CLIMATE CHANGE

AN INTRODUCTION

In this chapter we will explore some of the major trends in the study of climate change.

As far as we know the Earth is a unique planet in that it is the only one in our solar system that has an atmosphere and oceans of water. Currents in these carry heat and moisture around the globe so that life is basically widespread. These currents also create the weather. The pattern of weather in a particular place is its climate and climates vary slowly over time forcing life to adapt to new conditions. However, recently the rate of change has increased.

In the 1890s the Swedish chemist Svante Arrhenius claimed that past ice ages might have been caused by fewer volcanic eruptions pumping gases such as carbon dioxide into the atmosphere. These gases maintain heat so reducing them would make Earth cool down. He then wondered what would happen if intense industrial activity produced more of these gases by burning fuels such as coal. He really discovered the factor that linked industrialization and fuel use with changing global temperatures. For a really clear exposition of the basic theories in climate change please read the DK guide to Climate Change 2008.

The most important greenhouse gases are water vapour, carbon dioxide, methane, nitrous oxide and ozone. Like all gases they exist as clusters of atoms called molecules. A molecule of carbon dioxide is made up of one carbon atom and two oxygen atoms. A methane molecule has one carbon atom and four hydrogen atoms. Not all greenhouse gases contain carbon e.g. nitrous oxide. However, of the main atmospheric greenhouse gases carbon dioxide is one of the most important. It absorbs a lot less energy per molecule than other greenhouse gases such as nitrous oxide and methane but there is much more of it. Measurements of carbon dioxide in the air by US scientist Charles Keeling show its concentration has been increasing every year since 1958.

This brings us to a brief description of the carbon cycle itself. Basically carbon is constantly being absorbed and released by living things. Plants and other photosynthesizers absorb carbon dioxide and use some of the carbon to build their tissues. The carbon is released as carbon dioxide or methane when plants die and decay. If animals eat the plants, they use some of the carbon to build their own tissues but eventually die too. Meanwhile both plants and animals release carbon dioxide when they turn sugar into energy by respiration. In fact carbon uptake is one of the main checks on the greenhouse effect involving plants and marine plankton, as the more carbon dioxide, there is the more they absorb.

There are a number of checks and balances that work for climate stability. These may be either via negative or positive feedbacks. Some natural processes resist change. For example when intense sunlight warms the ocean surface water evaporates and rises into the air as invisible water vapour. As it rises it cools and forms clouds which shade the ocean so it cools down. Eventually evaporation and cloud formation stops so sunlight can warm the ocean again. This is an example of negative feedback. When ice forms and snow falls the white surface acts like a mirror. It reflects solar energy so that less heat is absorbed by the ground and more ice it forming. This is called the albedo effect and is an example of a positive feedback which promotes change rather than resists.

The British scientist James Lovelock is famous for his theory that living things regulate the climate and the chemistry of the atmosphere in their own interest. Over the long term a web of negative feedbacks ensures that life survives despite catastrophes that cause mass extinctions. The theory is names after Gaia, the Greek goddess of the Earth.

NATURAL CAUSES OF CLIMATE CHANGE

Before considering the human impact on global climate change let us first briefly examine some of the factors in natural climate change. Climate changes have occurred on Earth many times before humans came on the scene. These shifts were caused by natural cycles that affect the Earth's orbit around the sun, by changes in solar radiation levels and by catastrophic natural events such as massive volcanic eruptions. Some of these changes seem to have triggered positive feedback events that dramatically increased their effect.

We know for example that the Earth has passed through several ice ages that were caused at least partly by orbital cycles. We are now living in a warm phase of an ice age that peaked 20,000 years ago. In a much longer view evidence from rocks, fossils and other sources show how Earth's average temperature has changed since it was formed 4,600 million years ago. During most of geological time it has been warmer than it is now but with ice ages during the Pre-Cambrian and Paleozoic eras. The Mesozoic age of dinosaurs was a warm period but temperatures fell during the Cenozoic era until they reached the coldest phases of the current ice age.

In addition to the Earth's orbit we should also consider variations in tilt of the Earth, Axis drift, sunspots and plages, effects of continental drift, volcanic eruptions and mini ice ages in a full discussion of natural climate change. For example from the 1300s to around 1850 the Northern hemisphere suffered a little ice age which reached its coldest point in the mid 15th century. Henry Kamen wrote an excellent book about this period and Braudel's works in history show the link between climate and short term events. In Europe harvests failed, people starved and the bitterly cold winters created the frozen landscapes portrayed in many paintings of the period such as the work of Dutch artist Hendrick Avercamp in the early 1600s. The cause of this particular little ice age is still not clearly understood but may have resulted from volcanic activity.

HUMAN IMPACT

Now we move on to the human impact on global climate change. The last century has seen an average global air temperature rise of nearly 0.8 degrees C measured at ground level. This does represent a relatively sharp upturn in the rate of warming since in the 20,000 years since the peak of the last ice age the temperature has risen only by 4 degrees C. Most of man's advances have been made using fuel that releases carbon dioxide in the process of burning. This has increased the concentration of carbon dioxide in the air and this closely matches the rise in global air temperature so it is very likely that accelerated global warming is being caused by our modern energy-hungry way of life. From ice core samples we know that in the 1700s the level of carbon dioxide was roughly 280 parts per million of air. Today it is 380 ppm. Let us now consider some of the ways in which humans are increasing the amount of carbon dioxide released into the atmosphere. We will look at two major aspects of this - the burning of forests and the use of fossil fuels. We will then conclude this section with a note on the production of other greenhouse gases.

Burning the Forests

The most basic of all fuels is wood which people have been burning for thousands of years. Huge increases in human population have greatly increased the amount of wood that is burned and at the same time vast forests are being felled for farming, ranching and road building - this also contributes to climate change by releasing all the carbon that the forest trees have absorbed in their lifetimes. Brazil has lost more than 423,000 square kilometers of forest. Indonesia has lost nearly 300,000 square kilometers. It is true that wildfires are part of the natural carbon cycle and that the carbon dioxide they release is soon absorbed by young trees but if a forest is felled, burned and not allowed to regrow all the carbon is turned into carbon dioxide that increases the greenhouse effect.

Fossil Fuels

Coal fueled the rise of modern industry as well as the steamships and railways of the 1800s. In the 20th century oil and natural gas have been developed into fuels for road vehicles and aircraft. The world's first oil wells were sunk at Baku on the Caspian shore in 1847 but the oil industry really took off in the early 20th century when refined forms of oil could be used as fuel for cars. All these are carbon rich fossils fuels created from long dead organisms by processes that take millions of years. They are being burned far more quickly than they were formed thus releasing carbon back into the atmosphere and adding to the greenhouse effect. Different fossil fuels release different quantities of carbon dioxide. Coal is the worst, followed by oil then gas. Coal contains other pollutants such as soot and sulphur dioxide which can combine with water vapour to form smog and acid rain. For a more detailed discussion please read Harding and Starzynska's 2008 work on a comparison of fuel types.

Other aspects of modern life

Other aspects of modern life also add to the problem. Methane, nitrous oxide and chlorofluorocarbons (CFCs) are released in much smaller quantities than carbon dioxide but they have a serious impact because they are much more powerful. A molecule of methane for example has the same effect as 25 molecules of carbon dioxide. We will look at several aspects of modern life that add to the problem of greenhouse gases and global climate change. Some of these are obvious but some less well known. Firstly there is the landfill problem. Developed countries produce huge amounts of waste - a lot is burned releasing carbon dioxide and noxious gases but a lot is also buried where it is broken down by bacteria which produce methane - a very potent greenhouse gas as we have seen. Therefore even burying rubbish can increase global warming. Perhaps a less well known issue concerns the production of cement. Cement is made from limestone in a process that turns the rock into calcium oxide and carbon dioxide. Pulverizing and heating uses a lot of fuel. Cement is also heavy so transportation also uses a lot of fuel. Cement production releases huge amounts of carbon dioxide in total for every bag of cement made. Harding and Starzynska will release a more detailed study of the impact of the construction and cement manufacturing industries on world climate change.

Thirdly artificial fertilizers also release nitrous oxide and this is 300 times more powerful a greenhouse gas than carbon dioxide! In fact food production can cause problems. Our taste for beef encourages cattle ranching yet cows produce a lot of methane. Rice growing also produces relatively high levels of methane.

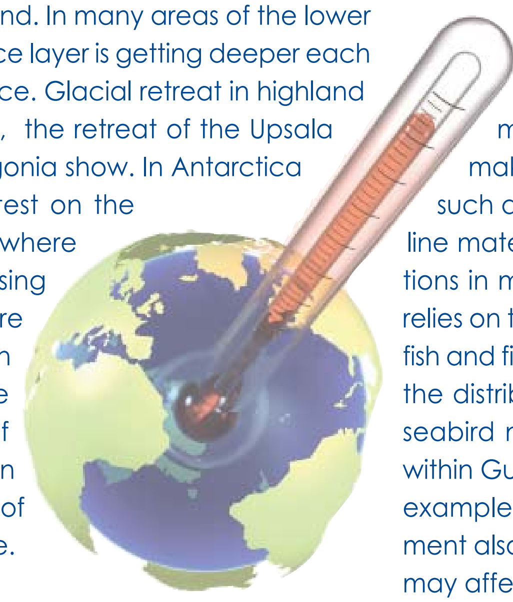
RESULTS

Therefore by burning, felling, excessive use of fossil fuels, cement production, transportation, intensive agriculture, use of fertilizers, and CFC gases humans accelerate the greenhouse effect. Lets us now turn to an examination of some of the major results of climate change. We can broadly divide these into topics such as heat waves and droughts, melting ice, warming oceans, and effects on wildlife.

Scientists can record temperature rise but to many people the evidence of climate change is much more obvious in the form of heat waves, shrinking lakes, desertification, droughts, famine and wildfires. Higher extreme temperatures are becoming more common. These are not always the highest temperatures recorded but they are sustained periods of exceptional heat such as the European heat wave of August 2003. Irrigation projects make the problems of shrinking lakes worse. One classic example of this the dramatic shrinking of Lake Chad - now one twentieth of its original size. Desertification is also taking place. The Gobi and Sahara deserts are both expanding with the Sahel region of Africa most influenced. Many people who live on the dry fringes of deserts rely on seasonal rain to make crops grow and provide water for livestock. If the rains fail owing to climate change disaster follows as in Ethiopia in 2006. Wildfires are also becoming more common in Australia, California and other regions as the land becomes drier - there are even wildfires in parts of Amazonia - a region unused

to wildfires generally.

Just as dramatic is the phenomenon of melting ice in the world's polar regions. Arctic pack ice is shrinking and vast Antarctic ice shelves are collapsing and mountain glaciers everywhere retreating. On the polar fringes higher temperatures are also melting ice that lies beneath the ground, transforming tundra landscapes. Since 1979 the size of the summer Arctic ice sheet has dwindled by about 1.5 million square kilometers. In the 1990s its thickness also decreased by 1m. We see other effects on the 3km thick Greenland ice sheet with the fringes melting more each summer and ice berg formations breaking away faster. This phenomenon will cause a rise in sea level. About a quarter of the land in the Northern hemisphere is so cold that it is permanently frozen beneath the surface. This permafrost is covered by a surface layer that is frozen in winter but thaws in summer creating vast areas of swampland. In many areas of the lower Arctic the active surface layer is getting deeper each year, melting ancient ice. Glacial retreat in highland areas is also dramatic, the retreat of the Upsala glacier in Upper Patagonia show. In Antarctica the ice is melting fastest on the Antarctic Peninsula where temperatures are rising faster than anywhere else on Earth with a 3 degree C rise since 1951. The collapse of the Larsen Ice shelf in 2002 shows the power of global climate change.



Warming Oceans

The effects of global warming on land are therefore obvious in terms if wildfires, desertification, heat waves etc but the impact on the ocean is less obvious. However, warming oceans mean rising sea levels and meltwater adds to this problem. In addition warmer water at the ocean surface reduces plankton growth and carbon dioxide absorption. In fact rising sea levels are already causing serious flooding e.g. on the coral island nation of Tuvalu in the Pacific where most of the land lies just 2-3 meters above sea level. Since sea levels will continue to rise for a time even if global warming slows down it seems inevitable that such areas will be destroyed. The Maldives are also particularly vulnerable.

Just as serious is the phenomenon of current slowdown. Dense salty water at the surface of the northern Atlantic sinks and pushes currents through the deeper parts of the world's oceans but melting icebergs, glaciers and permafrost adds fresh water to the oceans reducing salinity and this effects the driving of deepwater currents. Finally we are seeing more intense storms caused by warmer oceans. In the temperate north we see rainfall increasing by 5-10% causing floods like those that hit England in 2007 or Mumbai in 2005.

Effects on wildlife

In the long term wildlife evolves to cope with both warmer and cooler climates but the process of evolution can be harsh and recent wildlife losses may be signaling that we are at the beginning of a time of extinctions. We will look at the effects of global climate change on wildlife with respect to acidified oceans, disruptions to the food webs, altered patterns of migrations and expansions, early losses of species, overheated reefs and disappearing wetlands.

When rain dissolves atmospheric carbon dioxide it forms weak carbonic acid and the same process is affecting the oceans as they absorb extra carbon dioxide from the air. This is making the oceans less alkaline and this can make life more difficult for more marine animals such as corals, clams and lobsters that need alkaline materials for shell formation. We also see disruptions in marine food webs. The oceanic food chain relies on the drifting micro-life of the plankton feeding fish and finally seabirds. Warmer oceans are changing the distribution of plankton so fish move away from seabird nesting sites. We see this in falling numbers within Guillemot communities in the north Atlantic for example. Our chapter on the Deepwater Environment also provides examples of how global warming may affect marine life.

We also see altered patterns of migrations and expansions. Some animals seem to be adapting to climate change. For example, insects have short life spans and rapid breeding rates enabling them to evolve quickly and move into habitats easily. These

include disease carrying mosquitoes which are spreading diseases such as malaria and West Nile virus to areas that were once too cold for the insects.

In fact climate change may already have made some animals extinct. The golden toad was discovered in the Monteverde cloud forests of Costa Rica in 1966. By 1991 it was deemed to be extinct because the toads' young were attacked by a fungal disease that flourished as nights became warmer. As the tropical oceans get warmer coral reefs also start to suffer with coral bleaching occurring. Rising ocean temperatures will probably cause more bleaching events thus threatening vulnerable corals with extinction. Finally as droughts become more common and human populations grow and use more water, wetlands such as marshes and lakes are starting to dry up.

These wetlands are vital to many animals as places to live and drink so their shrinkage or disappearance can be disastrous for wildlife.

Perhaps the more famous examples of global climate change on wildlife are to be found in the Arctic. The ice is shrinking each year and summer ice may disappear altogether by 2070 or even earlier. The most vulnerable species is the one at the top of the food chain - the polar bear. If the food webs are disrupted by global warming they will be severely affected. In addition polar bears are adapted to hunting on the ice shelf. If this disappears the bears may disappear too. Rising temperatures mean that large areas of ocean that once stayed frozen throughout the year now become open water. Polar bears may have to swim long distances in order to hunt. The ice also melts earlier in summer and forces bears ashore before they have built up fat reserves.

CONCLUSION

This chapter has given the briefest outline of some of the issues and results of global warming. We will look at some of the possible solutions in the next chapter. However, it should be noted that some climate change scientists believe we may already have advanced beyond a tipping event and there are simply no quick solutions now.

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