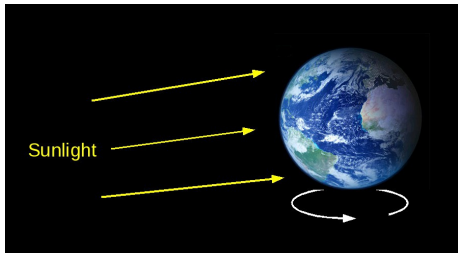
Climate Change for Non-Scientists

You can't see climate change. We see weather, not climate, and we see the local picture, not the global one. Climate changes gradually, but what gets our attention is short term, extreme, events.

What does science tell us about it? Is it true? Can scientists be trusted? Do we need to do anything about it? Here is a guide for non-scientists.

Part 1: The Underlying Science

The starting point: it is the sun that keeps us warm



If there were no sun, the earth would be almost unimaginably cold. It is a bit like a doner kebab on a winter day, turning slowly while the sun warms it. Sunshine has kept the earth at a temperature suitable for life, for millions of years.

It's difficult to grasp the scale of the solar system, or how hot the sun is. If planet earth were scaled down to the size of a tennis ball, the sun would be nearly ½ mile away, and about the size of a house. Imagine a house fire so hot that even at that distance it alone could make the difference between extreme cold and comfortable warmth.

Radiant heat

Everything radiates heat: the sun, the earth, you and me, even a block of ice. The hotter it is, the more heat it radiates. When it gets really hot – red hot and hotter - we see the radiant heat as light.

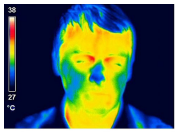
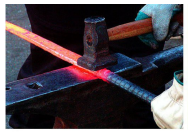
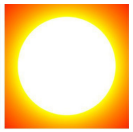


Image of a face, using radiant heat



Red hot: about 700°C

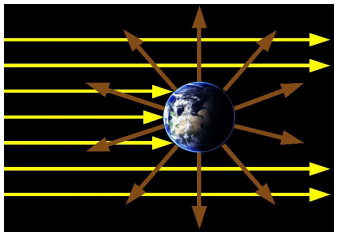
White hot filament: 2700°C



The sun: 5500°C

Radiant heat is also called infra red radiation, but it is not a type of radiation that is dangerous.

The temperature of the earth keeps in balance



The yellow arrows are the sunlight coming in that heats the earth, and the brown arrows are heat going out from the earth into space (which we can't see, because the earth is not hot enough).

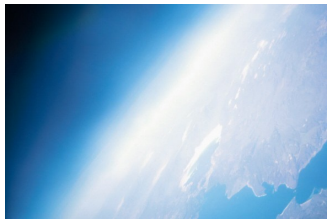
They balance. If the heat going out is less than the heat coming in, the surplus heat causes the earth to warm up until balance is restored. If there is more heat going out, the earth cools down until balance is restored.

How warm should the earth be?

The tropics are much warmer than the poles, but an average temperature can be calculated. The calculation has to take account of factors such as how much sunlight is reflected back by clouds, but it can be done fairly accurately.

The result turns out to be below freezing - about 30 degrees cooler than the temperature in fact is. The earth's surface is a lot warmer than a simple calculation says it should be. Why? The explanation is called the greenhouse effect.

The atmosphere



What matters to us is the temperature at the earth's surface, because that is where we live and grow food. Above us is the atmosphere, like a blanket a few miles thick. It is not completely transparent. To understand global temperatures, it is vital to understand its behaviour.

The greenhouse effect

When the sun shines on soil or plants, it warms them. They warm the air around them, and the air rises and carries away the heat, so they do not get too hot.

However in a greenhouse, the warm air is trapped, so the inside of the greenhouse warms up. It keeps warming until the heat from the sun shining in matches the heat escaping through the glass.

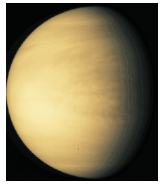
That is the greenhouse effect. It happens inside any enclosure that lets the sun's heat in but blocks some of the heat that would otherwise escape – a car parked in the sun is another example.

The greenhouse effect on planet earth

As there is no air out in space, the only way heat can escape from the earth is by radiating it away. If the radiant heat is blocked, the earth will warm up, just as in a greenhouse.

The atmosphere is like an enclosure that blocks some of the radiant heat. The blocking is done by a number of gases in the atmosphere, collectively called greenhouse gases. The main ones are water vapour and carbon dioxide. This is not obvious, because we cannot see them. Greenhouse gases behave like a thin layer of invisible cloud: clouds block radiant heat, which is why it gets colder on a clear night than on a cloudy one.

Climate change



Venus

The greenhouse effect is real - no serious scientist disputes it. The extreme example (and awful warning) of the effect of carbon dioxide is the planet Venus. Venus is like the earth in many ways, but it has a dry, high density carbon dioxide atmosphere. That makes its surface hotter than an oven - about 400 degrees more than it would be without carbon dioxide.

The greenhouse effect is nothing new: the blanket of greenhouse gases has always been there in our atmosphere and raised the temperature. Burning of fossil fuels puts extra carbon dioxide into the atmosphere and makes the blanket thicker. The climate change case follows logically: the ***extra*** greenhouse gases that we are producing will cause ***extra*** warming. It is like saying that a double glazed greenhouse will get warmer than a single glazed one.

That is the core of the science: *extra* greenhouse gases will *increase* the greenhouse effect. It is inevitable and the only question is how much warming to expect.

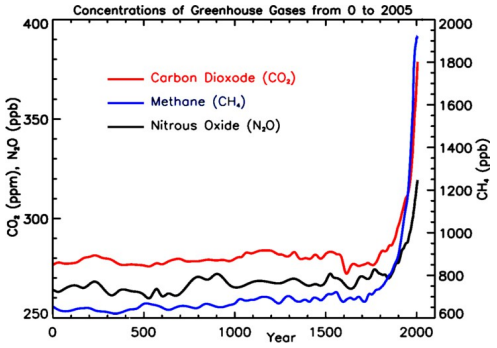
Part 2: How Much Warming?

How long is a piece of string? It depends on whereabouts you are, the amount of greenhouse gases we produce, and how long we wait.

How much carbon dioxide

The gases in the atmosphere can be measured accurately, and the levels in the past are known, mainly by analysing air bubbles trapped in polar ice. As a proportion, the quantity of greenhouse gases is small, so they are measured in parts per million or parts per billion.

Sorry if you don't like graphs, but they are a wonderful way to show information. This one shows three greenhouse gases - carbon dioxide, methane and nitrous oxide - over the last 2,000 years (water vapour cannot be measured in ice cores).



Carbon dioxide, the red graph, has the biggest effect. The amount was very stable, at around 280ppm, for thousands of years, then in the last two centuries it has increased faster and faster. It is now over 380ppm, and rising by over 2ppm per year. Calculations of the amount, in billions of tons, show that it comes from burning of fossil fuels (coal, oil, and gas) and from changes in land use (agriculture, and burning of forests). Such a big and rapid change is totally unnatural and it is unprecedented. We must expect it to have some effect. We are doing something to our planet that has never been done before, with little concern for the consequences. Until now.

How much warming, how fast?

How much warming is not a new question. Simple estimates were done over 100 years ago. The result was about 2 degrees, if carbon dioxide were doubled. However the earth does not respond instantly to changes in greenhouse gases, it warms very gradually over a long period, several decades. It is only 20 to 30 years ago that alarm bells started to ring about how serious the warming could get.

A detailed calculation is very difficult. The problem is called feedback. It makes the earth's weather systems behave in complex ways. For example, warming melts sea ice, which replaces its white surface by dark sea, which absorbs more sunlight and causes more melting. Warming causes more water to evaporate into the atmosphere, which produces more clouds, which both reflect sunlight above and trap radiant heat below. And so on - warming causes some change, which changes the original warming. Negative feedback reduces it (but cannot eliminate it) and positive feedback amplifies it. Both types of feedback are at work all the time, causing the earth's climate to behave in complex ways.

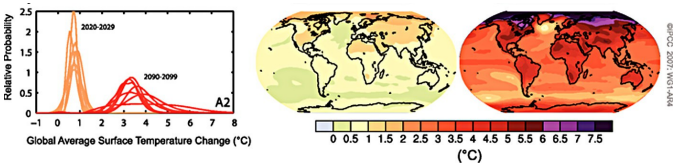
Research on the subject is a mixture of measurement and calculation. Feedback is simulated with mathematics. A simulation is called a model, and the models are run on computers. The models are run thousands of times with different conditions. The results are compared with measurements of what the earth is actually doing. This builds up a picture of how the feedback loops behave, and gives a better understanding of how reliable the forecasts are.

The IPCC

The Intergovernmental Panel on Climate Change is a very big collaborative effort, sponsored by governments. Its brief is to bring together the research on climate change, and make predictions and recommendations. It has produced assessments about every 6 years, the fourth one in 2007. There are three topics: the underlying science; the impact on life on earth; what can be done about it. For each topic there is a major report of nearly 1000 pages, with references to the work of thousands of researchers. It is all published openly, and is on their web site at www.ipcc.ch.

In all of science, the formal way of sharing work is through scientific journals. Quality is maintained by a system called peer review. When a paper is submitted to a journal, the editor sends it anonymously for review by one or more experienced scientists who know the subject. It is not published if it is substandard. Libraries will not buy journals if scientists are not going to read them, and scientists will not read them if they do not trust the contents. So publication in a peer-reviewed journal has become the standard of quality. The system is not perfect, and journals do not all set the same standard, but scientists know which are the better ones.

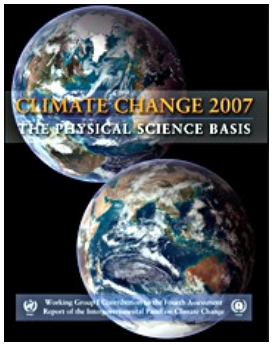
The IPCC's climate predictions



As in any complex science, forecasts are not clear cut. Scientists use the language of probability, in the same way as when a weather forecast says “an 80% probability of rain”. So, are global average temperatures rising? The IPCC says unequivocally yes. But is it caused by burning fossil fuels? In the 2007 report they said “very likely”, with a 90% probability (but new results since then have pushed it up to 95%).

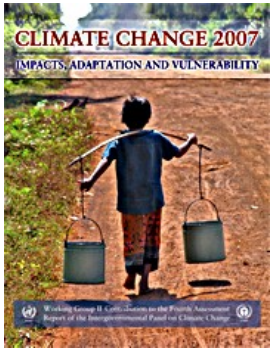
Unfortunately we have doomsayers and we have editors who want punchy headlines. So they ignore the caveats, and what ends up in the mass media tends to be exaggerated.

What will the climate will do in future? The headline results are for temperature averaged over the whole earth, and how much it will go up this century. The IPCC has a number of different scenarios. For “business as usual” it is roughly 3 degrees by the end of the 21st century. That does not sound much, but the amount of warming since the last ice age is only about 6 degrees, and that happened far more slowly. On top of the warming there will be greater extremes in the weather - heat and cold, flood and drought – and sea levels slowly rising.



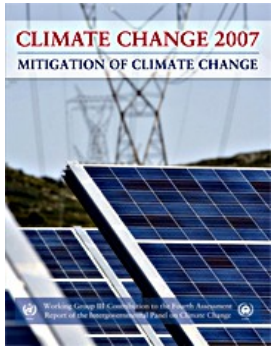
There is a risk that positive feedback could become so strong that it is impossible to stop, as in “The Age of Stupid”, or Lovelock's “The Revenge of Gaia”. For example, if permafrost melts it can release huge amounts of methane, which is a powerful greenhouse gas. The more greenhouse gases the world produces, the bigger the risk. Even if we stopped immediately, the temperature would rise a bit further before it stabilised.

Impacts and mitigation



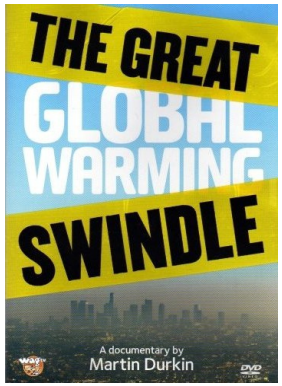
The IPCC also reports on how climate change will impact life on earth for the rest of the century, and what can be done about it. Those two reports are very wide ranging.

The report on impacts shows in some detail what is likely to happen as the climate changes. Although it is cautious where the predictions are uncertain, it is difficult to read the 16 page summary without concern for the future. There is strong evidence that changes have already started, with shifts in seasons and weather patterns. They are affecting farming, fishing, wildlife, and many activities. Loss of fresh water in dry areas, and flooding of coastal areas, are serious risks. A warmer climate offers some benefits to those in temperate regions, but they are far outweighed by the penalties, especially for those who are already at subsistence level or living on marginal lands.



The report on mitigation looks at how the world can move to a low carbon economy. There is much economics in it as well as science. Greenhouse gas emissions must fall drastically, not just stabilise. The report looks at economic development in different parts of the world and what kind of investments in food, fuel, infrastructure, etc would be most effective. Of course the report can only show how to get there, not whether it will actually be done.

Part 3: The Opposition



Many people reject the idea that human activity is causing climate change. They call themselves sceptics, although that includes a range of views, from admitting some link but not accepting that it should affect our behaviour, to total denial. Clearly they cannot all be right. It is worth asking critics what would satisfy them, because some refuse to accept any evidence that they don't like. They tend to be the ones who shout loudest. That attitude is the exact opposite of good science.

Why?

When the dangers of burning fossil fuels began to emerge, environmentalists thought the world would wake up and deal with it. It was an unpleasant shock to be greeted with hostility and ridicule. Nobody likes being told that their way of life is causing long term damage. Voluntary action is one thing, but being told you must act is another. People who don't want to believe that we are changing the climate will grasp at anything that allows them room for doubt.

There are large industries with a vested interest in feeding that doubt and resisting change. The world is hooked on oil in particular. There is rising demand and limited supply, controlled by oil companies, and they make huge profits. If the world agrees to limit its consumption, the price falls and they lose their profits. They are gradually accepting the climate change case, but they drag their feet and lobby behind the scenes, and they provide finance for others to campaign.

Far more militant opposition is led by free market believers and institutes. With a semi-religious belief in free markets, they are fiercely opposed to anything they see as a restraint on their freedom. They portray limits on greenhouse gases as government trying to raise taxes or restrict our freedom, and have made the debate highly political. The IPCC is not a political body, but they find themselves in the firing line. The aim is to undermine their credibility: if you don't like the message, shoot the messenger.

The strategy

A generation ago a clear link was revealed between smoking and lung cancer. The tobacco companies fought a long rearguard action to discredit the science and keep their public image clean, in order to delay legislation. In their terms, it was quite successful. Legislation was delayed many years, during which they were able to open up new markets in emerging economies.

It is a similar story with climate change. The truth is that the denial lobby has already lost the scientific argument, and what we see now is a rearguard action. They are not really interested in the science, only in public opinion. The more doubt they can spread among the public, the harder it is for governments to legislate.

The approach to science

Disagreements in science are nothing new, in fact that is often how it makes progress. Scientists meet at conferences, and get to know each other, and rival ideas are compared and debated in meetings and in reputable journals. Sooner or later a consensus emerges, until new results or a better theory come along.

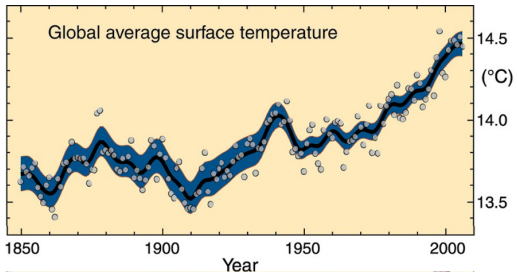
Very few climate change critics take an active part in this process. They portray climate science as a closed shop which has locked them out. The real reason is that they have nothing to present that will stand up to examination. They have published very little in peer-reviewed journals, and have produced nothing remotely like the IPCC reports.

Instead of offering an alternative to the mainline science, that can be examined critically, they rely on a relentlessly negative approach. Much of it is quite bad tempered and personal, or political, some of it is contradictory, and the general level of their science is abysmal. But it's not about science, it's about swaying public opinion. Scientists are not used to this and are still learning how to handle it.

What they say

They want to give the impression that if one hole can be picked in climate science then the whole case falls apart. In fact climate science has a solid foundation and it is the critics whose arguments fall apart when you examine them. But they are slippery customers, and when you point out an error in what they say, they don't follow their own logic by accepting that you are right after all, they ignore it and move on to another point.

The main area of dispute is not over whether extra greenhouse gases will cause extra warming, but whether they already are. This graph, covering the last 150 years, shows a rising temperature, especially since about 1950:



The critics want to deny that greenhouse gases are the cause. There are three options:

1. It is not rising, the temperature data is wrong;
2. The climate varies anyway, and this rise is purely natural;
3. The rise has a real cause, but it is not human activity.

Option 1: not many try this one because there is so much global data since the thermometer was invented, and it gives a consistent picture. They criticise it loudly, but they do not offer any alternative graph with solid evidence to support it. They like to pick out small parts of the data to fit what they want to say, and ignore the rest.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CLIMATE CHANGE IS NATURAL: 100 REASONS WHY

Tuesday December 15,2009

Have your say(90)

HERE are the 100 reasons, released in a dossier issued by the European Foundation, why climate change is natural and not man-made

Climate change campaigners: 100 reasons why climate change is natural and not man-made

Option 2: "climate change is natural" is a more popular argument. They quote examples of past changes before fossil fuels were being burnt, such as the mediaeval warming period, or the ice ages. Those were natural, but they do not match the speed and extent of the present change. Our huge increase in greenhouse gases is entirely unnatural. The changes in the past simply tell us that the climate is not very stable. This cannot be an excuse for saying that since it changes anyway, a bit of greenhouse warming is neither here nor there. That is like saying it's OK to ill-treat the patient because the patient's condition is already unstable. Just the opposite: as the climate is unstable, that is all the more reason for treating it with care.

The usual candidate for **option 3** is the sun. Satellites have been monitoring it for many years, and solar physics is a well established subject. The sun does affect the atmosphere, but nowhere near enough to explain the present temperature rise. Option 3 is a last resort for denial theories – we don't accept that greenhouse gases are the cause therefore it must be something else.

There is a halfway house between options 2 and 3: ancient data shows changes in carbon dioxide coming after changes in temperature, not before, therefore they say that greenhouse gases are an effect not a cause. But those natural changes in carbon dioxide only occurred after delays of hundreds of years, not in decades that we see now. We come back to the greenhouse effect and the huge amount of greenhouse gases being added to the atmosphere, taking it far above pre-industrial levels. A natural past is no guide to an unnatural present.

There are plenty more arguments out there, too many to cover here. The sheer number shows the weakness of the denial case. A natural explanation for climate change does not need 100 reasons against, it needs just one that can be supported with good science. If it did exist, fossil fuel companies would be shouting it from the housetops. Instead we get a barrage of criticism. Most is so weak that no self-respecting scientist would make it, and often they contradict each other. Ten bad arguments do not make one good one; on the contrary, they show that a good argument has not been found.

Part 4: A response

It's not just climate change

In a technically advanced society, it is easy to forget that we are totally dependent on the earth for our survival. Our health depends on its health, and the earth faces serious environmental threats. Climate change is a big one, and it tends to make the other ones worse.

Increasing demand for land and food, for example, puts pressure on ecosystems and is causing deforestation, collapsing fish stocks, loss of biodiversity, and extinction of species. Then climate change on top of that changes habitats and patterns of food production. That causes plant and animal species to lose their ecological niche, so it becomes even harder for them to survive.

The growing demand for fresh water for agricultural and human use is another major challenge. Add climate change, and water management gets harder, by adding floods and drought, and there is the huge long term threat from rising sea levels.

The big picture is of a growing demand for natural resources, from a planet which has a shrinking capacity to provide them. One response from critics is to say that we are ignoring the biggest threat, population growth. It is hard to find out what alternative they propose. Of course population is a major issue, but it is our consumption that does the damage. Rich people consume many times more per head than poor people, and we in this country are first class passengers on spaceship earth.

Yet another threat

There is another danger, distinct from climate change. Only about half of the carbon dioxide we produce stays in the atmosphere. The other half dissolves in the oceans, and it is slowly making them more acidic. That harms the tiny shellfish at the bottom of the ocean food chain, and presents another big long term threat to food supplies.

A parallel

Borrowing and lending money are a vital part of a healthy economy, as it allows money to be used in productive ways, and then loans can be repaid with interest. The present financial crisis was the result of millions of people borrowing more than they could repay. The lenders and authorities seemed to believe that this could go on and on. The free market was going to give us an new era of economic growth - which it did until the credit dried up. Printing more money postpones the crunch, but the debts remain, and they keep growing. Living on borrowed money is unsustainable.

The same is happening in the way we treat the earth. We are borrowing resources from the earth faster than they are being renewed. It is a way of life that cannot be sustained. There are still free market believers in high places, who brush aside the threats and want to carry on as we are. They pretend that economic growth and technology will provide the extra resources. Technology probably can postpone the crunch, but the debt is still increasing and it will catch up with us.

Responding to the science

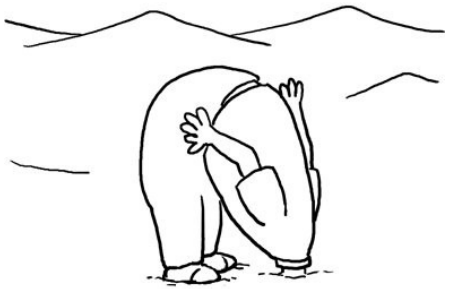
Science, practised with integrity, gives us a deep understanding of how the world works. It is built on objective truth: facts that remain the same whatever our personal beliefs. Al Gore's “An Inconvenient Truth” is a good example of presenting the facts as best he could at the time. Some of his critics focussed on the science, which would have been fair enough, except that they offered no credible alternative. However others simply dismissed it or attacked him personally. They saw their task as scoring points rather than engaging with the truth.

Science is not a matter of opinion. Scientists are not free to decide first what they want to believe, then pick out the bits that support it and ignore the rest – that is post-modernism. In science the evidence, all of it, comes first, and the conclusions follow.

Science is about objective truth, but how we respond is an ethical issue. Those who are most at risk from climate change are the world's poor and vulnerable, living on marginal land. Already climate change is the cause of more refugees than war, and we face the prospect of famine and migration on an unprecedented scale. In the longer run everyone is at risk. Western governments receive good scientific advice, and they know many of the changes that are necessary, but they need the consent of ordinary people before they can do it.

Climate science is not complete and not exact, but its predictions are compelling enough to take action now, and they give a good guide to the changes that we need to make. If we are not willing to accept them, and wait until change is forced on us because of the way we have treated the earth, that will be far more painful.

Those who deny that we need to act are quick to criticise others, but they are not being challenged or treated with the scepticism they themselves deserve. The science is clear and won't go away; climate scepticism at root is not scientific, it is a denial of the science.



Conclusion

Perhaps the final piece of evidence should be non-scientific: the behaviour of fossil fuel companies. They probably have the biggest resources of any industrial sector, and the most to lose. If they really believed their scientists could prove that burning fossil fuels does not affect the climate, surely they would be fighting legislation openly, and running the biggest sales and marketing campaign the world has ever seen. They are not, because they know that they do not have a case.

One way or another, our way of life will change, and some of the changes we will regret. But we cannot go on as we are. Instead of resisting change, let's learn to tread more lightly on the earth. It's about consuming less instead of demanding more, but that can be very satisfying. At a personal level it means:

- treat electricity and fuel as limited resources, to be used with care;
- expect energy costs to increase;
- less heating and better insulation;
- less travelling, and by more efficient means
- eating more seasonal and local foods
- reduce, reuse, recycle

… and so on – you have heard them before.

This is the only planet we have – let's learn to look after it.

This document is written for Abingdon Carbon Cutters, to try to make the science of climate change a little more accessible to non-scientists.

If you would like to suggest changes in it, or want to take issue with it, or would like to see it distributed more widely, you can contact the author at
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