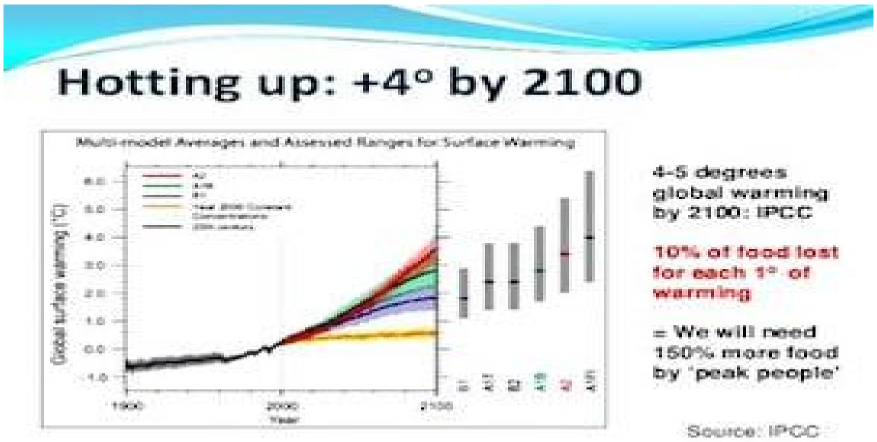
Climate Change and Food Security



Climate Change Impacts on Production



Temperatures and Food Production

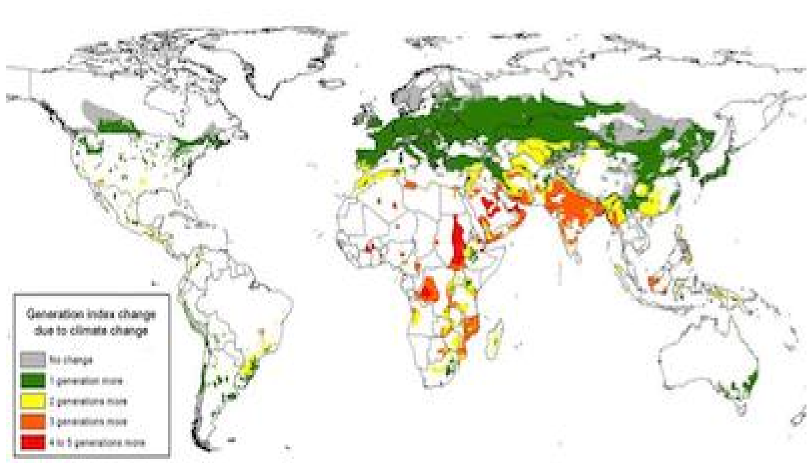


Pests and Disease

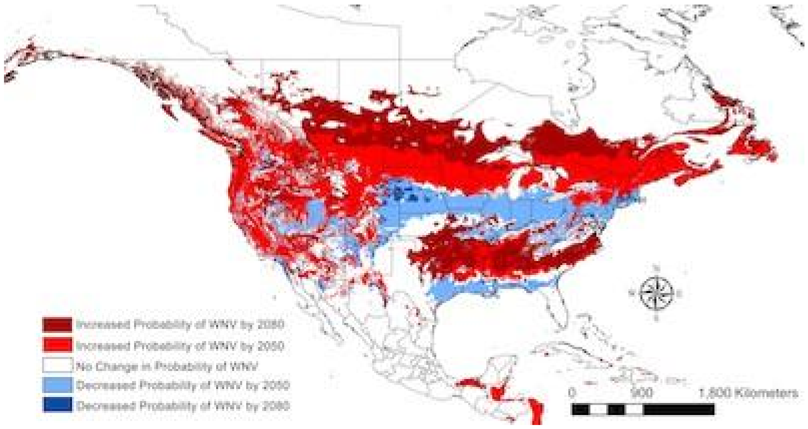
Rising temperatures favor agricultural pests, diseases and disease vectors.

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).

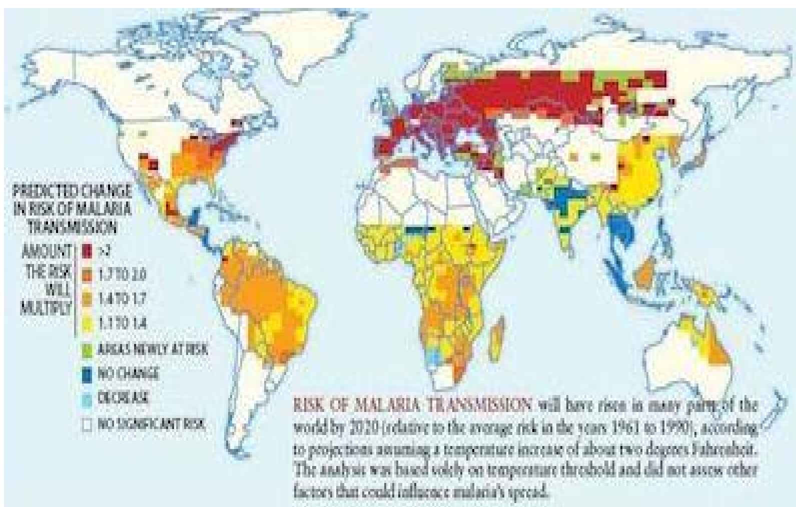
Pest Generations present to 2050

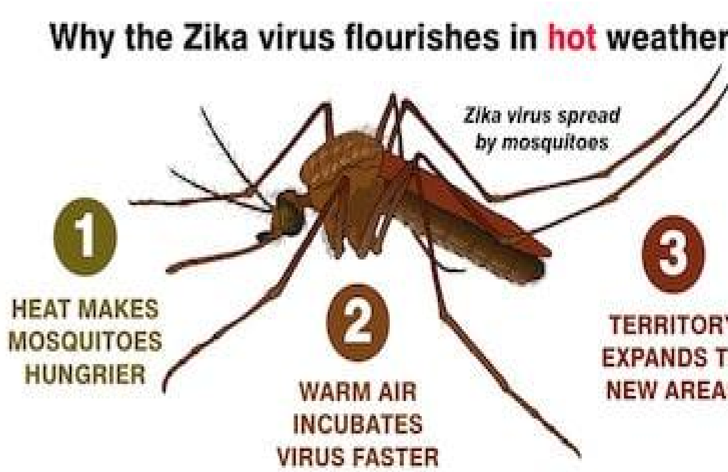


West Nile virus risk

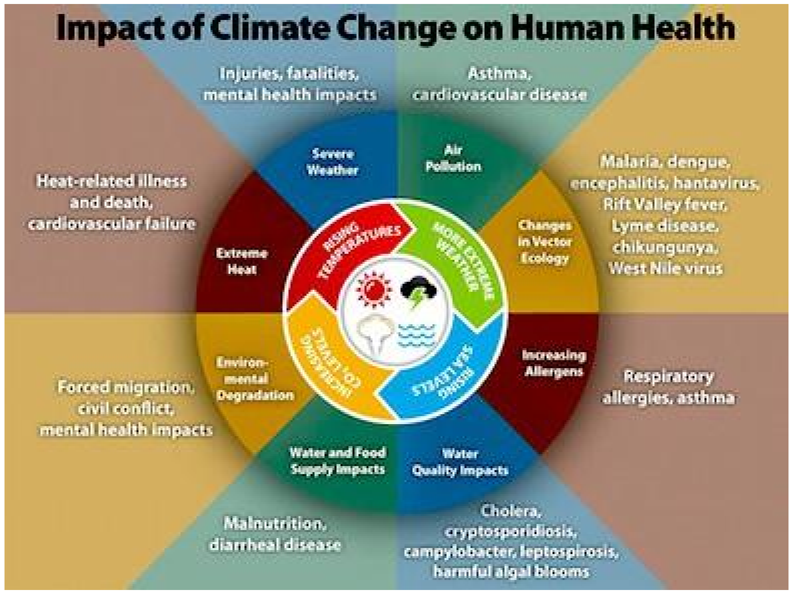


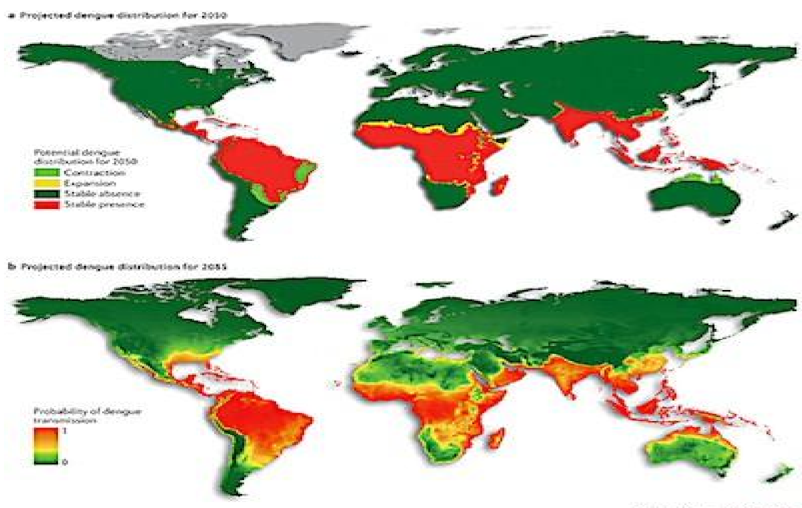
Projected change in risk of Malaria





Dengue distribution by 2050





What have we done to manage climate change?

To date, the effort to manage climate change has been a matter of high level diplomatic negotiations involving states and international organizations with a loud, but largely excluded fringe of NGOs, business groups, and minor political actors. The logic for this is that global climate change affects us all, but individual countries can manage only the activities that take place within their borders; to confront a global problem, we need a global solution. As the United Nations history of these negotiations begins:

"Climate change is a global challenge and requires a global solution. Greenhouse gas emissions have the same impact on the atmosphere whether they originate in Washington, London or Beijing. Consequently, action by one country to reduce emissions will do little to slow global warming unless other countries act as well. Ultimately, an effective strategy will require commitments and action by all the major emitting countries."

The global effort to manage climate change has been organized through what is called the United Nations Framework Convention on Climate Change (UNFCCC). The UNFCCC was launched at the 1992 Rio Earth Summit to achieve GHG concentrations

"at a level that would prevent dangerous anthropogenic interference with the climate system".

It also set voluntary GHG emissions reductions that countries did not meet.

With the failure of the Rio initiatives, the then 191 signatories to the UNFCCC agreed to meet in Kyoto in 1997 to establish a more stringent regime. The resulting Kyoto Protocol created a global trading system for carbon credits and binding GHG reductions for ratifying countries. (The US did not sign; China and India were exempt as developing countries.) So-called Conferences of the Parties (COPs) were held almost annually thereafter in places such as The Hague, Cancun and Doha without progress being made. (Following the failure of the 2012 Doha meetings, the unrenowned Kyoto carbon trading system collapsed.)

Climate change difficulties – Why are climate change difficulties so hard to manage?

Managing climate change difficulties arise from two, related reasons: climate change management is viewed as expensive and it poses what we call a collective action problem.

Why managing climate change difficulties seems so expensive

- When business and politicians talk about climate change, the first thing they mention is cost. If you start from the status quo today, adding CO2 removing equipment to a coal power plant is expensive – but only if you do not value the environment. When you buy coal for a power plant, you pay for a limited resource and the cost of supplying it to you.

  Today, when you dump the GHGs and black carbon from burning coal into the air, you pay nothing. But a clean atmosphere is a limited resource; the atmosphere will absorb only so much GHGs and black carbon before it is not clean, at which point it is costly to clean it. Logically, there is no reason why businesses that pay for a scarce resource like coal as an input should not pay for a scarce resource like the environment as a disposal site.

  This is called "costing" or "accounting" the environment. If the environment is included among the basic costs of doing business that all businesses plan into their profit and loss statements, then "managing climate change" would no longer be an expensive extra. It would be a standard cost of doing business.

  Today, however, no one values the environment and, therefore, environmental expenses are considered "extras" and so expensive, not expenses.

What is a collective action problem?

- Collective action problems arise when all of the members of a large group enjoy a resource equally – say clean air – but protecting that resource must be paid for by each group member. When such situations arise – especially when the cost of protection is high – each member really, really wants his/her neighbors to pay and to avoid paying him/herself. Each person's thinking is simple: "I'm just one person. If I don't contribute, it won't make any difference to the total amount of money raised, but it will save me money – and I will still get to breathe clean air! In our case, everyone enjoys a world which is not too hot and the climate is normal, but who wants to pay to change our dependence on cars and trucks and plastics and? So what happens? Where there are collective action problems there are collective action failures – and the higher the cost to each actor, the more likely the actor is to "free ride" – that is, to welch on his/her commitment and hope that others will pay (which they don't for the same reason).In the case of managing climate change difficulties, as in all such cases, collective action failure means that all of us end up with less of what we want – an end to climate change.

What does this portend for the current process?

- Don't hold your breath. Slowing global and domestic growth, rising global and domestic divisions, especially the increasingly strident "us first" tone of domestic politics worldwide, and increasingly unsure leaders everywhere do not bode well for the kind of strong leadership by a small group of critical players necessary to overcome collective action problems.

Learn more

- Many authors – academics, clerics, diplomats – have written on why progress toward a meaningful climate change treaty has been so slow, difficult and ultimately disappointing. You might want to start with a few of the following authors.None of these articles or authors are well known, but each comes to the subject from a different perspective – the Pontificate, a Nordic think tank, an Ecosocialist blog, an academic journal, a German magazine – and applies very different analytic tools. What is interesting is that beneath all of their differences (not least of jargon), all of these authors come to essentially the same conclusion for the same reasons.

Climate Change – can we do more? What more can we do to manage climate change?

Can we do more? It is clear that even if the international community manages to make further progress, it has a long way to go before it has exhausted its current agenda of negotiated restrictions on carbon emissions. It should also be clear that even with unimaginably successful negotiations, restrictions on carbon emissions will not do the job.

To be blunt: there is too much carbon in the atmosphere and existing technology – cars, factories, airplanes, ships, buildings – will continue to emit huge amounts more into the foreseeable future.

The only thing to do is to reduce the amount of atmospheric carbon.

There are many experiments underway to find ways to do this. So far, only a few processes show promise. While different in many ways, these processes are similar in one critical way: they all remove carbon from the atmosphere by converting it into an inert form that can be sequestered permanently, that is, returned to a form where, like the fossil carbon forms, it is truly out of sight, out of mind and out of the atmosphere – forever.

New techniques for doing this are remarkably simple chemically, but the innovations in business modeling to make them work are complex. In ~~Iceland~~, for example, scientists have demonstrated that CO_2 pumped underground into porous basalt formations will quickly turn to stone. (Ten percent of continental land and the entire seabed are basalt; the technology already costs less than one half as much as current (and unreliable) underground sequestration techniques.)

Another technology passes air across a huge surface of flowing alkali bath to capture CO_2 so that it can then be converted to pellets. (Unfortunately, because CO_2 is just 0.04% of the air, meaningful systems will have to be huge and much more efficient.) In each case, and in those of many other possible technologies, the issues are not scientific, but how to scale production cost-effectively.

Can we do more?

The second method of sequestration is at least 4,000 years old: biochar production. The "pyrolysis" of biomass, or heating it to high temperatures (450^0-750^0 C) in the absence of oxygen produces a pure form of carbon known as "biochar."

From a global climate change point of view, biochar production has great potential as it eliminates all of the black carbon and long-term GHGs from biomass burning, and is carbon negative.

Estimates of sequestration rates vary, but by atomic weight, the production of 1 ton of biochar permanently removes 3 tons of CO_2 from the atmosphere, as well as 6 kilograms of particulates and large amounts of NO_x and SO_2.

Widespread biochar production in the developing world where most agricultural waste is field burned would annually remove millions of tons of CO_2 from the atmosphere, and eliminate millions of tons of black carbon and GHGs.

Can we do more? Yes!

A Power Plant in Iceland Deals with Carbon Dioxide by Turning It into Rock

Climate change developing world – What impacts will climate change have in the developing world?

Climate change affects the entire globe; its impacts are more pronounced in the developing world than in the developed world.

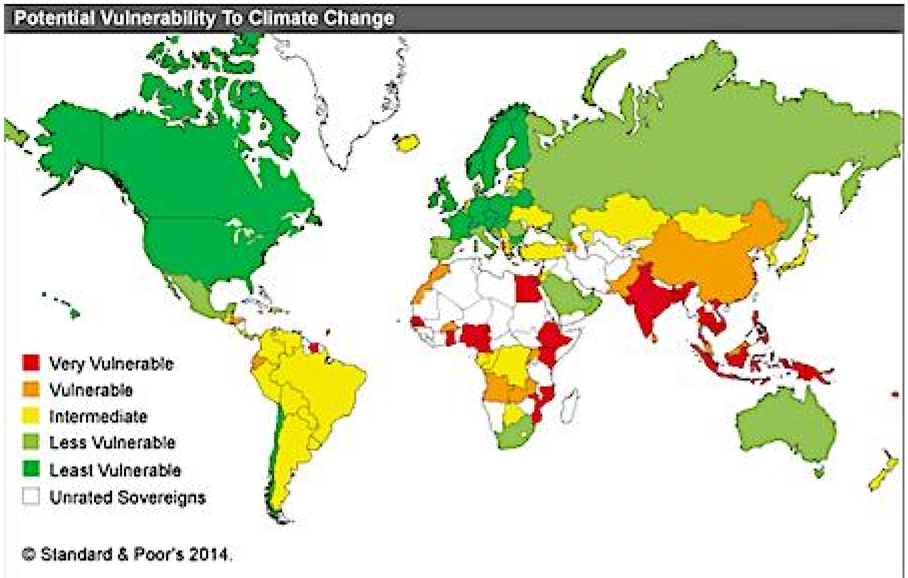
In fact, ironically, although most of the human activity that produces climate change occurs in the developed world, many of climate changes' effects will actually be beneficial in the developed world. In the short- and middle-term, for example, climate change will likely increase fish and agricultural yields where populations are small and shrinking and productivity is highest.

Climate change's impacts in the developing world will be almost exclusively negative, often terribly so.

As K. Smith tartly observed in 2008:

"The rich will find their world to be more expensive, inconvenient, uncomfortable, disrupted and colourless; in general, more unpleasant and unpredictable, perhaps greatly so. The poor will die."

(Source: J. Samson et al., Geographic disparities and moral hazards in the predicted impacts of climate change on human populations)



Sea rise

Sea rise is expected entirely to submerge a number of small, island countries, and to flood coastal spawning grounds for many staple marine resources, as well as low-lying capital cities, commercial agriculture, transportation and power generation infrastructure and tourism investments. For an interactive map of how different sea levels will affect different coastal areas worldwide, see Sea Surge at Climate Central.

Downpours and storms

Torrential downpours and devastating storms will increase large-scale damage to fields, homes, businesses, transportation and power systems and industry in countries without the financial or human capital resources to respond.

Heat waves and droughts

Heat waves and droughts will increase pressure on already fragile power, healthcare, water and sewage systems, as well as reducing countries' ability to feed themselves or export agricultural products.

Heat will also become an increasingly important killer, especially of the very young and the old. The handful of deaths during the European heat wave of 2003 resulted in a storm of press outrage that this could happen in the developed world.

In 2016, sections of North Thailand suffered two straight months of temperatures of 105^{0} F (44^{0} C) without air conditioning, cooling centers, public health or hospital support. No one counted the dead, but there is no question that across the tropical developing world heat will become a major killer.

Changing ecosystems

In the developing world, changing ecosystems seem to result almost exclusively in the loss of important food species, for example of fish and staple crops, and the increase of malign species such as disease vectors.

A study published in Nature, a leading scientific journal, provides data that suggest that climate change related phenomena have killed 150,000 people annually for the past 30 years, and that numbers will increase.

The authors contend that included in the death count should be those killed by, for example, heat induced cardiovascular attacks, as well as those killed by malnutrition resulting from climate change induced crop failures, most of them, needless to say, live in the global South.

Food security, already shaky, is crumbling under rising temperatures and related climate changes. Major staple crops are declining in productivity, while unlike in the developed countries, there are no new, more tropical staples to move in to take their places. Rising population combined with declining productivity, increasing incidence of drought and storms is increasingly leaving developing countries vulnerable of food shortfalls.

Rising temperatures increase the reproduction rates of pests and so shorten the time required for insects and plant pathogens to develop resistance to control regimes. For a review of many of the different ways in which climate change affects pests, see JH Porter etal.

Diseases, like pests, develop more rapidly in the heat and so do their insect vectors. Moreover, with climate change, the range of critical vectors – mosquitos, for example, vectors for dengue, encephalitis, malaria, West Nile and Zika – all expand putting larger and larger populations at risk.

Ongoing ocean acidification threatens more and more small shell fish, which form the broad base of the ocean food chain. Ultimately, this will threaten the entire ocean population and so the critical protein source for a third of the people on earth and a major industry.

Can we adapt to the negative impacts of climate change?

Yes.

What happens in any given region, country or district, or how a given farmer or fisherman responds to the challenges can make a huge difference.

Scientific, technological and extension resources in the developed world, for example, combined with highly educated and well-resourced farmer's makes adaptation fast and easy. Developing world farmers, too, can adapt. They have, for example, fundamentally changed how they farm over the past 50 years, largely on their own. (Aid agencies and government ministries will contest this observation, but out in the field, there is little evidence that aid agency or government extension programs have reached very deep.

Farmers have learned through imitation and judicious borrowing, not training and wholesale adoption.) The same problems that have constrained very small farmers and fishermen for the past 50 years will also inhibit their ability to adapt to rapid climate change.

They have no financial cushion and so are risk constrained; they have little access to new techniques and materials; they lack the capital to invest in big changes to farming or fishing practice, however much they might like to make such changes; and they have no outside support. They are on their own to observe, understand and develop responses to climate change.

More generally, a country's capacity to respond will be a function of income, technological capacity, extent, type and variability of vulnerability and, not least, ruling elite interest in acting. (It is not simply that the developed world will look to itself first; ruling elites everywhere are ruling elites because they can shift benefits to themselves and costs to the poor.)

What can we do in the developing world to slow climate change?

Countries in the developing world can make two major contributions to slowing climate change:

1. They can pursue smart development, avoiding the worst mistakes of the developed world; and
2. They can reduce – even reverse – their one major contribution to climate change: unsustainable agriculture practices.

What can the developing world do to avoid the mistakes of the developed world?

Look first at the primary sources of the GHGs that cause global warming: Power generation (25%); industry (21%); transportation (14%); and buildings (6%)

Power

Most power is generated in the developed world, much using old, dirty technology and carried long distances over inefficient power grids. Developing countries have the opportunity to build entirely new, distributed generation power systems that require no grids and use non-polluting technologies.

Industry

Building Greenfield industrial economies, developing countries have the opportunity to cost the environment and construct with non-polluting technologies.

Transportation

Not yet entirely dependent upon massive road-based transportation infrastructures, developing countries have the opportunity to design efficient, low-cost, high volume transportation systems to serve cities and industrial centers, and to use policy incentives to discourage personal automobile ownership and construct high quality public transportation systems.

Building

And because so much existing building stock must be replaced in short order, developing countries have the opportunity to build efficiency into individual structures and to design urban areas for high density, high energy efficiency living.

Excellent models already exist in China, Korea and Singapore, and even the medium-term cost savings are so great that not investing to do better than the developed world today is foolish.

How can the developing world reduce its own impact on climate change?

Improve agriculture. Globally, agriculture accounts for approximately one third of total GHG and black carbon emissions; the developing world, however, produces a disproportionate amount of this total – Asia and Africa between them producing 59% of the total.

While developed country contributions have dropped as a result of reduced biomass burning and reduced agrochemical use per unit, developing country contributions have risen. (In 1990, for example, Europe's contribution was 21% and Asia's 38%; today, Europe contributes 12% and Asia 44 %.)

Three immediate steps stand out.

Warm Heart Foundation

First, rice production in the developing world, largely in Asia, which grows 90% of the world's rice, needs to switch from flooded paddy propagation to SRI (system for rice intensification) techniques. This will largely eliminate the tremendous amount of methane produced by anaerobic decomposition in flooded paddies that alone contributes 10% of global GHGs annually.

Second, developing countries need to control the practice of the open field burning of agricultural wastes (rice straw, corn stalks), which annually contributes millions of tons of eCO2 and black carbon to global warming.

Third, developing countries need to develop aggressive national programs to promote the transformation of field wastes into biochar, which will sequester millions of tons of CO_2 annually and eliminate both particulate and GHG emissions, while adsorbing NO_x and other fertilizer derives emissions if added to soil.

What are the prospects that such policies will be adopted?

Low to middling. At issue are not scientific, technical or even cost considerations. The issues are, as everywhere, political.

The international climate change regime sits very lightly on developing countries and with few exceptions there is no domestic ground swell of support for environmental initiatives.

This allows rulers of any stripe to prioritize other, more pressing short-term concerns over abstract environmental programs with long-term pay-offs.

Where tax systems rely heavily on customs duties and/or sales taxes, for example, governments often seize the popular populist option of incentives to encourage car ownership.

Where elites are uncertain about their tenure in office, quick (and lucrative) deals with big utilities or mining companies are understandably tempting, whatever their climate change consequences. (Does this sound familiar? How long did it take Britain to close down coal mining? Why is coal mining still pushing presidential candidates around in the US? Why does even China concede ground to coal operators?)

What does the likely failure of these efforts suggest about the global effort to stop climate change?

Here it is possible to see why countries free ride in the global effort to manage climate change causing the collective action failures that have left us looking at climate disaster.

Leaders lack international incentives to act in politically costly ways and face powerful domestic incentives to do other, more politically pressing things.

But do not leap to the conclusion that developing world leaders are the problem or are in some way special.

The crisis of our times is not the result of tin pot dictators misbehaving. Don't leave these final sections of our primer thinking that the rulers of the developing world are merely ignorant or misinformed or corrupt or the tools of malign outside actors.

Talk to them and you will find that they are generally very well informed. Talk to folks in the know and you will find that, yes, they are corrupt by your standard and, yes, outside actors ply them with all sorts of temptations.

But that said, you will also discover that their actions are seldom easily explained by the blandishments of their almost always frustrated "corrupters".

Think about what you learn when listening in on local politics and you will discern a very familiar political logic, the stay-in-power logic.

These guys got to power by knowing how to mix-and-match, how to appease-and-pay. Every one of them has his or her ideals and everyone has his or her agenda – but everyone knows that the quickest way to kill a long-term goal is to blow a short-term necessity.

Is this really a developing world phenomena? Think of American presidents who have left a real legacy. They were not nice guys. They were connivers. They played even their closest friends and allies. They were tricky. But FDR left us Social Security. And Richard Nixon left us Medicare. And Barak Obama left us The Affordable Care Act.

And Clinton, Bush, Obama – no American president to date has signed a global climate change accord.

What does all of this suggest about your becoming a climate change maker?

Start by embracing three things: (1) no one's opinion makes them stupid; (2) nothing about the process is or will ever be simple; and (3) everyone you confront has really good reasons for doing what they do.

If you can't respect the opposition, deal with complexity or recognize that what you want may not be first on everyone's wish list, get out of the business now!

Climate change in Iraq

Iraq is grappling with significant and interconnected environmental, security, political, and economic challenges, with the effects of climate change likely increasing the extent of these challenges. Rising temperatures, intense droughts, declining precipitation, desertification, salinization, and the increasing prevalence of dust storms have undermined Iraq's agricultural sector. Additionally, Iraq's water security is based on two declining rivers, the Tigris and Euphrates. National and regional political uncertainty will make mitigating the effects of climate change and addressing transnational water management very difficult. Climatic changes such as increasing temperatures, reduced precipitation, and increasing water scarcity will likely have serious implications for the state of Iraq for years to come.

Excessive heat and limited air conditioning

In Iraq, climate change has resulted in "prolonged heat waves, erratic precipitation, higher than average temperatures and increased disaster intensity," according to a 2018 report by the Expert Working Group on Climate-related Security Risk.

Baghdad is experiencing an earlier onset of 48C days. In 2019, air conditioning has become unaffordable or impossible to maintain for lower income residents, due to erratic electricity supplies.

Drought and erratic precipitation

Drought between 2007 and 2009 was followed by very heavy rains which contributed to flooding and soil loss.

Iraq's years of drought became especially acute in 2018, at which time its land under cultivation was reduced by half. Cultivation of irrigated crops such as rice, corn and other cereals was suspended by the government; losses in rice production were estimated at 39 million dollars.

In 2019, an unusually wet winter "restored freshwater marshes of southern Iraq," and also caused widespread flooding on the Tigris and Euphrates rivers.

Water supply

As water levels fall, increasing salinity of the water supply has become a concern in southern Iraq, especially in Basra.

Security risks of climate change

When agricultural livelihoods are disrupted, local residents in ISIS-liberated areas may become dependent on terrorist groups for access to resources. Demonstrations and clashes over water rights have occurred in southern Iraq.

Geography of Iraq

Topography of Iraq

The geography of Iraq is diverse and falls into five main regions: the desert (west of the Euphrates), Upper Mesopotamia (between the upper Tigris and Euphrates rivers), the northern highlands of Iraq, Lower Mesopotamia, and the alluvial plain extending from around Tikrit to the Persian Gulf.

The mountains in the northeast are an extension of the alpine system that runs eastward from the Balkans through southern Turkey, northern Iraq, Iran, and Afghanistan, eventually reaching the Himalayas. The desert is in the southwest and central provinces along the borders with Saudi Arabia and Jordan and geographically belongs with the Arabian Peninsula.

Major geographical features

Most geographers, including those of the Iraqi government, discuss the country's geography in terms of four main zones or regions: the desert in the west and southwest; the rolling upland between the upper Tigris and Euphrates rivers (in Arabic the Dijla and Furat, respectively); the highlands in the north and northeast; and the alluvial plain through which the Tigris and Euphrates flow. Iraq's official statistical reports give the total land area as 438,446 km2 (169,285 sq mi), whereas a United States Department of State publication gives the area as 434,934 km2 (167,929 sq mi).

Upper Mesopotamia

Further information: Upper Mesopotamia

The uplands region, between the Tigris north of Samarra and the Euphrates north of Hit, is known as Al Jazira (the island) and is part of a larger area that extends westward into Syria between the two rivers and into Turkey. Water in the area flows in deeply cut valleys, and irrigation is much more difficult than it is in the lower plain. The southwest areas of this zone are classified as desert or semi-desert. The northern parts, which include such places like the Nineveh Plains, Duhok and Zakho, mainly consist of

Mediterranean vegetation. The vegetation cyclically dries out and appear brown in the virtually arid summer and flourish in the wet winter.

Lower Mesopotamia

Further information: Lower Mesopotamia, Mesopotamian Marshes, and Shatt al-Arab

An Alluvial plain begins north of Baghdad and extends to the Persian Gulf. Here the Tigris and Euphrates rivers lie above the level of the plain in many places, and the whole area is a river delta interlaced by the channels of the two rivers and by irrigation canals. Intermittent lakes, fed by the rivers in flood, also characterize southeastern Iraq. A fairly large area (15,000 km2 or 5,800 sq mi) just above the confluence of the two rivers at Al Qurnah and extending east of the Tigris beyond the Iranian border is marshland, known as Hawr al Hammar, the result of centuries of flooding and inadequate drainage. Much of it is permanent marsh, but some parts dry out in early winter, and other parts become marshland only in years of great flood.

Because the waters of the Tigris and Euphrates above their confluence are heavily silt-laden, irrigation and fairly frequent flooding deposit large quantities of silty loam in much of the delta area. Windborne silt contributes to the total deposit of sediments. It has been estimated that the delta plains are built up at the rate of nearly twenty centimeters in a century. In some areas, major floods lead to the deposit in temporary lakes of as much as thirty centimeters of mud.

The Tigris and Euphrates also carry large quantities of salts. These, too, are spread on the land by sometimes excessive irrigation and flooding. A high water table and poor surface and subsurface drainage tend to concentrate the salts near the surface of the soil. In general, the salinity of the soil increases from Baghdad south to the Persian Gulf and severely limits productivity in the region south of Al Amarah. The salinity is reflected in the large lake in central Iraq, southwest of Baghdad, known as Bahr al Milh (Sea of Salt). There are two other major lakes in the country to the north of Bahr al Milh: Buhayrat ath Tharthar and Buhayrat al Habbaniyah.

Baghdad area

Main article: Baghdad Belts

Between Upper and Lower Mesopotamia is the urban area surrounding Baghdad. These "Baghdad Belts" can be described as the provinces adjacent to the Iraqi capital and can be divided into four quadrants: northeast, southeast, southwest, and northwest. Beginning in the north, the belts include the province of Saladin, clockwise to Baghdad province, Diyala in the northeast, Babil and Wasit in the southeast and around to Al Anbar in the west.

Highlands

Main article: Iraqi Kurdistan

The northeastern highlands begin just south of a line drawn from Mosul to Kirkuk and extend to the borders with Turkey and Iran. High ground, separated by broad, undulating steppes, gives way to mountains ranging from 1,000 to 4,000 meters (3,281 to 13,123 ft) near the Iranian and Turkish borders. Except for a few valleys, the mountain area proper is suitable only for grazing in the foothills and steppes; adequate soil and rainfall, however, make cultivation possible. Here, too, are the great oil fields near Mosul and Kirkuk. The northeast is the homeland of most Iraqi Kurds.

Desert

Main articles: Syrian Desert and Arabian Desert

The desert zone, an area lying west and southwest of the Euphrates River, is a part of the Syrian Desert and Arabian Desert, which covers sections of Syria, Jordan, and Saudi Arabia and most of the Arabian Peninsula. The region, sparsely inhabited by pastoral bedouins, consists of a wide stony plain interspersed with rare sandy stretches. A widely ramified pattern of wadis–watercourses that are dry most of the year–runs from the border to the Euphrates. Some wadis are over 400 km (250 mi) long and carry brief but torrential floods during the winter rains.

Western and southern Iraq is a vast desert region covering some 64,900 square miles (168,000 square km), almost two-fifths of the country. The western desert, an extension of the Syrian Desert, rises to elevations above 1,600 feet (490 metres). The southern desert is known as Al-Hajarah in the western part and as Al-Dibdibah in the east. Both deserts are part of the Arabian Desert. Al Hajarah has a complex topography of rocky desert, wadis, ridges, and depressions. Al-Dibdibah is a more sandy region with a covering of scrub vegetation. Elevation in the southern desert averages between 1,000 and 2,700 feet (300 to 800 metres). A height of 3,119 feet (951 metres) is reached at Mount 'Unayzah at the intersection of the borders of Jordan, Iraq and Saudi Arabia. The deep Wadi Al-Batin runs 45 miles (75 km) in a northeast-southwest direction through Al-Dibdibah. It has been recognized since 1913 as the boundary between western Kuwait and Iraq.

Tigris–Euphrates river system

Main article: Tigris–Euphrates river system

The Euphrates originates in Turkey, is augmented by the Balikh and Khabur rivers in Syria, and enters Iraq in the northwest. Here it is fed only by the wadis of the western desert during the winter rains. It then winds through a gorge, which varies from two to 16 kilometers in width, until it flows out on the plain at Ar Ramadi. Beyond there the Euphrates continues to the Hindiya Barrage, which was constructed in 1914 to divert the river into the Hindiyah Channel; the present day Shatt al Hillah had been the main channel of the Euphrates before 1914. Below Al Kifl, the river follows two channels to As-Samawah, where it reappears as a single channel to join the Tigris at Al Qurnah. The Tigris also rises in Turkey but is significantly augmented by several rivers in Iraq, the most important of which are the Khabur, the Great Zab, the Little Zab, and the Adhaim, all of which join the Tigris above Baghdad, and the Diyala, which joins it about thirty-six kilometers below the city. At the Kut Barrage much of the water is diverted into the Shatt al-Hayy, which was once the main channel of the Tigris. Water from the Tigris thus enters the Euphrates through the Shatt al-Hayy well above the confluence of the two main channels at Al Qurnah. Both the Tigris and the Euphrates break into a number of channels in the marshland area, and the flow of the rivers is substantially reduced by the time they come together at Al Qurnah. Moreover. The swamps act as silt traps, and the Shatt al Arab is relatively silt free as it flows south. Below Basra, however, the Karun River enters the Shatt al Arab from Iran, carrying large quantities of silt that present a continuous dredging problem in maintaining a channel for ocean-going vessels to reach the port at Basra. This problem has been superseded by a greater obstacle to river traffic, however, namely the presence of several sunken hulls that have been rusting in the Shatt al Arab since early in the Iran-Iraq war. The waters of the Tigris and Euphrates are essential to the life of the country, but they sometimes threaten it. The rivers are at their lowest level in September and October and at flood in March, April, and May when they may carry forty times as much water as at low mark. Moreover, one season's flood may be ten or more times as great as that in another year. In 1954, for example, Baghdad was seriously threatened, and dikes protecting it were nearly topped by the flooding Tigris. Since Syria built a dam on the Euphrates, the flow of water has been considerably diminished and flooding was no longer a problem in the mid-1980s. In 1988 Turkey was also constructing a dam on the Euphrates that would further restrict the water flow. Until the mid-twentieth century, most efforts to control the waters were primarily concerned with irrigation. Some attention was given to problems of flood control and drainage before the revolution of July 14, 1958, but development plans in the 1960s and 1970s were increasingly devoted to these matters, as well as to irrigation projects on the upper reaches of the Tigris and Euphrates and the tributaries of the Tigris in the northeast. During the war, government officials stressed to foreign visitors that, with the conclusion of a peace settlement, problems of irrigation and flooding would receive top priority from the government.

Coral reef

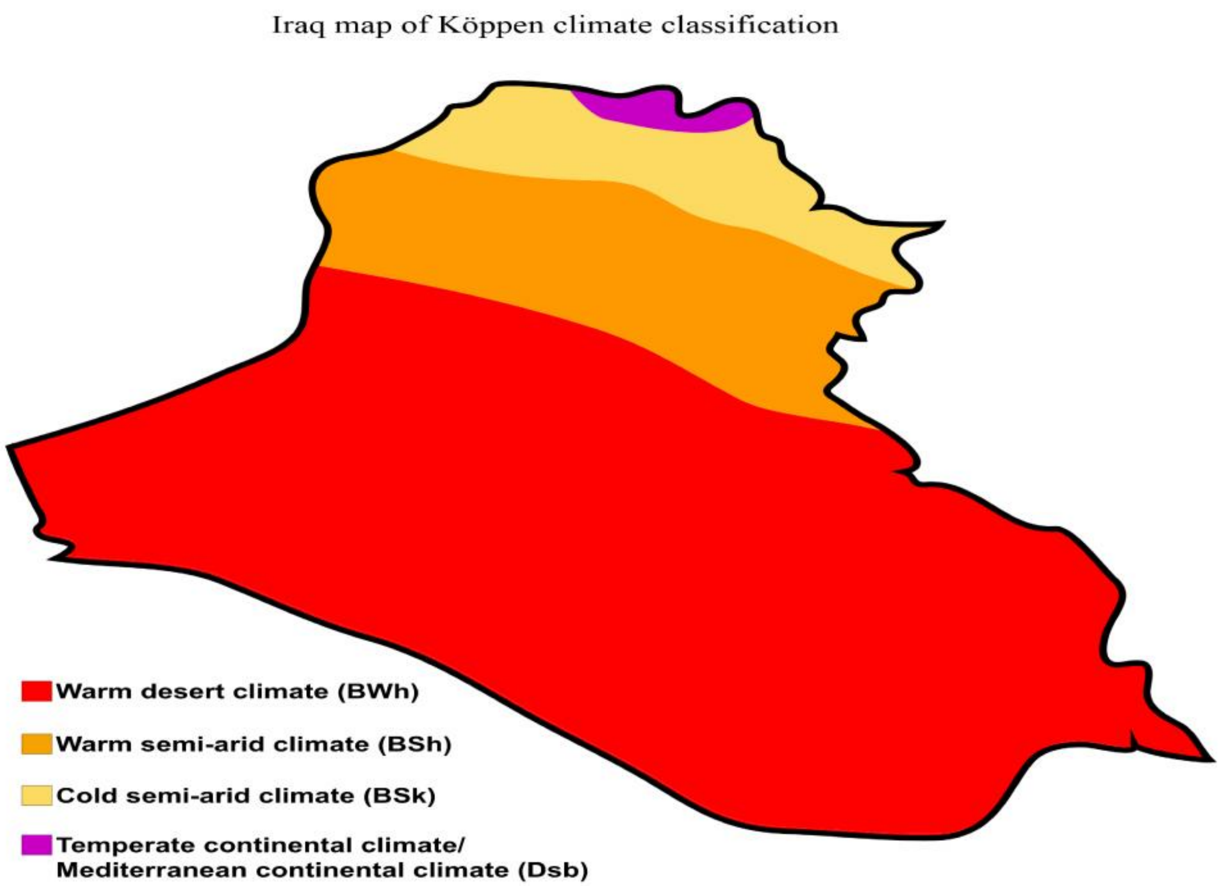
Iraqi coastal waters boast a living coral reef, covering an area of 28 km2 in the Persian Gulf, at the mouth of the Shatt al-Arab river (29°37'00"N 48°48'00"E).[1] The coral reef was discovered by joint Iraqi–German expeditions of scientific scuba divers carried out in September 2012 and in May 2013.[1] Prior to its discovery, it was believed that Iraq lacks coral reefs as the local turbid waters prevented the detection of the potential presence of local coral reefs. Iraqi corals were found to be adapted to one of the most extreme coral-bearing environments in the world, as the seawater temperature in this area ranges between 14 and 34 °C.[1] The reef harbors several living stone corals, octocorals, ophiuroids and bivalves.[1] There are also silica-containing demo-sponges.[1]

Settlement patterns

In the rural areas of the alluvial plain and in the lower Diyala region, settlement almost invariably clusters near the rivers, streams, and irrigation canals. The bases of the relationship between watercourse and settlement have been summarized by Robert McCormick Adams, director of the Oriental Institute of the University of Chicago. He notes that the levees laid down by streams and canals provide advantages for both settlement and agriculture. Surface water drains more easily on the levees' back-slope, and the coarse soils of the levees are easier to cultivate and permit better subsurface drainage. The height of the levees gives some protection against floods and the frost that often affect low-lying areas and may kill and/or damage winter crops. Above all, those living or cultivating on the crest of a levee have easy access to water for irrigation and household use in a dry, hot country. Although there are some isolated homesteads, most rural communities are nucleated settlements rather than dispersed farmsteads; that is, the farmer leaves his village to cultivate the fields outside it. The pattern holds for farming communities in the Kurdish highlands of the northeast as well as for those in the alluvial plain. The size of the settlement varies, generally with the volume of water available for household use and with the amount of land accessible to village dwellers. Sometimes, particularly in the lower Tigris and Euphrates valleys, soil salinity restricts the area of arable land and limits the size of the community dependent on it, and it also usually results in large unsettled and uncultivated stretches between the villages.

Fragmentary information suggests that most farmers in the alluvial plain tend to live in villages of over 100 persons. For example, in the mid-1970s a substantial number of the residents of Baqubah, the administrative center and major city of Diyala Governorate, were employed in agriculture. The Marsh Arabs of the south usually live in small clusters of two or three houses kept above water by rushes that are constantly being replenished. Such clusters often are close together, but access from one to another is possible only by small boat. Here and there a few natural islands permit slightly larger clusters. Some of these people are primarily water buffalo herders and lead a semi-nomadic life. In the winter, when the waters are at a low point, they build fairly large temporary villages. In the summer they move their herds out of the marshes to the river banks. he war has had its effect on the lives of these denizens of the marshes. With much of the fighting concentrated in their areas, they have either migrated to settled communities away from the marshes or have been forced by government decree to relocate within the marshes. Also, in early 1988, the marshes had become the refuge of deserters from the Iraqi army who attempted to maintain life in the fastness of the overgrown, desolate areas while hiding out from the authorities. These deserters in many instances have formed into large gangs that raid the marsh communities; this also has induced many of the marsh dwellers to abandon their villages. The war has also affected settlement patterns in the northern Kurdish areas. There, the struggle for a Kurdish state by guerrillas was rejected by the government as it steadily escalated violence against the local communities. Starting in 1984, the government launched a scorched-earth campaign to drive a wedge between the villagers and the guerrillas in the remote areas of two provinces of Kurdistan in which Kurdish guerrillas were active. In the process whole villages were torched and subsequently bulldozed, which resulted in the Kurds flocking into the regional centers of Irbil and As Sulaymaniyah. Also as a "military precaution", the government has cleared a broad strip of territory in the Kurdish region along the Iranian border of all its inhabitants, hoping in this way to interdict the movement of Kurdish guerrillas back and forth between Iran and Iraq. The majority of Kurdish villages, however, remained intact in early 1988. In the arid areas of Iraq to the west and south, cities and large towns are almost invariably situated on watercourses, usually on the major rivers or their larger tributaries. In the south this dependence has had its disadvantages. Until the recent development of flood control, Baghdad and other cities were subject to the threat of inundation. Moreover, the dikes needed for protection have effectively prevented the expansion of the urban areas in some directions. The growth of Baghdad, for example, was restricted by dikes on its eastern edge. The diversion of water to the Milhat ath Tharthar and the construction of a canal transferring water from the Tigris north of Baghdad to the Diyala River have permitted the irrigation of land outside the limits of the dikes and the expansion of settlement.

Climate



Iraq map of Köppen climate classification zones

The climate of Iraq is mainly a hot desert climate or a hot semi-arid climate to the northernmost part. Averages high temperatures are generally above 40 °C (104 °F) at low elevations during summer months (June, July and August) while averages low temperatures can drop to below 0 °C (32 °F) during the coldest month of the year during winter The all-time record high temperature in Iraq of 52 °C (126 °F) was recorded near An Nasiriyah on 2 August 2011. Most of the rainfall occurs from December through April and averages between 100 and 180 millimeters (3.9 and 7.1 in) annually. The mountainous region of northern Iraq receives appreciably more precipitation than the central or southern desert region, where they tend to have a Mediterranean climate.

Roughly 90% of the annual rainfall occurs between November and April, most of it in the winter months from December through March. The remaining six months, particularly the hottest ones of June, July, and August, are extremely dry. Except in the north and northeast, mean annual rainfall ranges between 100 and 190 millimeters (3.9 and 7.5 in). Data available from stations in the foothills and steppes south and southwest of the mountains suggest mean annual rainfall between 320 and 570 millimeters (12.6 and 22.4 in) for that area. Rainfall in the mountains is more abundant and may reach 1,000 millimeters (39.4 in) a year in some places, but the terrain precludes extensive cultivation. Cultivation on no irrigated land is limited essentially to the mountain valleys, foothills, and steppes, which have 300 millimeters (11.8 in) or more of rainfall annually. Even in this zone, however, only one crop a year can be grown, and shortages of rain have often led to crop failures. Mean minimum temperatures in the winter range from near freezing (just before dawn) in the northern and northeastern foothills and the western desert to 2 to 3 °C (35.6 to 37.4 °F) and 4 to 5 °C (39.2 to 41.0 °F) in the alluvial plains of southern Iraq. They rise to a mean maximum of about 16 °C (60.8 °F) in the western desert and the northeast, and 17 °C (62.6 °F) in the south. In the summer mean minimum temperatures range from about 27 to 31 °C (80.6 to 87.8 °F) and rise to maxima between roughly 41 and 45 °C (105.8 and 113.0 °F). Temperatures sometimes fall below freezing and have fallen as low as −14 °C (6.8 °F) at Ar Rutbah in the western desert. A summer heat, even in a hot desert, is high and this can be easily explained by the very low elevations of deserts regions which experience these exceptionally searing high temperatures. In fact, the elevations of cities such as Baghdad or Basra are near the sea level (0 m) because deserts are located predominantly along the Persian Gulf. That's why some Gulf's countries like Iraq, Iran and Kuwait experience extreme heat during summer, even more extreme than the normal level. The searing summer heat only exists in low elevations in these countries while mountains and higher elevations know much more moderated summer temperatures. The summer months are marked by two kinds of wind phenomena. The southern and southeasterly Shari, a dry, dusty wind with occasional gusts of 80 kilometers per hour (50 mph), occurs from April to early June and again from late September through November. It may last for a day at the beginning and end of the season but for several days at other times. This wind is often accompanied by violent dust storms that may rise to heights of several thousand meters and close airports for brief periods. From mid-June to mid-September the prevailing wind, called the shamal, is from the north and northwest. It is a steady wind, absent only occasionally during this period. The very dry air brought by this shamal permits intensive sun heating of the land surface, but the breeze has some cooling effect.

The combination of rain shortage and extreme heat makes much of Iraq a desert. Because of very high rates of evaporation, soil and plants rapidly lose the little moisture obtained from the rain, and vegetation could not survive without extensive irrigation. Some areas, however, although arid, do have natural vegetation in contrast to the desert. For example, in the Zagros Mountains in northeastern Iraq there is permanent vegetation, such as oak trees, and date palms are found in the south.

Area and boundaries

In 1922 British officials concluded the Treaty of Mohammara with Abd al Aziz ibn Abd ar Rahman Al Saud, who in 1932 formed the Kingdom of Saudi Arabia. The treaty provided the basic agreement for the boundary between the eventually independent nations. Also in 1922 the two parties agreed to the creation of the diamond-shaped Neutral Zone of approximately 7,500 km2 (2,900 sq mi) adjacent to the western tip of Kuwait in which neither Iraq nor Saudi Arabia would build dwellings or installations. Bedouins from either country could utilize the limited water and seasonal grazing resources of the zone. In April 1975, an agreement signed in Baghdad fixed the borders of the countries. Through Algerian mediation, Iran and Iraq agreed in March 1975 to normalize their relations, and three months later they signed a treaty known as the Algiers Accord. The document defined the common border all along the Khawr Abd Allah (Shatt) River estuary as the thalweg. To compensate Iraq for the loss of what formerly had been regarded as its territory, pockets of territory along the mountain border in the central sector of its common boundary with Iran were assigned to it. Nonetheless, in September 1980 Iraq went to war with Iran, citing among other complaints the fact that Iran had not turned over to it the land specified in the Algiers Accord. This problem has subsequently proved to be a stumbling block to a negotiated settlement of the ongoing conflict. In 1988 the boundary with Kuwait was another outstanding problem. It was fixed in a 1913 treaty between the Ottoman Empire and British officials acting on behalf of Kuwait's ruling family, which in 1899 had ceded control over foreign affairs to Britain. The boundary was accepted by Iraq when it became independent in 1932, but in the 1960s and again in the mid-1970s, the Iraqi government advanced a claim to parts of Kuwait. Kuwait made several representations to the Iraqis during the war to fix the border once and for all but Baghdad repeatedly demurred, claiming that the issue is a potentially divisive one that could inflame nationalist sentiment inside Iraq. Hence in 1988 it was likely that a solution would have to wait until the war ended.

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