Climate Change: Facts and Impacts

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Climate Change: Facts and Impacts

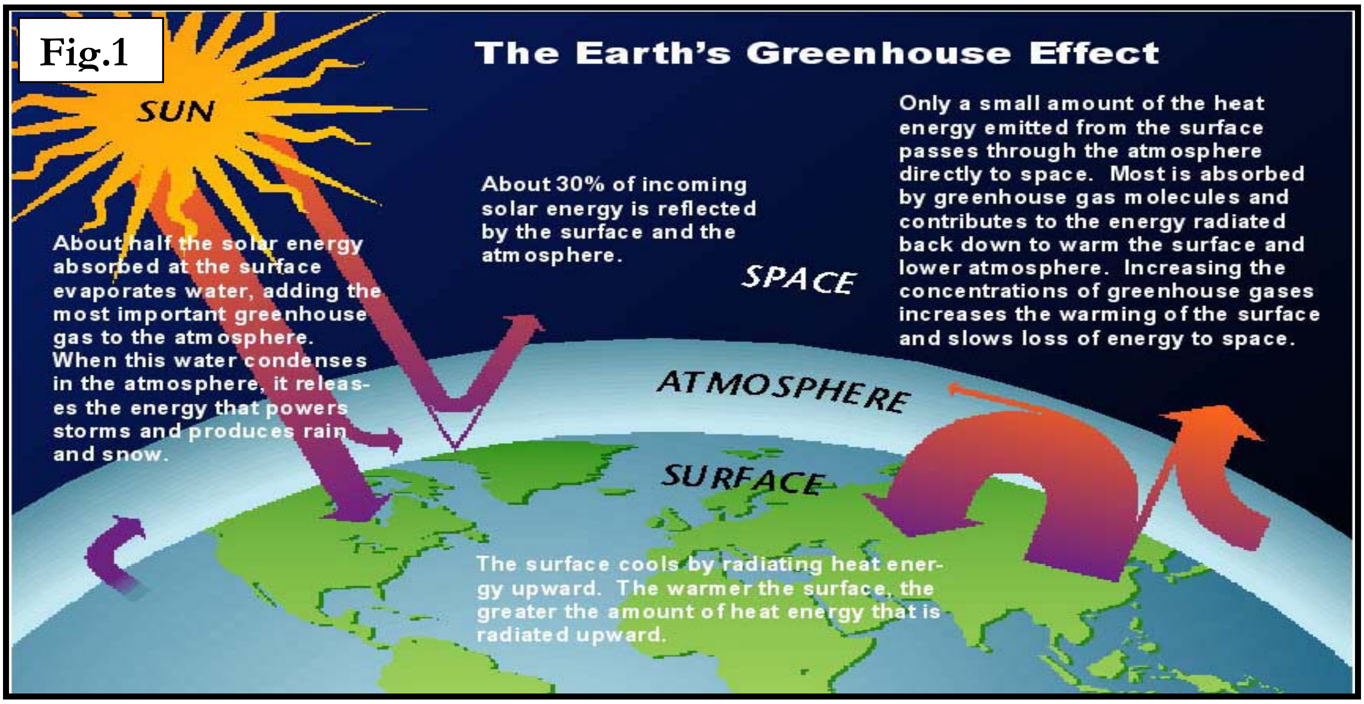
➢ Is it happening, is it human caused?

Human induced Climate Change is the more accurate of two terms, the other being Global Warming. The importance of this is that in a complex system such as earth's atmosphere a general warming does not necessarily lead to warming everywhere, it leads to changes in climate throughout the world, a redistribution of an increased amount of energy in a far from uniform manner. The two primary questions you might ask about what I have just said are:

1. **Do we know for sure that the climate is changing?**
2. **Couldn't this be as a result of natural variation in the climate system?**

Climate Change was in fact predicted back in 1894 by the famous Swedish chemist Svante Arrhenius. The reason for this is that it was well known even back in 1894 that carbon dioxide is produced by burning fossil fuels and that it absorbs strongly in the infra red region of the spectrum, but allows visible light to pass through (fig.1).

Fig.1



There is a natural greenhouse effect caused by water in the atmosphere and natural levels of carbon dioxide, if it weren`t for this the planet would be far colder than it is today, and life would probably be impossible. We know the levels of carbon dioxide in the atmosphere where stable at 270ppm for thousands of years before the industrial revoloution and they are now ate around 370ppm. The scope of the second question is therefore limited to quantification: is natural variation of a magnitude so great that the warming created by emissions of fossil fuel and deforestation derived carbon are not significant?

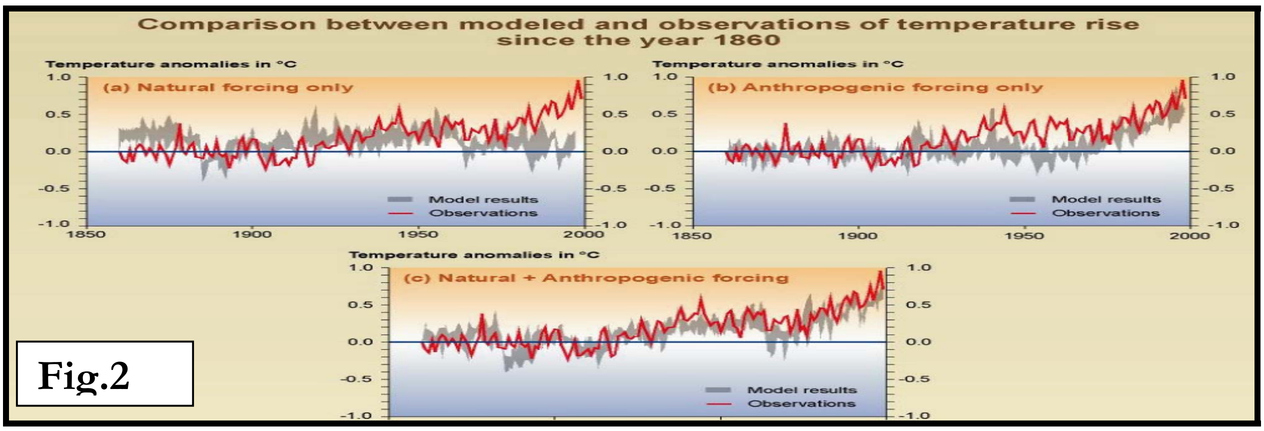


Fig.2

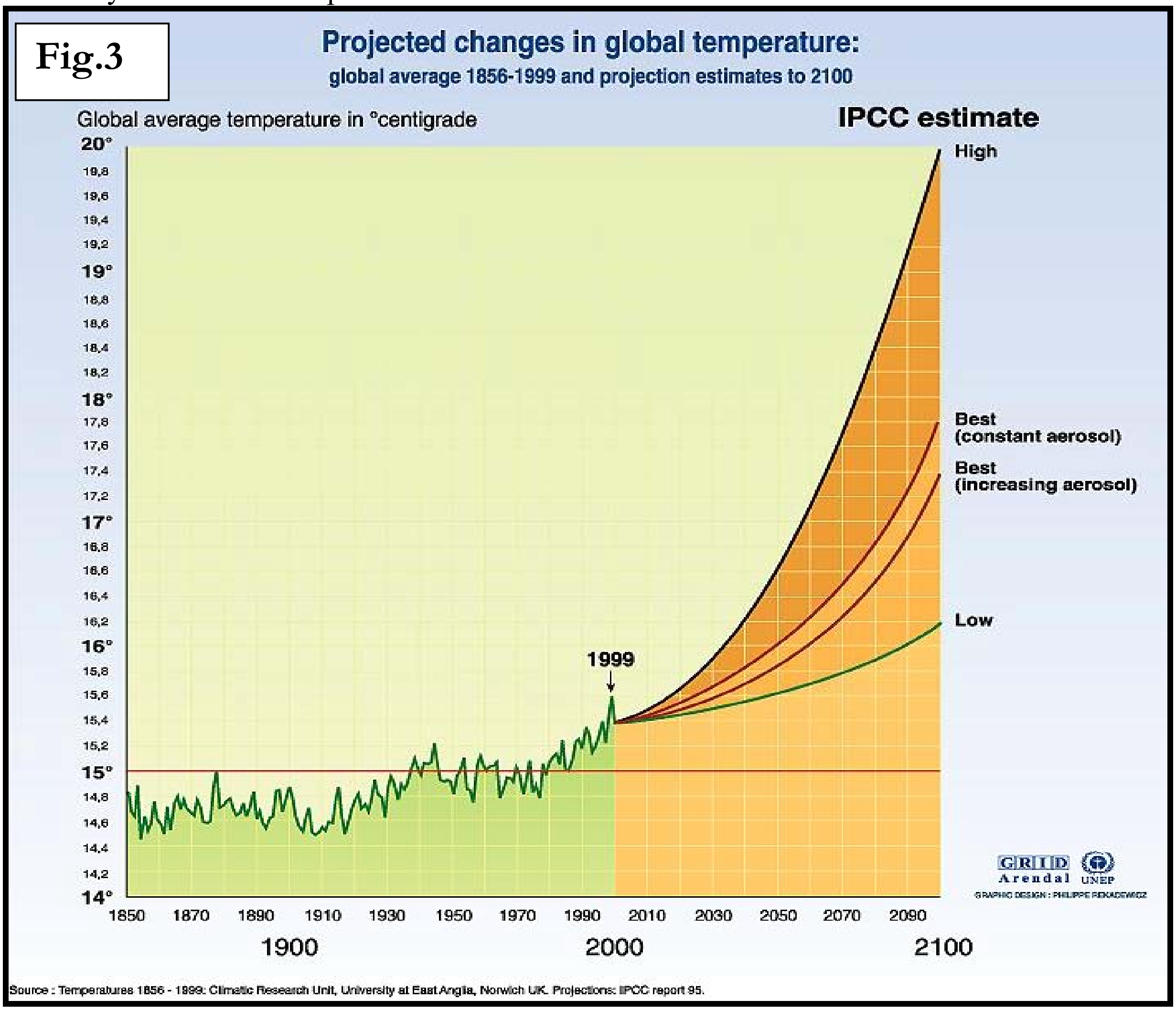
The answer to this is no, we can distinguish a clear signal of human caused (anthropogenic) Climate Change for at least the last forty years (fig.2), this is found across all climate models and is superbly illustrated by the Intergovernmental Panel on Climate Change in there Third Assessment Report (TAR). On a planet entirely covered by solid ground the warming effects of carbon emissions would be felt very rapidly. Earth however is covered largely by water and there is therefore a lag before atmospheric warming is seen to the expected degree. This is why even if we stopped emitting carbon now, there would still be a significant further warming.

➢ <u>There is some climate variability though, how much?</u>

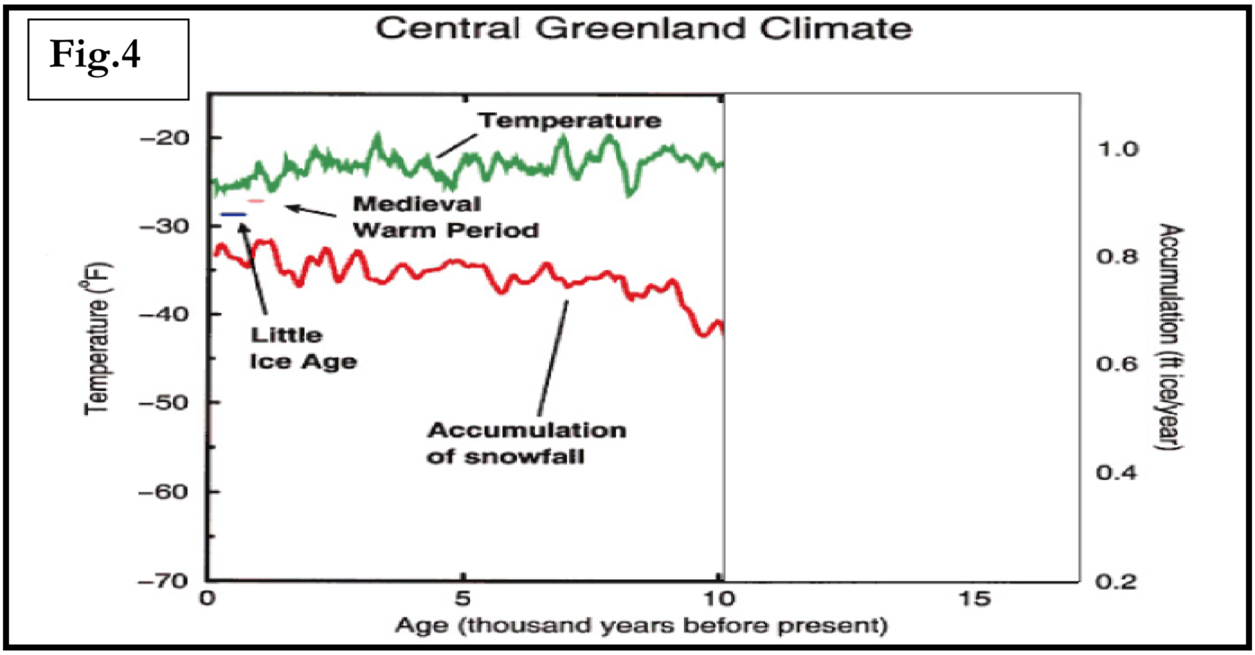
This question has two important parts which need addressing:

1. **<u>What are the timescales of natural variability and of what magnitude are these variations.</u>**
2. **<u>Abrupt climate change its dangerous to whether or not it is natural.</u>**

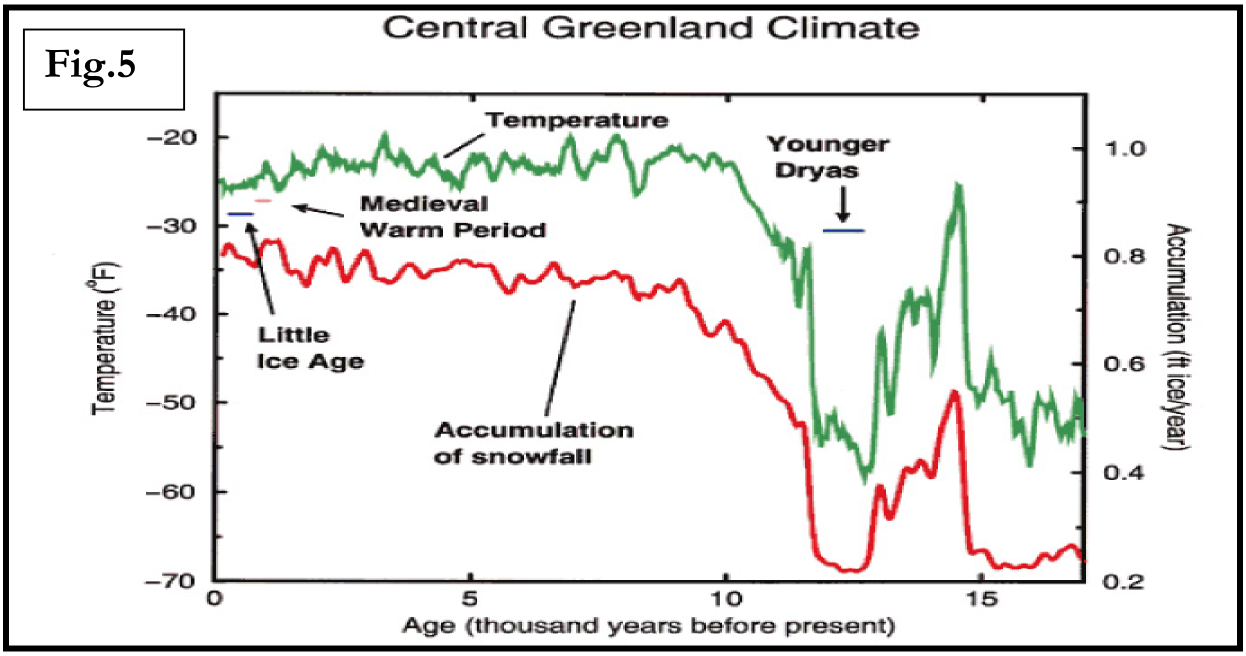
Human civilization has developed in a particularly stable climatic period, and we have benefited enormously from this fact. The figure below (fig.3)shows how the climate has varied over the past hundred and fifty years. Based on these historical temperature data and carbon dioxide concentrations models have been used to project forward the likely increases in temperature.



When compared to human lifetimes climate change tends to be relatively slow, the rate of the coming change is one of the most worrying things to many people, particularly ecologists and humanitarian charities who know that both ecosystems and human societies take time to adapt to change. The diagram below (fig.4) shows the relative stability of the climate system over the last ten thousand years.



You can just about see times such as the 'medieval warm period' that allowed the Vikings to colonise Greenland, and the 'little ice age' which drove them out, hitting Viking civilisation in general very hard. This leads on to the second point that needs addressing. What is shown on this diagram is the small magnitude variation within a 'climatic mode' that is still capable of brining down civilizations such as the Vikings, Assyrians, Maya and Anasazi. It is *hoped* however that this is the kind of climate change that we are going to see in the future, there will be a greater degree of warming than seen in the past ten thousand years but hopefully it will continue to be a linear process, a given amount more carbon dioxide producing a given rise in temperature. Unfortunately more extreme changes can occur (fig.5).

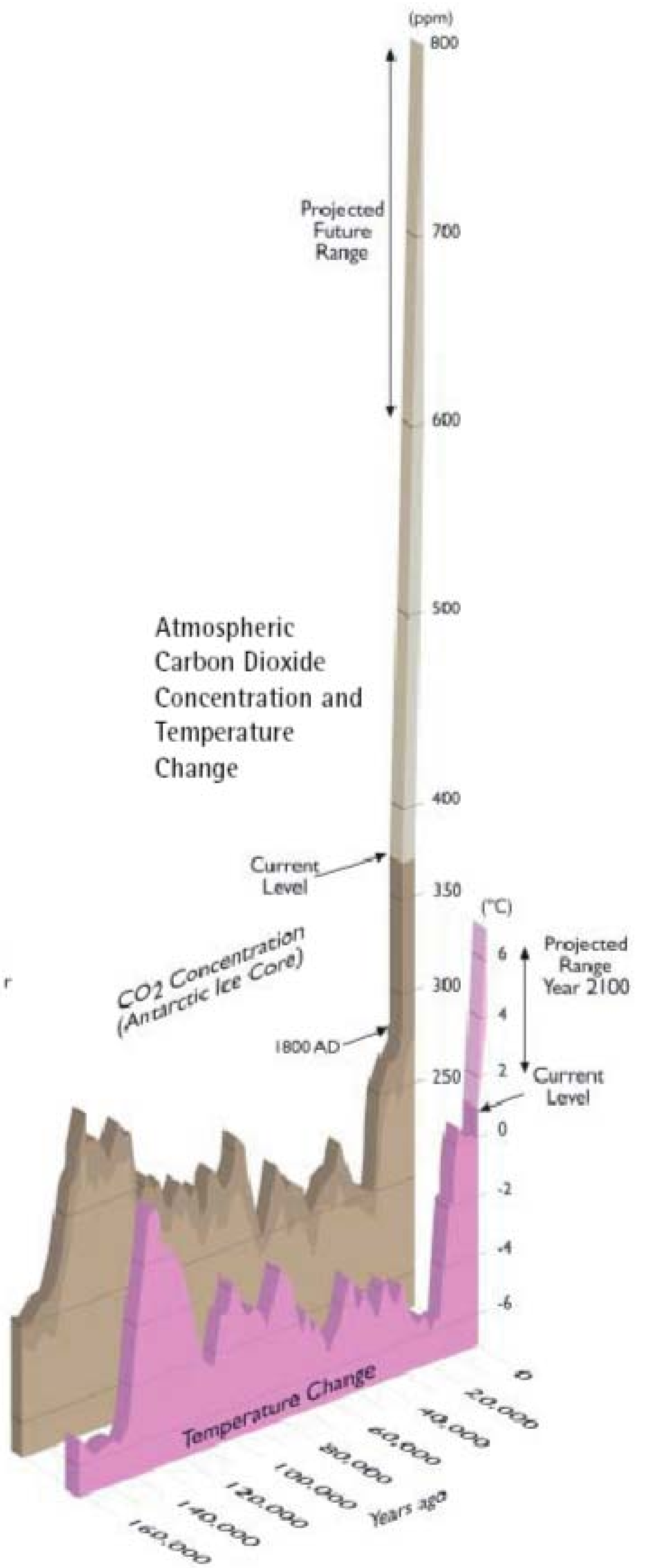


The younger Dryas event is the most recent and best-studied example of abrupt, or non-linear, climate change. The details aren't all known, but it is clear that the atmosphere/ocean system changed state in some dramatic way: a small variation became amplified. To clarify, a certain degree of Climate Change is happening and will continue, however there is potential for dramatic climate change of unknown severity to occur. Richard Alley is a paleo-climatologist from Penn State University, he studies ice-cores for information on past climate, and his team has found that:

"Sometimes a small push has caused the climate to change a little, but other times, a small push has knocked Earth's climate system into a different mode of operation, brining new weather patterns to Earth in only a few years or decades"

(A push being any change; solar radiation, carbon dioxide, methane etc..)
How much are we 'pushing' the system, what are the observed and predicted changes in carbon dioxide concentration in the atmosphere? The answer to this is that we are emitting carbon dioxide at an alarming and increasing rate and this may well continue without concerted global action by all countries, including the USA as the most polluting of all, on a per capita and absolute basis. For a comparison of carbon dioxide concentration over the last *160'000 years*, look at the graph below.

Fig.6



➢ What are the expected effects of anthropogenic Climate Change?

This question has already been partially answered, climate change is already happening and around the world vulnerable communities, ecosystems and nations are feeling the impacts. To answer this question effectively it is necessary to look at two questions, each from an environmental and a human perspective:

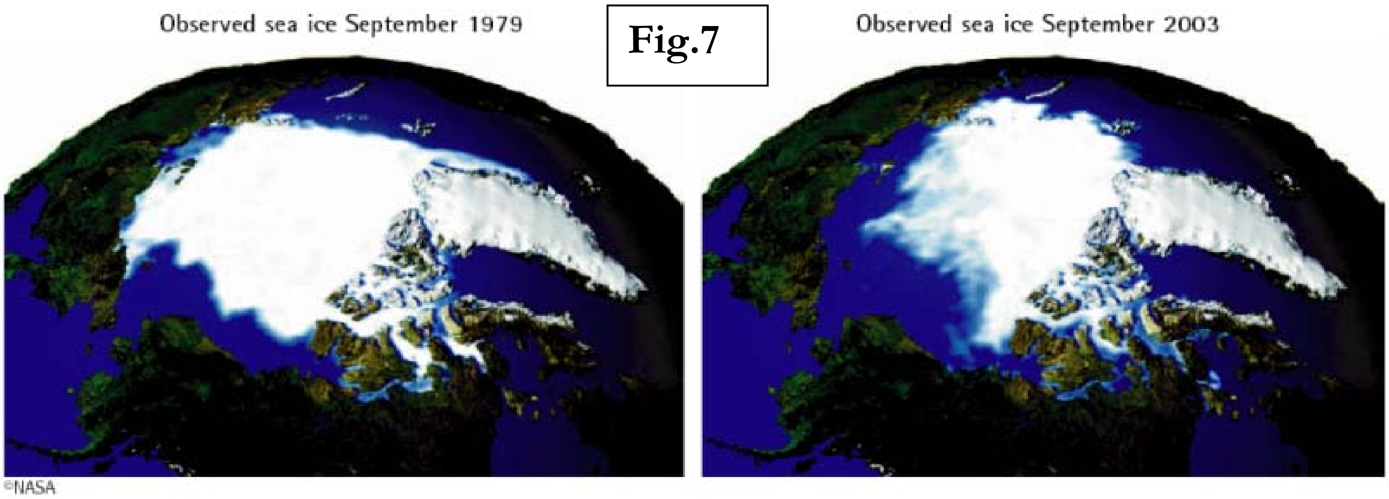
1. **What changes have already been observed?**
   - What effects on the environment will these changes have?
   - What effects these changes have on humans?
2. **What changes can we expect if emissions continue in an unmitigated fashion?**
   - What effects on the environment will these changes have?
   - What effects these changes have on humans?

1. What changes have already been observed?

The Cryosphere (all the frozen stuff)

Many of the most prominent changes that are already occurring are doing so in the arctic region. The reason for this is strong positive feedback associated with occurs with ice and snow melt. As we all know ice and snow are highly reflective and white, for this reason, when the ground or ocean beneath is revealed more absorption occurs. This leads to further warming…further melting etc… The pictures bellow show the effects of climate change in recent years. The reduction of sea ice since 1979 is quite striking, but as I will show latter the predictions for changes over the next one hundred years are far more dramatic.

Fig.7



The two images above, constructed from satellite data, compare arctic sea ice concentrations in September of 1979 and 2003. September is the month in which sea ice is at its yearly minimum and 1979 marks the first year that data of this kind became available in meaningful form. The lowest concentration of sea ice on record was in September 2002.

A recent conference on climate change was held in Greenland, this was no accident; the melting of the Greenland ice cap is one of the most potent symbols of human impacts on the planet. The Pictures below show the increase in melting that has started to occur between 1992 and 2002. Clearly the level of warming currently occurring in the arctic is having an enormous impact on the region and the magnitude of further warming is set to be disastrous for the region, as the Arctic Climate Impact Assessment (ACIA) states:

"*The reduction in sea ice is very likely to have devastating consequences for polar bears, ice-dependant seals, and local people for whom these animals are the primary source of food"*

The ACIA is a major contribution to our understanding of the climate change in the arctic; it utilizes the latest climate science, satellite and temperature data along with the experiences and cultural knowledge of the indigenous peoples.

The effects of climate change are very important to people who depend so directly on the land, an indigenous Siberian woman voices concerns typical of the people in the high arctic:

"Nowadays snow melts earlier in the spring time and the lakes, rivers and bogs freeze much latter in the autumn. Reindeer herding becomes more difficult as the ice is weak and may give way… all sorts of unusual events have taken place. Nowadays the winters are much warmer than they used to be. Occasionally during the winter time it rains. We never expected this. It is very strange…the cycle of the yearly calendar has been disturbed greatly and this effects the Reindeer herding negatively, for sure"

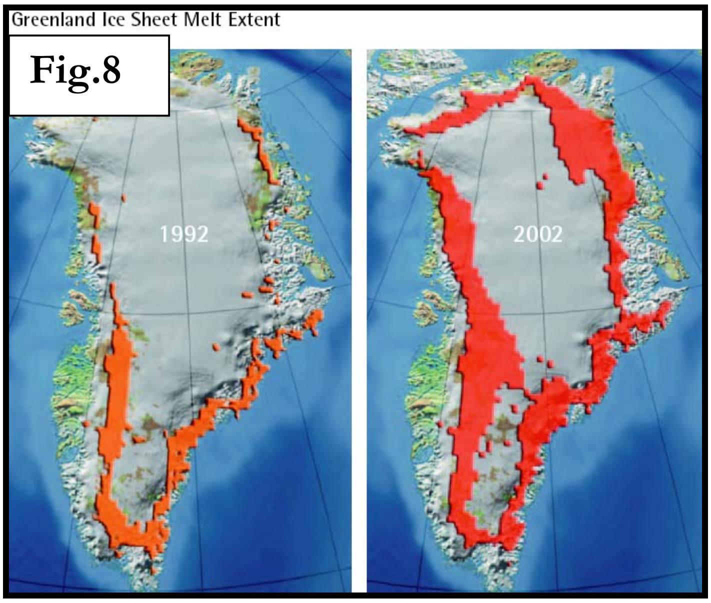


Fig.8

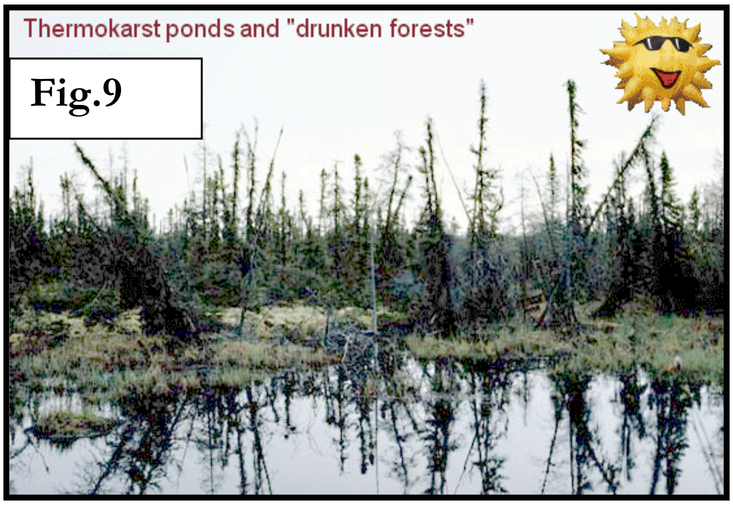


Fig.9

Throughout the world losses of ice and warming have been affecting peoples livelihoods. Glaciers throughout the temperate and tropical regions are being particularly hard hit. In Austria for example this glacier (fig.10) has disappeared between 1875 and 2004. Large areas of taiga forest (fig.9) are also being effected by climate change, they are drowning and rotting as the permafrost on which they grow is melting and turning to anoxic sludge which can no longer support the trees.

Fig.10

The loss of glaciers in itself is a huge problem; there is usually a balance between accumulation during the winter and melting during the summer. Glaciers therefore act as a buffer against low river flows that would typically occur during the summer. This melt water is crucial for tens of millions of people around the world. Many of the most vulnerable are subsistence farmers, who are now facing crisis and the more warming that we allow to happen the more people will be affected. This demonstrates the fact that fighting climate change is not an activity in competition with fighting poverty; it is *key to* fighting poverty!

The Oceans

The main reason for the rise in sea level that has occurred so far and that will continue in the medium term is thermal expansion; warm water is less dense and takes up more room. The response of the oceans to the warming effects of climate change is however relatively slow, this is due to several factors, the enormous volume of the oceans, the high heat 'thermal capacity' of water (water takes more energy to heat per unit mass than virtually any other substance) and the and the relatively slow rate of mixing between the surface and deep ocean waters. It is for this reason that: The oceans haven't yet wiped out the whole of the Maldives and; It is now impossible to prevent the ocean from rising further, although the levels of future warming will determine the exact extent of sea level rise that will occur. One of the most sensitive nations on earth to rising sea levels is the Maldives, a nation of small atolls, islands formed by millions of years of coral growth. Already the state is losing some land such as the 'island' in the picture below (fig.11), all of the plant life on which has now been removed by repeated flooding as the sea levels rise.

Fig.11

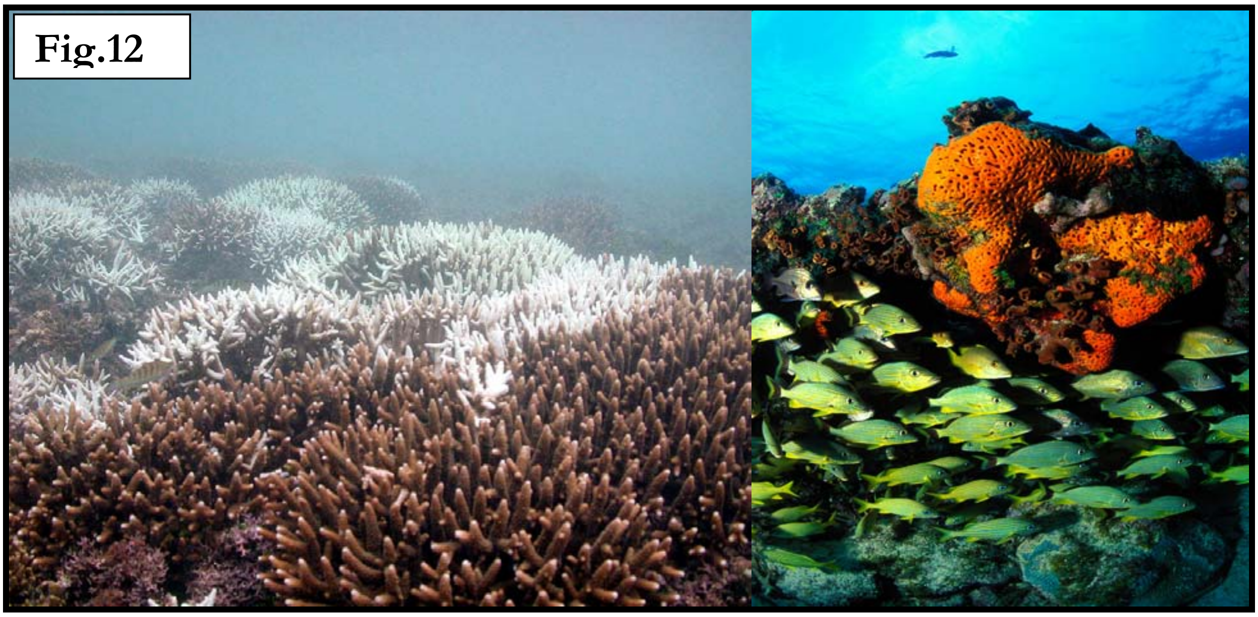
An increasingly El Nino like state to the oceans is also likely to occur. The El Nino event is a complex pattern of atmospheric and ocean interactions, and its effects are felt across the tropical and sub-tropical regions. There are many consequences to this cyclical event including failing of the cool nutrient rich ocean waters which well up along the west coast of south America. These currents usually make this region one of the most productive areas of ocean in the world; productivity on which much of the wildlife living along the Pacific coast of South America are dependant.

El Nino events in recent years have acted to compound human damage to coral reefs worldwide. Coral bleaching is caused by increased stress, abnormally warm temperatures being an example of such a stress. The El Nino events of recent years have been some of the worst in history. A state close to El Nino becoming the norm is likely to be devastating for the corals worldwide. The pictures below (fig.12) illustrate the impact of irrevocable bleaching; the 'Amazon of the sea' becomes a virtual desert.

The Biosphere (everything that lives)

"There is no realistic doubt that continued climate change will cause further degradation of coral reef communities, which will be even more devastating in combination with the continuing non-climatic stresses that will almost certainly increase in magnitude and frequency"
(Pew Center on Global Climate Change)

Fig.12



The loss of coral ecosystems is a disaster both environmentally and economically.

"Coral reefs represent some of the most biologically diverse ecosystems on Earth, providing habitat for approximately 25% of marine species. In addition, these ecosystems provide economic benefits through tourism and fisheries. One recent estimate valued the annual net benefit of the worlds coral reefs at 30 $ billion."
(Pew Center on Global Climate Change)

Some of the first species losses to have been attributed to climate change are the collection of around 70 species of harlequin frog (fig.13) Genus *Atelopus,* Endemic to Central and South America. **(J.Alan Pounds and Robert Puschendorf, Nature, 2004)**

Fig.13

A recent report on climate change observations in the USA by the Pew Center for Global Climate Change found that e.g. laying, flowering, migration and breeding of a diverse range of flora and fauna where all occurring earlier in the season (fig.14). All these effects are known as Phenological phenomena, some of them are shown in the table below.

Fig.14 **Changes in Phenological Events** Induced by Climate Change

Organism	Study period (years)	Spatial scale	Phenological event	Phenological shift	Reference
Mexican jay	1971-1998	Mountain range in southern Arizona	Egg laying	10 days earlier	Brown et al., 1999
Tree swallow	1959-1991	North America	Egg laying	9 days earlier	Dunn and Winkler, 1999
Various	1930-1990s	One farm in Wisconsin	Breeding, migration, flowering	7.3 days earlier	Bradley et al., 1999
Amphibians	Early 1900s vs. 1990s	One city in New York state	Breeding	10-13 days earlier	Gibbs and Breisch, 2001
Plants	1981-1999	Boreal region	Greening period	12 days longer	Myneni et al., 1997; Zhou et al., 2001; Lucht et al., 2002
Flowering plants	30-year period	Washington, D.C.	Flowering	4.5 days earlier	Abu-Asab et al., 2001

Weather Patterns (The direct effects of a changing climate on humans life)

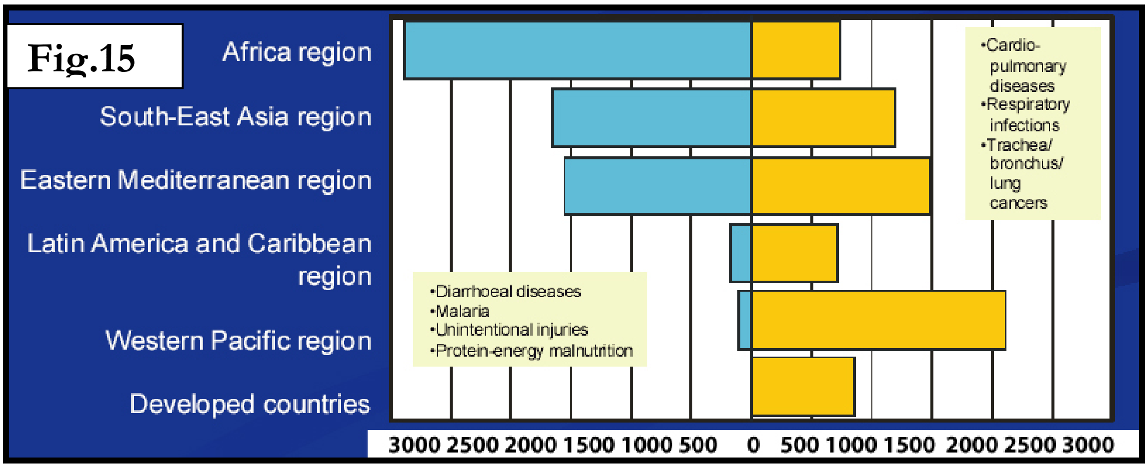
Sub-Saharan Africa is one of the areas feeling the effects of climate change most keenly at present. The Sahel region is particularly vulnerable. A region defined by its sparse forests and widely separated trees, seasonally rich grassland is crucial for feeding the cattle of the indigenous nomadic peoples. The variation in annual rainfall has long been a strong influence on the way of life these people have evolved. On the southern margins of the Sahara however climate models predict problems ahead. Indeed rainfall has historically been widely variable, but over the last 30 years the average rainfall has fallen by 25% and this has forced the proud tribes people of Kenya to become dependant on international food aid. Other areas affected include the Sudan, Ethiopia many individual situations have received significant media coverage; a changing climate is the central theme. Another prediction made by climate models and subsequently supported by weather stations is that there will be an increase in the proportion of rainfall that occurs in intense bursts.

"Most countries that experienced an increase or decrease in monthly or seasonal precipitation also experiences a disproportionate change in the amount of precipitation falling during heavy or extreme precipitation events"

(David R.Easterling et.al., Science 2000)

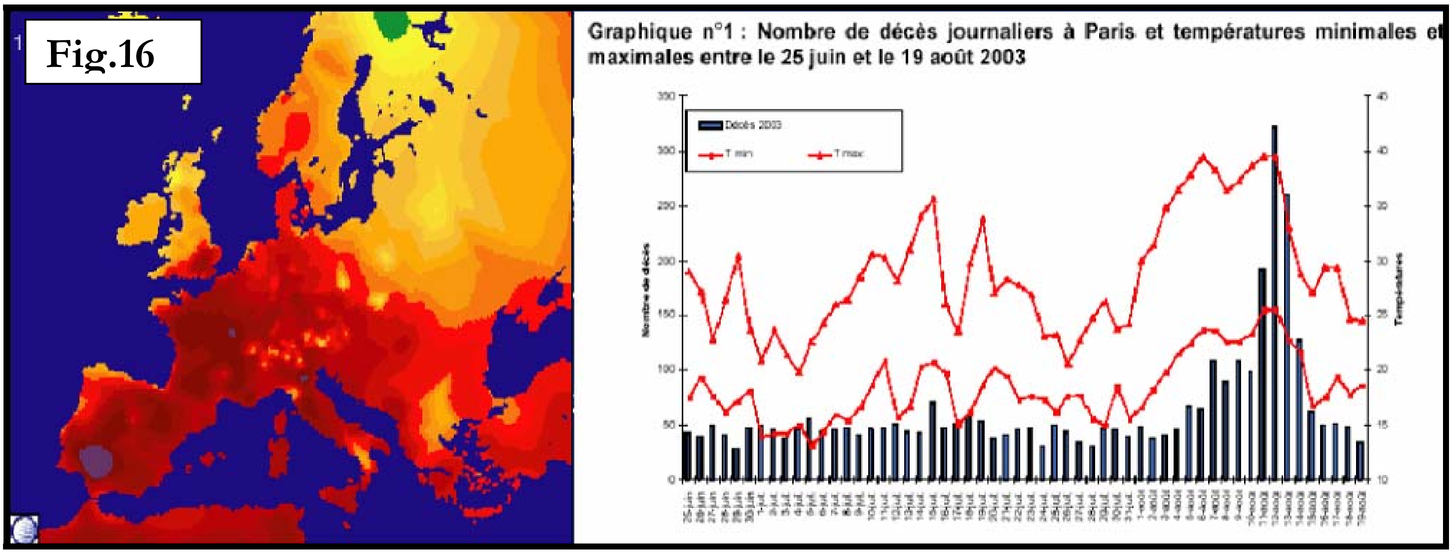
The burden of the climate change is falling disproportionately on the already poor, particularly in Southern and Central Africa. The effects of on human health are just beginning to bite. The world health organization (WHO) estimates that:

"Climate Change is currently causing the loss of around 5.5 million years of healthy life per year, equivalent to 150`000 lives lost annually."



This chart shows the numbers of 'disability adjusted life years' per million population due to climate change (right) and air pollution (left) WHO report 2002

More 'developed' countries are however still susceptible to the effects of climate change. Across Europe in the summer of 2002 a record-breaking heat wave caused tens of thousands of deaths(fig.16), particularly in France. Although single weather events cannot be usually be attributed to climate change there was a detailed study carried out into the heat wave, its extent and severity. This study published in the journal Nature found that the chances of the summer heat wave occurring without climate change where less than one in a thousand.

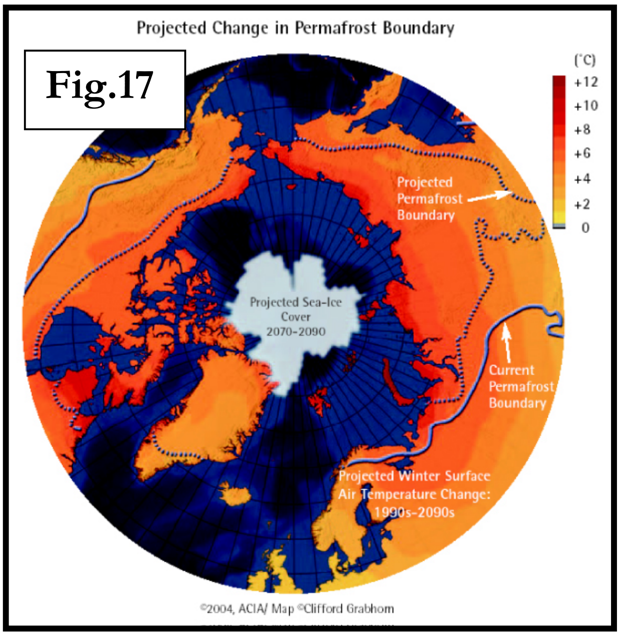


This table shows the area affected by the heat wave and the chart on the right shows the daily maximum and minimum temperatures along with the number of deaths on the bar chart.

2. What changes do we expect?

The answer to this question is complex. I will limit my attempt to answer this question by making one big assumption: Abrupt Climate Change will not occur. This assumption is useful for me because I can explain the known impacts of 'business as usual' relatively easily. This is not a luxury that policy makers or economists have, if they are acting responsibly. Just as businesses 'hedge against' uncertainties and take out insurance policies so policy makers need to hedge against the chance of abrupt climate change. The shut down of the gulf stream for example is of uncertain probability but a 10% chance is the level at which many climate scientists regard this occurrence. As Richard Alley, one of the world's top climate scientists points out:

Fig.17



"The debate in the US is usually about whether things could really be as bad as the International Panel on Climate Change (IPCC) have suggested, But; It is hard to make the IPCC scenarios better and easy to make them worse!"

Like the IPCC I will focus on smooth climate change of the magnitude thought most likely; significantly worse outcomes are possible. Most importantly however, virtually all of this can be avoided by rapid, co-coordinated and determined international action. I will later describe the level of emissions cuts required and compare this to the climate policy of the UK government.

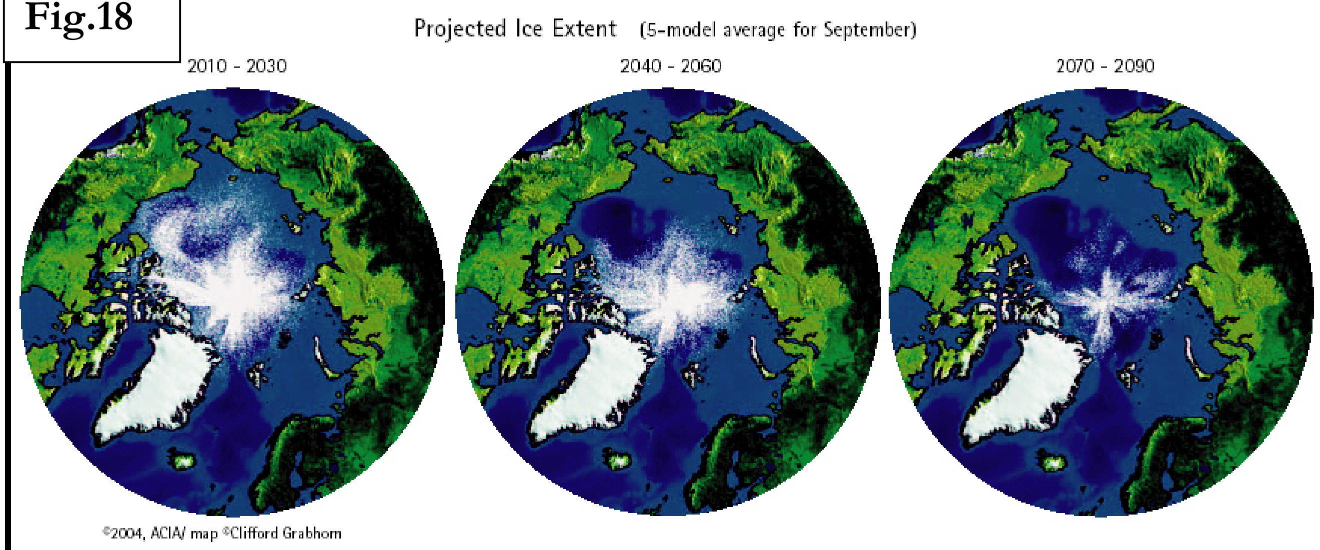
<u>Cryosphere.</u>

The Cryosphere is set for a rapid decline during the coming century. Virtually all tropical and temperate glaciers are set to disappear and the arctic will be enormously reshaped. Some have pointed out that this will open the arctic up to shipping, they are right. But the polar bears, the seals and the peoples of the arctic may not see this as just compensation for there extinction and loss of cultural heritage! As I will show later, the decline of the cryosphere will lead to an extension of the oceans, much to the detriment of costal communities the world over.

Another potentially very dangerous effect of warming in the arctic is the thawing out of vast areas of permafrost (fig.17). There are significant stores of methane locked up in, and trapped below the permafrost regions of the high Arctic. The release of billions of tones of this methane, which has around 23 times the global warming potential of carbon dioxide, could cause devastating positive feedback and further accelerate warming.

The predicted loss of sea ice is shown below, the pristine wilderness of the arctic will no longer be traversed by the occasional adventurer, walking to the north pole will no longer be an option, sailing to it may be.

Fig.18



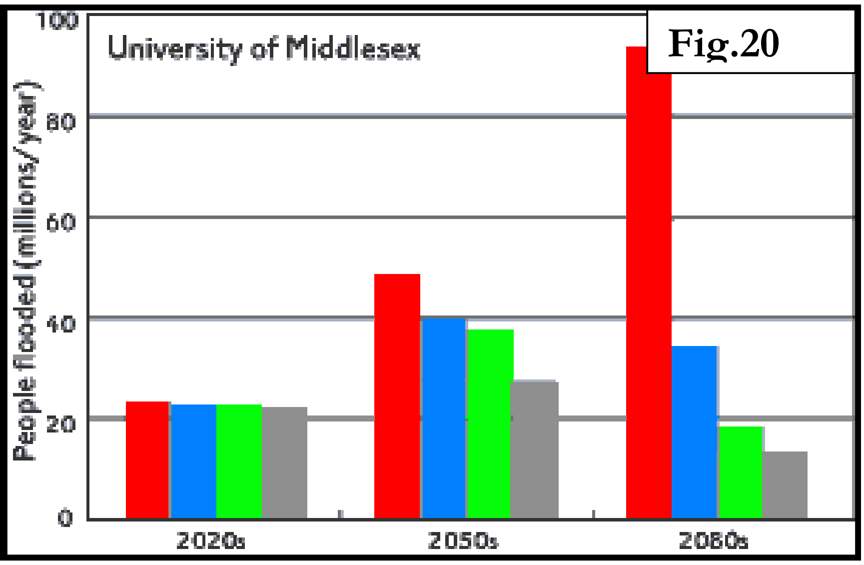
September sea-ice extent, already declining markedly, is projected to decline even more rapidly in the future. The three images above show the average of the projections from five climate models for three future time periods. As the century progresses, sea ice moves further and further from the coasts of arctic land masses, retreating to the central Arctic Ocean. Some models project the nearly complete loss of summer sea ice in this century.

<u>Oceans</u>

The National Oceanic and Atmospheric Administration (NOAA) have carried out research that indicates the likely effects of further climate change. The NOAA point out that many models indicate a more El Nino like climate in the future, but even if this doesn't occur, individual events will grow in severity.

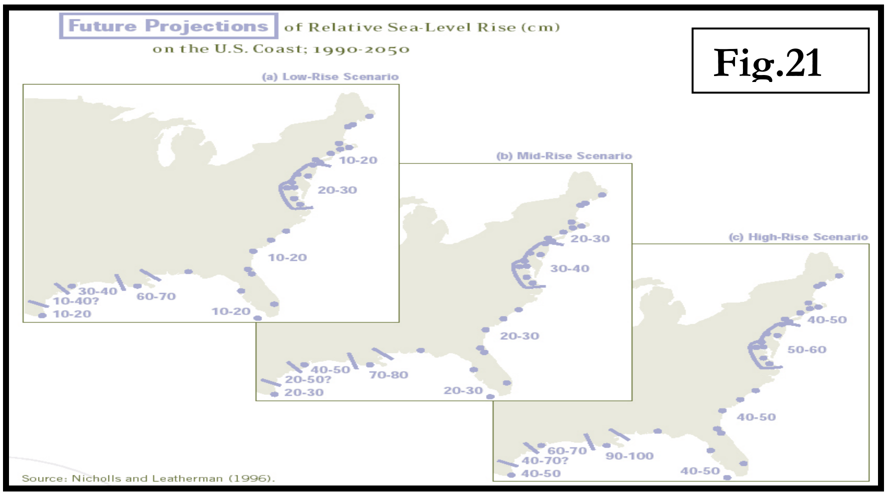
"For such El Nino-like climate change, or even for a more uniform future warming of SSTs [Sea Surface Temperatures] across the tropical Pacific as shown in some other models, future seasonal precipitation events associated with a given El Nino would be more intense than at present owing to the nonlinear relation between SST and evaporation [a little warming, a lot more evaporation]."
(David.R.Eastling et.al., Science, 2000)

Apart from the destruction of the coral reefs one of the most significant changes for both humans and wildlife will be the rising sea level. It is thought that around one meter of sea level rise will occur before the end of the century. The cost of this, economically and environmentally can scarcely be over estimated. Many of the ecologically richest regions in the world are low-lying delta areas, such as the Niger delta, much of Bangladesh, and the Amazon delta. The impact that this will have on Florida can be seen below, as can the number of people affected by flooding.



Average annual global number of people flooded for the 2020s, 2050s and 2080s under the three emissions scenarios: unmitigated (red), stabilisation at 750 ppm (blue) and at 550 ppm CO2 (green). Also shown are the numbers without climate change (grey).

These effects on Florida represent the effects of a one meter rise in sea level, over the next few hundred years it is likely that the sea will rise by around 7m and this will have dramatic impacts on costal cities around the world as well as much of the world wetland. The chart above shows the number of people flooded, based on different emission scenarios. The dramatic difference that mitigation can have is clearly apparent. Over just the next 45 years *relative* sea levels are set to rise by up to a meter on the Louisiana coast. Sea level increases of around 20-50 cm being typical along the coastline of the United States.



<u>Weather Patterns</u>

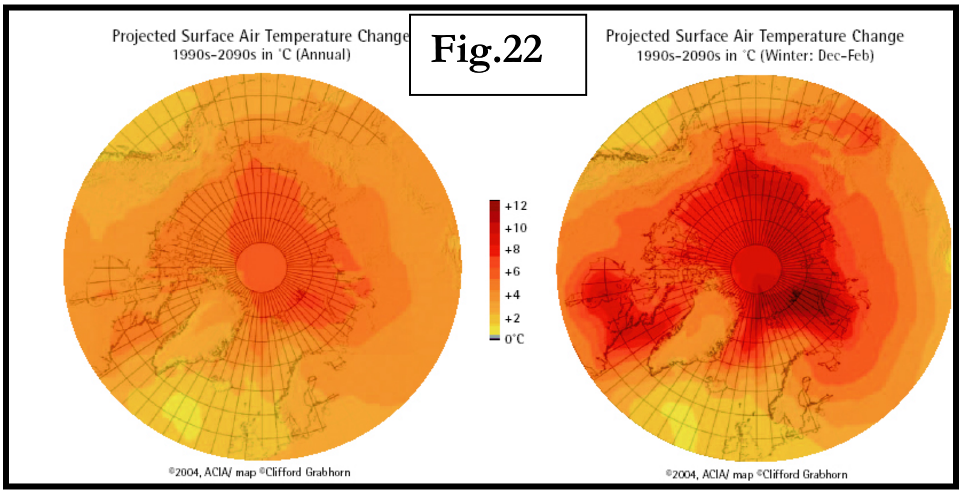


Fig.22

Other areas that are likely to suffer due to climate change related factors include large areas of India, and parts of China where the summer flow of many rivers will be drastically decreased due to the absence of glaciers in the high mountains. Much of inner china has already seen marked decrease in rainfall and large areas of formerly marginal land is now being consumed by the extension of the Gobi desert. Apart from the local inhabitants who are entirely dependent on subsistence agriculture for there livelihoods, numerous cities, including Beijing are feeling the negative health affects of the vast amounts of red dust scoured from the parched earth by the winds coming down from the Himalayan mountains and Tibetan plateau. The photos below show the effects of desertification on former farmland in China and the intensity of the dust storms that have already killed many people. This pattern of productive land loss is set to continue as climate change increases its pace. The effects we are currently seeing represent only a 0.6-0.7 degree increase in global average temperatures, the situation will be immeasurably worse with 5-8 degrees of average change, predicted by many of our current climate models for business as usual scenarios!

Fig 23, 24, 24, 26: top right to bottom right.

Figuers 23,24,25,26 show: The effects of climate change on the climate of central china, desertification is pressing ahead rapidly; the 'sight' experienced during a red dust storm as a result of this desertification; the effects on the health of people living in Bejing, thousands of miles away from the source of the daust and finally the evidence of drying out of inland china, one of many dried out river beads.

Biosphere

The impact of climate change on the biosphere will be enormous. Temperature will change, but so will annual precipitation, precipitation distribution and intensity, relative humidity, the number and severity of storms: virtually every characteristic of a given environment will change. The predicted level of extinctions in tropical forests are shown below. A recent paper (Thomas et.al., Nature, 2004) found that warming of 0.8-1.7, 1.8-2.0 and >2.0 degrees would lead to extinction of 18%, 24% and >35% of species respectively. This paper was reviewed by J.Alan Pounds and Robert Puschendorf who pointed out that these figures may be to low, climate change doesn't act in isolation but synergistically with other environmental pressures.

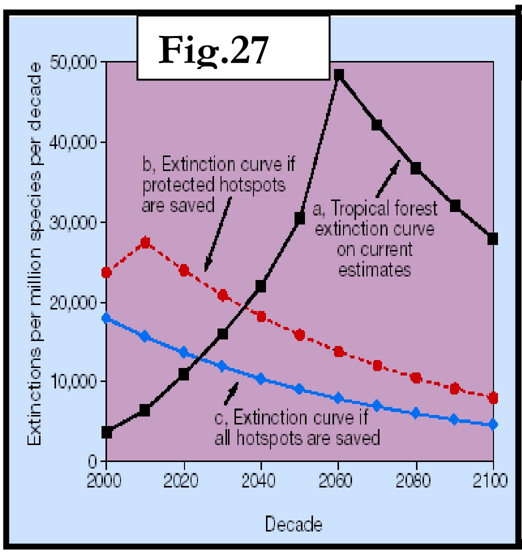


Fig.28

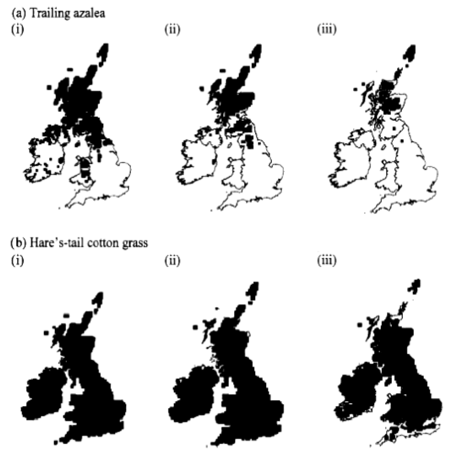


Fig. 1 Species losing suitable climate space, either because they are at the southern limit of their distribution in Britain and Ireland (trailing azalea) or selectively losing suitable climate space in southern England (hare's tail cotton grass): (i) current simulated distribution; (ii) simulated distribution 2050s Low scenario; and (iii) simulated distribution 2050s High scenario.

The UK environment ministry has funded research into the impacts of climate change, this program known as UKCIP has been used to predict the changes in distribution of numerous species, including the two shown above. Redistribution within the UK will probably occur readily (fig.28) but what about species in the far north that need cool temperatures? It is difficult for animals other than birds to find there way north to a more suitable climate such as Sweden.

The total number of extinctions that are likely to occur as a result of climate change depend largely on two factors, the magnitude of change and the rate of change. Species tend to be adapted to a relatively small climatic range, when climate change occurs the species will attempt to move to the area that is now optimal for its growth. There are several problems with this:

Natural Limits:

- Species have a limit to the rate at which they move, plants are often limited by there rate of seed distribution and animals are often limited by the requirement of having certain plant and prey species present in to feed on.
- This very heterogeneous ability of ecosystems to relocate en masse causes inevitable species loss, the degree of this loss is increased dramatically as the rate of change increases.
- Relocation is only possible if the species aren't on an island or surrounded by mountains etc… There is often no route for species to take, particularly plants and non-flying animals.
- When it gets warmer it would seem to make sense for a plant to simply move pole ward, or uphill. Moving uphill however is not simply a matter of moving to a cooler environment it involved adapting to more acidic and less nutrient rich soils as well as adapting to higher rates of evaporation in the desiccating strong winds characteristic of upland areas.

Human Limits:

- Many valuable ecosystems are protected in their current location only, or are surrounded by human development. The enormous impacts that humans have had on the planet, from the development of large urban centers to vast tracts of carefully managed farmland mean that in many parts of the world relocation is not possible.

Health

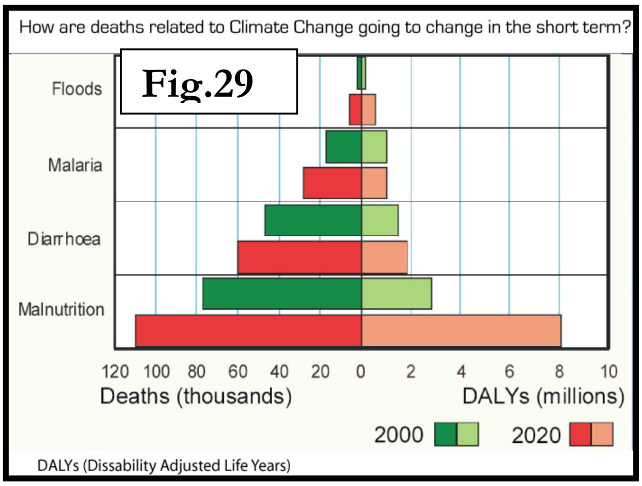
The future impact of climate change on health in general is going to be enormous. The WHO in their report on health and climate change published in 2002 finds that there are currently 150`000 climate change related deaths annually and they predict that this number will double by 2020. A report by the Working Group on Climate Change and Development published in June 2005 finds that:

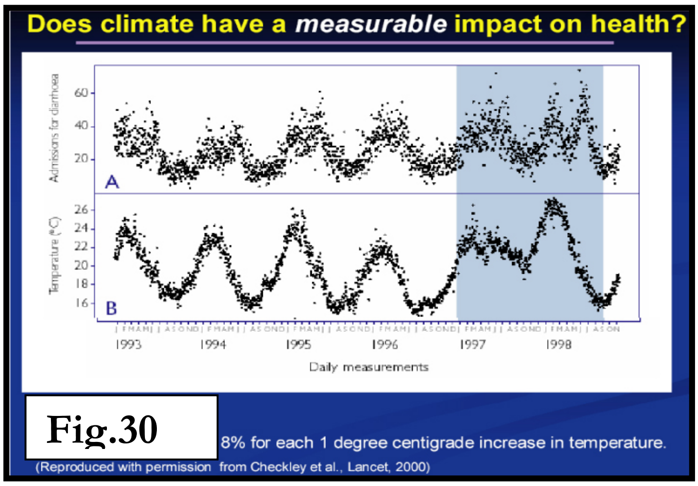
" A half century long trend of falling rainfall in Southern Africa is set to continue according to new research by the National Center for Atmospheric Research (NCAR). And it appears that the pattern is closely related to a warming of the Indian Ocean, which because it otherwise lacks the variability of the Atlantic and pacific. is reported to be a clear finger print of human caused climate change."

Dr James W.Hurrell an author of the NCAR report states that:

"*In our models, the Indian Ocean shows very clear and dramatic warming into the future , which means more and more drought for Southern Africa*"

As the charts below show the effects of climate change on human health are diverse; ranging from increased exposure to droughts *and* floods, an increase in the range of vector borne diseases such as malaria, increases in the number of cases of Diarrhea and an increase in starvation. Climate change must be tackled if development is to occur and failure to tackle climate change will make achievement of the UN's Millennium Development Goals impossible.





➢ Given the impacts of business as usual emissions we need to act now. What is the maximum increase in temperature the planet can tollerate?

The answer to this question has, necessarily, to be somewhat arbitrary, any change in climate from that we are currently experiencing will negatively impacts ecosystems that are well adapted to our current climate. The absolute level of change over the coming centuries will probably be of salient importance for global ecology, due to the limits on adaptation mentioned earlier. The rate of change is however still an important factor. For humans, the absolute level of change will have greatest impact on the cultures of various regions of the world and on levels of disease but in many ways, particularly economically the rate of change is likely to be the biggest problem, humans can adapt well to many different ways of living but time for this adaptation is required.

The impact of various degrees of warming, on ecosystems are shown in the tables below.

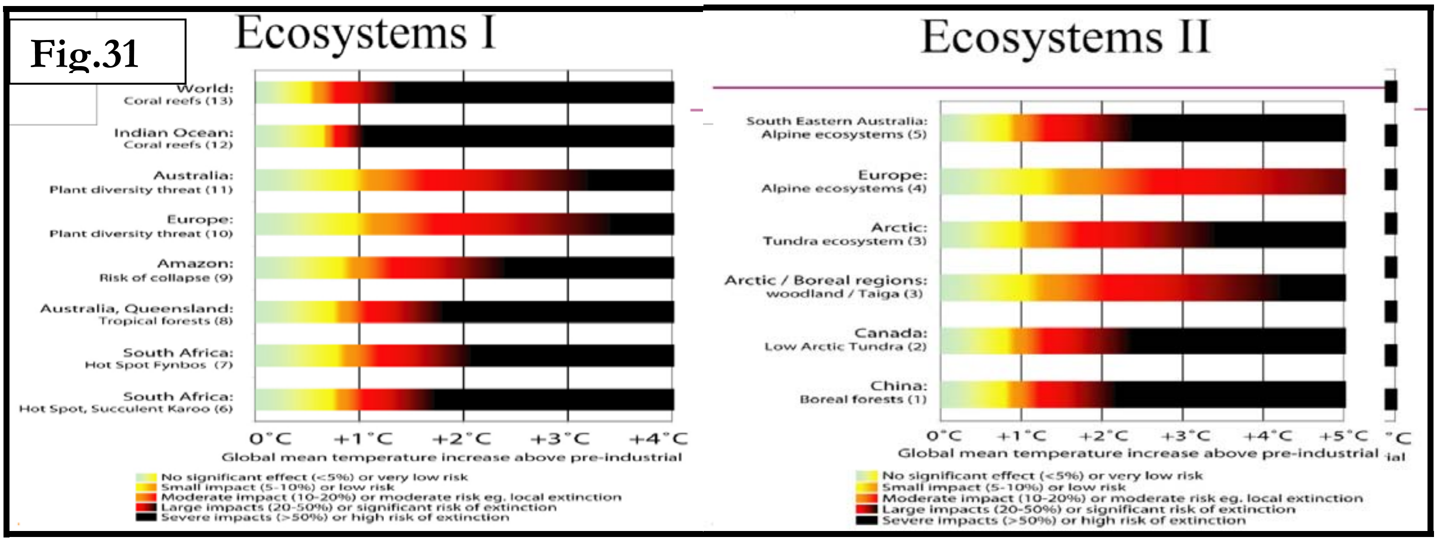


Fig.31

From these tables (fig.31) it is clear that at around one degree of warming there is a transition in many ecosystems from small to moderate levels of risk or impact. Moving to two degrees we find that we are close to the boundary between, large impacts (20-50%) or significant risk, and severe impacts (>50%) or high risk of extinction. This is the level of change that the Europeans have decided to use as their definition of avoiding dangerous climate change! The Europeans seem to be attempting to lead the world on climate change mitigation, this is indeed the partially sighted leading the blind! The European council however decided on 14 October 2004 that:

"the maximum global temperature increase of 2oC over pre-industrial levels should be considered as an overall long-term objective to guide global efforts to reduce climate change risks "

There is a recognition however that:

"2^{o}c would already imply significant impacts on ecosystems and water resources"

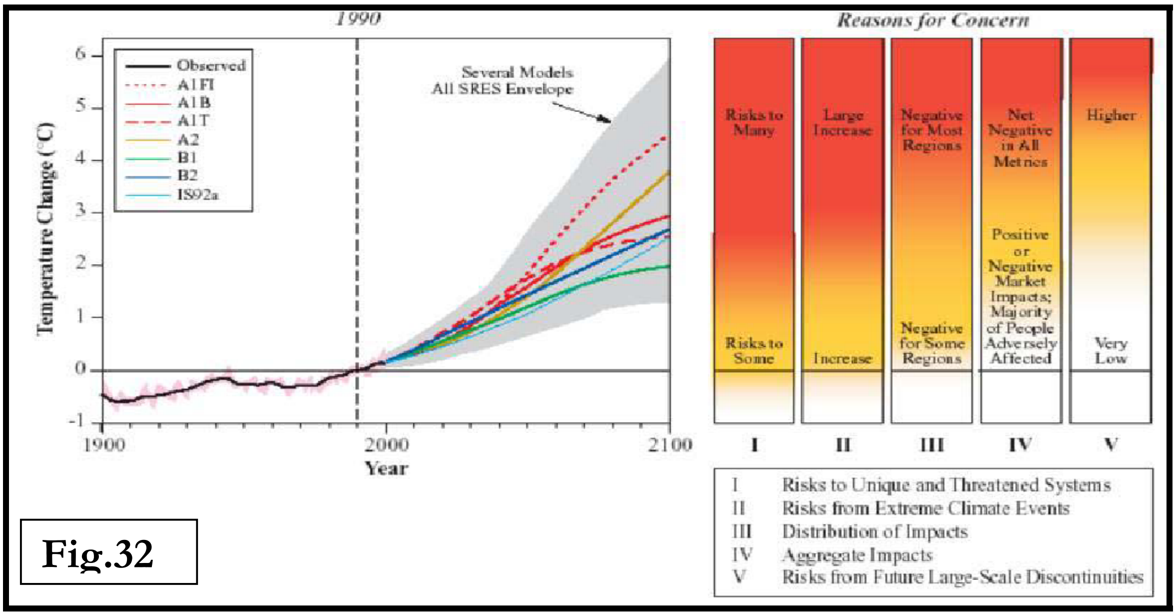
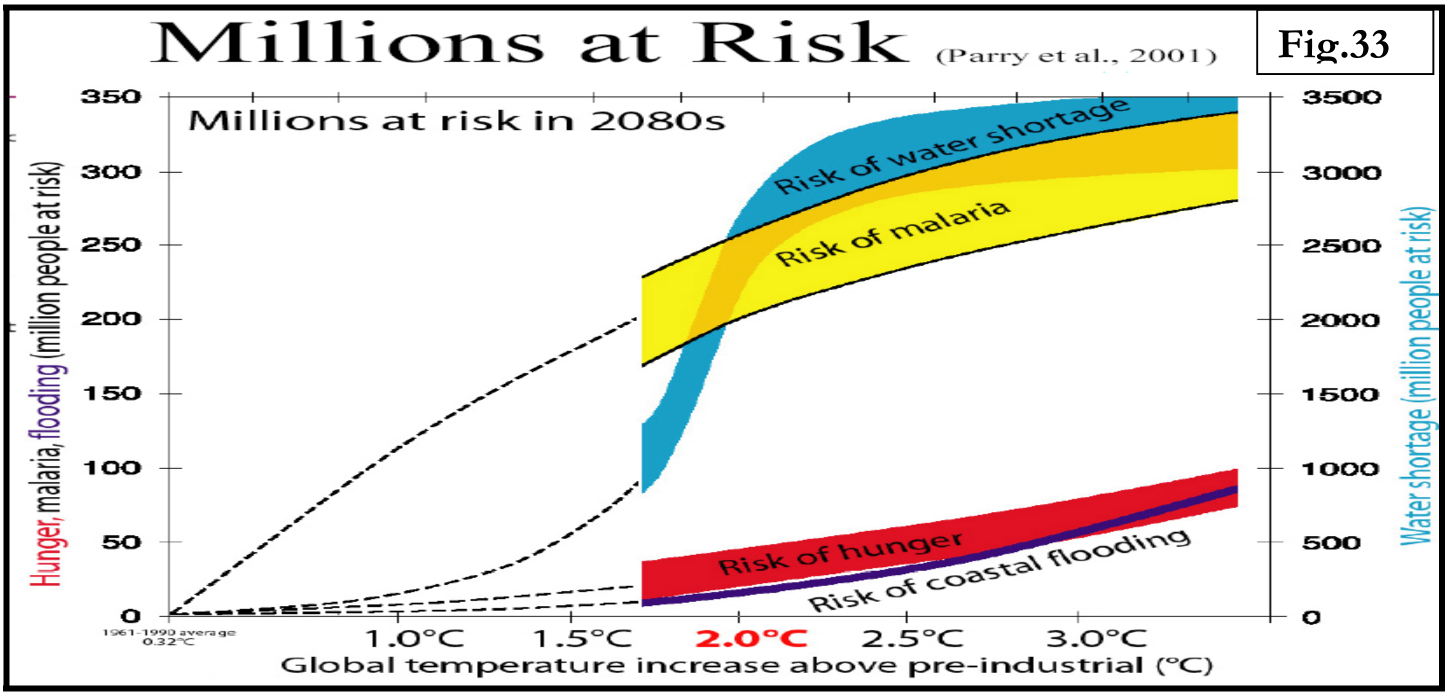


Fig.32

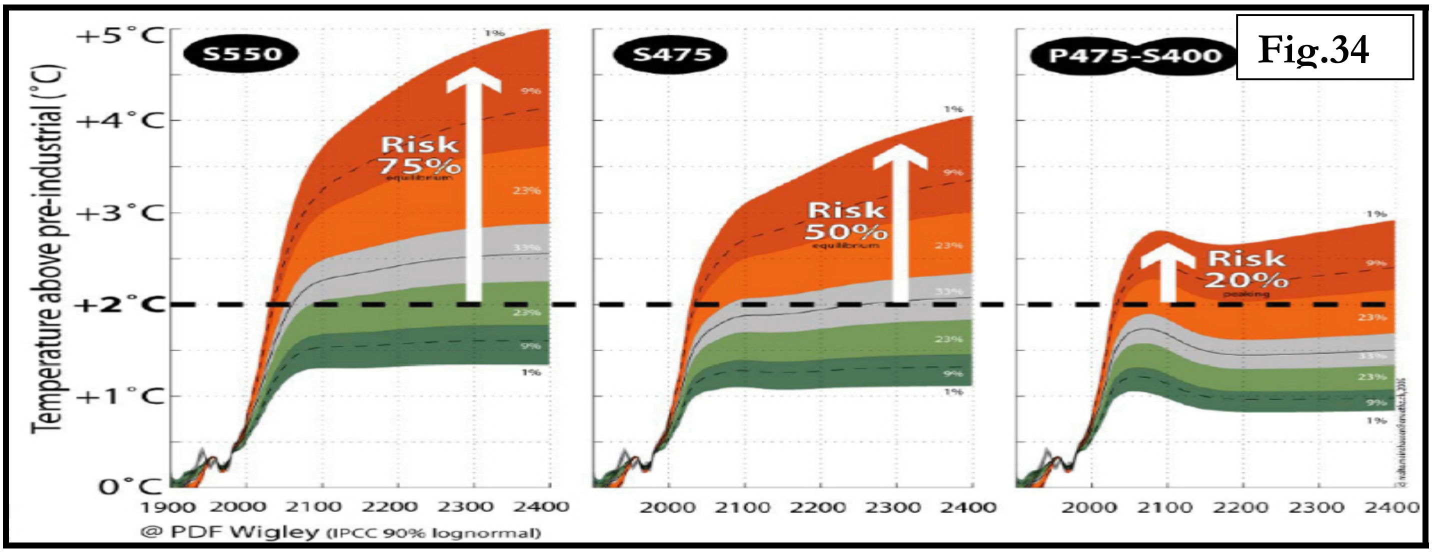
The table above highlights the range of impacts likely due to climate change and shows the likelihood of each posing problems. Looking at column V (fig.32) it can be seen that in the IPCC's TAR the risk of abrupt climate change was considered to be relatively low at a warming of up to three degrees. However professor Schneider of Stanford university who is currently in the process of helping to produce the fourth assessment report makes into clear that there is a significant risk of so-called "large-scale discontinuities" and that we ought to use the precautionary principle and do our best to avoid pushing the system harder, or further that we have to. The diagram bellow shows the health risks based on the level of climate change by 2080. The increase in number of people at risk from water shortages increases rapidly between 1.5 and 2.5 degrees. We cannot allow water shortages to be a significant risk for more than 3 Billion People! We again see the intimate link between climate change mitigation and development, we cannot reduce poverty unless the problem of climate change is addressed (fig.33).



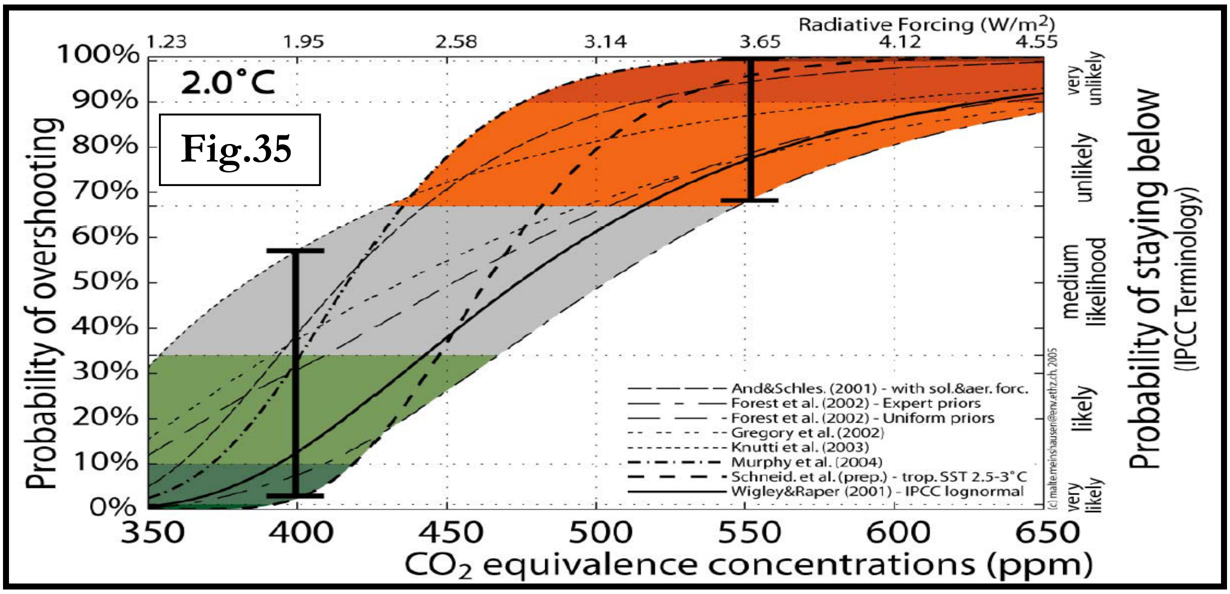
➢ What concentration of carbon dioxide in the atmosphere would lead to warming no greater than two degrees Celsius?

A conference of the world top climate scientists was convened at the world-renowned Hadley Center for Climate Change in Exeter UK to answer this question. Based on our current knowledge a peak at 475ppm and stabilization thereafter at 400ppm is generally accepted as the maximum permissible atmospheric carbon dioxide levels to make a warming of more that 2oC "unlikely" where unlikely is defined as less than 20% (fig.34). This contrasts strongly with the European Commission view that limiting global emissions of carbon dioxide to 550ppm will deliver the required constraints on climate change. In fact :

"Current research cannot exclude very high levels of warming e.g.> 4.5oC for stabliisation at 550ppm equivalence."

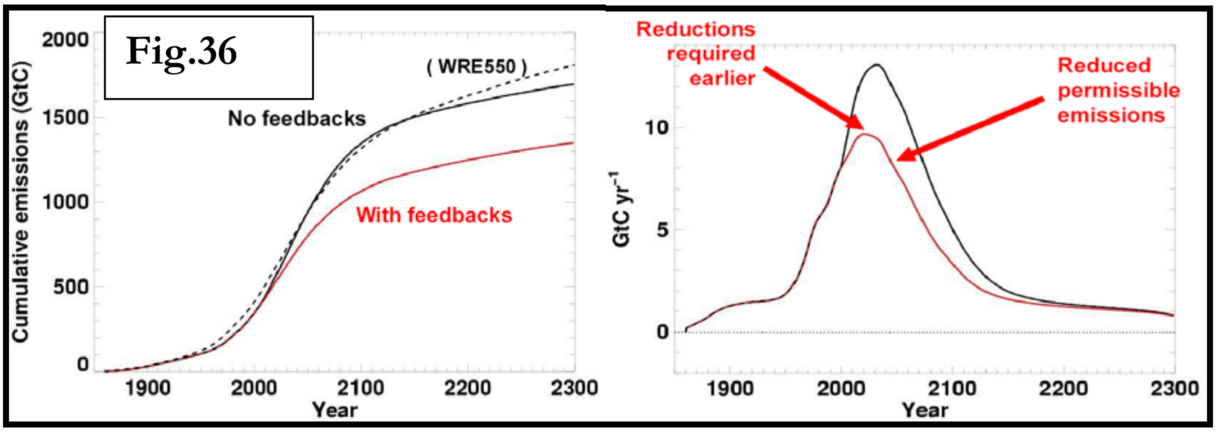


The above diagrams show that at a stabilisation level of 550ppm there is actually a 75% chance that warming of greater than 2 degrees Celsius will occur. For the chart on the right P475-S400 it can be shown that there is only a 20% chance of over run if we peak carbon dioxide concentrations in the atmosphere at 475ppm and then reduce our emissions further to allow reduction to a stable 400ppm level. The diagram below shows the predictions made by various models for different levels of stabilization.



➢ Limiting warming to this degree would allow for the emission of how much carbon dioxide by humans per year?

Models suggest that by reducing global emissions to 50% of 1990 levels by 2050 we can limit the carbon dioxide in the atmosphere to 450ppm (fig.35). Recent research by The Hadley Center and the Center for Ecology and Hydrology has been presented recently; this suggests we have a lower quota than previously thought. Previous scenarios are likely too be optimistic due to underestimating positive carbon feedbacks from the earth system (fig.36). Positive feedbacks act to increase the release of carbon dioxide into the atmosphere from natural sources i.e. release of carbon from rainforests due to increased degradation or more forest fires in temperate woodland. Another example of positive feedback is the release of methane stored in the permafrost of Siberia and in the cold deep seas of the arctic regions. It is now likely that a reduction of >70% in anthropogenic carbon emissions will be required by 2050 to limit carbon dioxide in the atmosphere to 450ppm.



These graphs show the difference in emissions reductions required to obtain Europe's current, and insufficient, guideline target of 550ppm. The effect of carbon feedbacks is to decrease our global emissions quota by 20-30%.

➢ The principle of equity suggests that everyone on the planet has an equal right to carrying out activities that release carbon. How much carbon per person per year does this amount to?

This depends on the global population and our global allowance. A 70% gross reduction on 1990 levels 7GtC a^{-1} equates to 2.1GtC a^{-1} by 2050. Given the estimated population in 2050 of 9 billion people this equates to 0.23tC per person. As carbon has a relative atomic mass (r.a.m) of 12 and an oxygen atom has r.a.m of 18 0.23tC is equivalent amount of CO_2 is = ((18+18+12)/12)*0.23tC .

This works out as 0.92 tCO_2 per person per year.

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