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THE ATMOSPHERE, ICE AGES, SUNSPOTS, INTERNAL HEAT AND VOLCANOES

GLOBAL WARMING stems from the greenhouse effect, which we talk about in detail in the next chapter. The greenhouse effect controls world surface temperatures and is vastly more significant than the only other heat source warming the planet; that being naturally occurring internal radioactive decay within the planet. There is nothing else that affects the surface temperature of this planet.

We know that the greenhouse phenomenon keeps the surface of our world at a comfortable living temperature. We now know we have upset the stability of that entire phenomenon by changing the composition of the relatively microscopically thin atmospheric skin that coats the Earth's surface. More and more this extra warming effect is going to influence every human being on the planet. It is going to influence all societies, all governments and all nations.

The greenhouse effect and Global Warming must therefore be made comprehensible and understandable, so we can make environmental decisions based on reason and common sense. No longer can our decisions be based on the rantings of some so-called "green movements". Nor can they be based on the diverting imagery created by the oil companies' public relations gurus. Nor can we allow our energy and our environmental responsibility and enthusiasm to be diverted into insignificant and doubtful causes that may well self-destruct in an overheated world.

It is essential for us to acquire a basic, but sound and rational, understanding of our atmosphere so we can monitor the myriad of often irrelevant environmental doctrines we are expected to swallow. The atmosphere and its movement are not easy things to visualize; but it is worth trying.

On movie sets when the director wants to create the image of a person walking on a cloud he might use a "fogging machine". (Coincidentally, the machine uses "dry ice" which is carbon dioxide frozen solid.) It produces an ankle deep, white fog that lies on the floor. When you watch this fog, it seems to rise and fall. Waves move across it. It sometimes might pulsate, and it all seems to happen in an eerie sort of slow motion.

On a much larger scale, that's exactly what our atmosphere looks like. That is what it would look like if you were looking down at it from a high-flying jet. It is however transparent, so you can't actually see it. So we have to use a little imagination. The never-ending waves and pulsations, the constant rises and falls in the top surface of the atmosphere changes the local depth and thickness of the air. Down on the surface, under all that air, we feel the difference as variations in our local "atmospheric pressure". When we measure these pressure variations and plot them on a chart and then join up all the equal pressure points, we have our familiar weather maps with its "high" and "low" pressure areas. The areas are usually called "high pressure systems" or "low pressure systems".

The constant changes in temperature, moisture content and air movement occurring within the thin skin of atmospheric gasses clinging to the surface of the planet, we know as weather. Climate is the name we give to the average weather that occurs over large specific areas of the Earth's surface.

Weather is controlled by many factors. The land, in more northerly or more southerly latitudes, receives less sunlight than does land nearer the tropics. Different land is warmed and cooled at different rates, and in turn, warms and cools local air masses. This differential has a big effect on our weather. The warming and cooling expands and contracts the air volume and this causes the waves and pulsations mentioned earlier.

The Earth is revolving and drags its atmosphere around with it. The irregular distribution of continents, their size and shape all affect the otherwise even flow of air masses, which would normally result from a continuously revolving spherical world. The nature of the land surface, whether it be covered in grass, trees or desert, has a big effect. The depths of oceans, their local temperature and salt content have their effects. The giant rivers of deep, cold, salt-rich water that circulate at the bottom of all the oceans of the world have profound effects. Some of these deep ocean currents almost totally determine the weather and weather patterns throughout Europe. The Arctic and Antarctic ice packs that reflect so much sunlight and heat back into space, also massively affect world climates.

All these inter-related phenomena create and control the variety of climates that cover the planet.

There is not very much to our atmosphere. It really is a very thin skin. You may drive 10 miles to the supermarket on the surface of the planet. Yet no man has ever been down 10 miles into its interior, and if you go up 10 miles, you are in the un-breathable outer edge of space.

One of the major problems in discussing the planet's atmosphere is that the discussions are always couched in terms meaningless to anybody who doesn't live with such numbers. It's like the national debt. It's like monopoly money! How can we even think of solving the problem of Global Warming and how can we even begin to understand it, if the problem is always stated in terms that are unfamiliar and in numbers and proportions that are meaningless? The talk is in mega tonnes, parts per million, parts per billion, giga tonnes and so on, and their often incomprehensible abbreviations; to most of us most of these units and symbols have no meaning whatever.

So let's try and get some perspective, and also, let's expand on the concept of considering the composition of the atmosphere as separate individual layers and as liquids; as we did in Chapter 2.

On a spherical world globe such as you might find in a school room, the atmosphere would be about as deep and as significant as the film formed by dipping the globe into a dish of very light salad oil. The slow movement of this thin oily skin around our globe, if we revolve it, would be the same as the movement of air on our planet.

Let's imagine our world globe model as being about eight inches (200 mm or a couple of hand widths) in diameter. As the world is roughly eight thousand miles in diameter (12,756 km at the equator), one-thousandth of an inch will therefore represent one mile or 5,280 feet. (1 mm will represent 64 km).

In this model, the deepest mine in the World would be two-thousandths of an inch (0.05 mm) deep – that's about the thickness of a cigarette paper. The average depth of all the oceans of the World is about three-thousandths of an inch (0.075 mm) or less than the thickness of the paper you are reading. Our highest mountain, Mount Everest is twenty-nine thousand feet or five and a half miles high (8,800 m) in the real world. In our model it would be less than six-thousandth of an inch high (0.14 mm). That's half the thickness of your fingernail.

The atmosphere of our planet, the air we breathe, gets thinner the higher up we go. On our little globe, at eight-thousandths of an inch (0.2 mm) above the surface, the air would be so thin you couldn't breathe. You would die. That's about the thickness of two pages of this book.

By the time you get to a height represented by the thickness of a paper clip on our eight inch globe, the reduction in atmospheric pressure would be such that your blood would long since have boiled away, as boiling point temperatures drop with decreasing pressure.

Our model world is also very smooth. It would be like a big ball bearing with a few tiny scratches representing deep ocean troughs. Those scratches would be deeper than the mighty mountain ranges are high and the thin atmosphere would barely reach the top of the higher mountains.

The atmosphere is made of gasses, the main ones being nitrogen, comprising about 78%, and oxygen, comprising almost the rest. All the other gasses combined, argon, carbon dioxide, water vapour, ozone, methane, nitrous oxide and minute traces of several other gasses don't add up to more than one percent.

Now substances take up a lot more room when they are in a gaseous state, than when they are in a liquid or solid state; for many gasses a thousand times more room. If a layer of water twelve inches or three hands deep, was all turned into steam or water vapour it would have expanded and become a column of steam, one thousand feet (300 m) high. It would still be the same amount of water, the same weight of water, but steam is a gas, and takes up a lot more room.

The same applies to our atmosphere, but let's look at it in reverse. If we could magically turn our atmosphere back into a liquid, it would become a mixture of liquid oxygen and liquid nitrogen. That liquid mix would cover our planet with a layer thirty-nine feet (12 m) deep.

You would still have the same quantity, the same mass of oxygen and nitrogen, the same number of atoms, but now it would simply be condensed to a liquid state. Of course, both oxygen and nitrogen cannot exist in a liquid state at the temperatures on the surface of the Earth, as their actual boiling points are well below even our coldest natural temperatures, but the concepts help our understanding of just how little mass – how little weight, is actually there.

Looking at it another way; atmospheric pressure is 14.7 pounds per square inch at sea level, or about 1013 millibars, or 1013 hectopascals, or 760 mm of mercury, (depending on which version of the metric system is currently decreed). In other words, a column of air covering one square inch of the ground and extending out to space, weighs 14.7 pounds. A column of water, one-inch square and thirty-four feet high weighs exactly the same and produces the same pressure at its base. The air covering one square centimetre on the ground weighs a little over one kilogram and that's the same as a little over ten metres of water (10.3 m). In aviation the figure of 1013 millibars has been nominated and is the universally accepted pressure standard for altimeter settings at sea level.

When considering Global Warming and the greenhouse effect, it is so very important to recognize and appreciate that the total mass of the atmosphere directly above our heads is so tiny, and in consequence, so dreadfully vulnerable.

Just think about it, how much beetroot juice would it take to colour a thirty-foot (ten metre) deep water tank or pool from the bottom to the top? Not very much. If you could "vaporize" exactly the same quantity of beetroot juice as the percentage of carbon dioxide in the air it would be enough to colour a column of air, with the same size base but extending all the way up to the outer reaches of space. Carbon dioxide just happens to be transparent to visible light, but that doesn't mean it is not there. If CO_2 was red we would now be able to see our atmosphere slowly getting redder year by year.

Back to our eight-inch globe, and considering air as a liquid so as to more easily understand its vulnerability, the atmosphere would then represent a coating over our globe, a mere six-millionth of an inch thick, that's 0.00016 mm.

Comparing this to coating our little model world with one coat of household paint then the paint would be one thousand times thicker, and one thousand times heavier, than the liquefied atmosphere coating our model world.

Vulnerable – could there be any doubt?

Visualizing the atmosphere as if all the gasses were somehow condensed into their liquid form, is a way of giving the problem a perspective that is both meaningful and valid. For example: on our planet the quantity of air that makes up our atmosphere is relatively tiny, whereas the quantity of water that forms our oceans, is gigantic. The oceans of the World average about 12,000 feet (3,600 m) deep. Even if the oceans were spread evenly over the entire planet and all landmasses were flattened out, the entire planet would still be covered with an ocean 8,000 feet (2,500 m) deep. We have the equivalent of 8,000 feet of water and a tiny 39 feet of liquefied air. There is a small quantity of water dissolved in the air as "humidity" but in this exercise the quantity is meaningless. That's 2,500 metres of seawater to 10 metres of air. So air is less than 0.5% of the stuff covering our planetary surface and water is 99.5%. There is 250 times as much water as air.

It becomes obvious why our atmosphere is so vulnerable to pollution. To pollute the oceans as much as we are polluting our air, we would each have to buy an extra 250 cars and then drive them all at once, and drive them just as regularly as we are driving our single car now. We would also require 250 times as many coal and oilfired power stations.

Technically, the actual depth of the gaseous atmosphere is not really a finite thing. At any height there is still some air above you, it just gets thinner and thinner. It's thicker and denser near the surface because the weight of the air above compresses it. Theoretically, the atmosphere extends up for hundreds of miles, but there is really nothing there. At those heights it is almost the vacuum of true space.

In an ordinary commercial jet flight, when it levels off to cruise, we could be well over 40,000 feet (12 km) high. At that height, the vast majority of our planet's atmosphere is underneath us. Next time you are going some place in a jet, look out the window and think about it. It tends to make a person realize just how little air we have here, and just how vulnerable it really is. All the world's weather and all the world's life, is down there below you.

The only significant things affecting us above that height are minute quantities of ozone gas and oxides of nitrogen. These protect us from the more harmful frequencies of ultraviolet light radiation that forms part of incoming sunlight. When this ozone is destroyed we have the creation of the "ozone hole" through which ultraviolet rays can penetrate down to the Earth's surface and give us, amongst other things, skin cancer. Ozone and its formation are discussed later.

On our Earth the fine balance between absorbing too much heat from the sun and not quite enough is determined in the main by the quantity of carbon dioxide in the atmosphere. That quantity of carbon dioxide in our atmosphere has been remarkably stable over several hundred thousand years. That stability, before the advent of fossil fuels, was self-maintaining within a relatively narrow range.

Vostok is a Russian research base on the high Antarctic Plateau. It is one of the coldest places on Earth and holds the low temperature record, at -89.6ºC. The ice at Vostok has accumulated in layers over hundreds of thousands of years. The station sits on ice two and a half miles (4 km) thick.

The Vostok area has the longest continuous record of ice deposition in the world. The scientists there have a drilling rig that cuts into the ice like an apple corer and collects samples down to a depth of over two miles. Analysis of the core samples has established how world atmospheric carbon dioxide levels varied over a 400,000-year period.

In all that time, a time that spanned four ice ages, carbon dioxide levels varied only slightly. They peaked out at 300 ppm (parts per million) just once, and that was 300,000 years ago. In today's world we have forced the levels to 360 ppm and they are rapidly climbing. Temperatures are following a few short years behind.

We can go back even further. A research report in the August 2000 issue of *Nature,* Vol. 406, described an elegant and brilliantly simple testing process for determining past atmospheric carbon dioxide levels. The system works by analyzing the boron-isotope ratios in precipitated calcium carbonate found in ancient marine planktonic foraminifer shells. The researchers were Paul N. Pearson and Martin R. Palmer of the Department of Earth Sciences, University of Bristol UK. The deposits were laid down on flat-topped seamounts in the tropical North Pacific. The sea bottom there has been geologically stable for at least 60 million years.

Their analysis showed that for the last 22 million years atmospheric carbon dioxide levels had never risen above 300 parts per million. Those levels were never ever exceeded until the 1950s and 1960s.

The results are disturbing because they show that by mining and burning fossilized carbon and by destroying the fertility of agricultural soils, we have increased world carbon dioxide readings to levels that have not existed on this entire planet for at least 22 million years.

What we are moving into is a man-made, total-world, environmental disaster. We have to stop it happening before it eventually becomes uncontrollable and irreversible.

Prior to the 1940s, the quantity of carbon dioxide in the atmosphere was determined by the mass and distribution of life on the planetary surface. This mass and distribution, of course, is subject to subtle influences but is generally consistent. Carbon deposits lying deep beneath the Earth's surface did not previously affect atmospheric carbon dioxide levels and therefore climatic variations.

There are of course, other influences on the world's climate. These need to be considered as they are too often used to instill doubt on the extreme dangers of our massive use of fossil carbon derived fuels and products.

Over thousands of years there has been a natural pattern of small recurring changes in the Earth's orbit. Although these changes appear almost insignificant, however, they have been enough to create and terminate ice ages. The subtle orbit changes have somehow been enough to slightly shift the balanced interrelationship of life and carbon dioxide and thus overall world temperatures.

A theory on the cyclic nature of ice ages was first suggested by a Scotsman, James Croll. His theories were originally published in *The Philosophical Magazine* in 1864. Croll's original ideas were upgraded and refined by a Yugoslav astronomer, Milutin Milankovic in the 1920s and 1930s. In the years since, these concepts have in general become widely accepted. Admittedly there are other theories, such as the effect of our solar system passing through waves of nebulous interstellar dust, so to a certain extent the jury is still out on what combination exactly trips the ice age trigger.

These are the known and established facts: Ice ages have been occurring about every 100,000 years for about a million years. Out of each of those 100,000-year periods, 80-90,000 years is actually ice age. The remaining 10-20,000 years is a period of somewhat warmer climates, called "interglacials". We are currently in an interglacial period and have been since just before the start of the Egyptians building their pyramids.

There are three main astronomical cycles in the Milankovic Model and they correlate with the frequency of the ice ages and the fluctuations within them. The first and most significant component in the model is a slight shift and return in the Earth's orbit each 100,000 years. The Earth's orbit changes from a slightly elliptical shape to a more rounded form, and then reverts back to the elliptical shape. It is a very minor change but is linked, very accurately to the now well-known frequencies of ice ages.

Secondly: the Earth spins about its axis of rotation daily, and this axis is tilted with respect to the plane of the Earth's orbit; it is this tilt that gives us our summer-winter seasonal variations. This total tilt of the Earth's axis oscillates backwards and forwards in cycles lasting roughly 41,000 years.

Thirdly, the daily spin of the Earth, a tiny twenty-four hour cycle, creates a spinning top effect. When a spinning top slows down slightly, it develops a characteristic wobble. The Earth is the same and it too has a wobble. The Earth's wobble takes between 19,000 years and 23,000 years to complete its period. In the time of the pyramid builders, the North Star would not have been the accurate indicator of true north that it is today. This apparent shift in the position of the fixed stars is called the "precession of the Equinoxes" but it is our Earth, not, as was once thought, the stars that are wobbling.

The last eight ice ages have occurred within the last million years, and *Homo sapiens*, that's us, have been around for about 100,000 years. Humans therefore have experienced and lived through maybe just one single ice age. *Homo sapiens* and before that, *Homo erectus*, or possibly *Homo heidelbergenis,* our probable evolutionary ancestors, survived and evolved through the trauma of five, or six, or maybe even more, ice ages.

Before that, according to the geological record, it appears that cyclic ice ages were not a regular thing at all.

One of the most intriguing things about these climatic fluctuations and the ice ages is that the actual astronomical variations in the Earth's orbit, its "shift", its "tilt", and its "wobble", seem so tiny and so inconsequential. Yet they still manage to cause ice ages by somehow triggering enormous weather and climatic fluctuations.

Even more intriguing is that the 100,000-year cycle, that sets the time and frequencies of the ice ages, is actually the weakest of the three astronomical fluctuations. Yet deep drilling of ice cores, and investigations of sediments laid down in long past mud deposits nevertheless conclusively establish the 100,000-year cycle of our planet's ice ages over this last million years.

A period of 41,000 years and a period of 19,000 years, the time period of the other two cycles, don't divide evenly into 100,000 years, nor are they multiples of each other. So there are variations in temperatures, ice formation and the associated weather in each particular ice age. Every ice age was a little different. And so was each inter-glacial period.

The overlying pattern of 100,000 years, however, is extremely consistent and leaves little doubt as to the interrelationship of glaciation and astronomical fluctuations. The lesson we learn is that it does not take much to totally change the weather patterns of the entire planet.

The changes in world atmospheric temperatures, between glacial and interglacial periods, are determined by the collating of many phenomena. One piece of evidence of temperature changes and their magnitude is demonstrated dramatically by the formation of glacial moraines.

A glacier is a giant river of ice, flowing and moving down its home valley until finally it descends to an altitude warm enough for it to fracture and melt. Or, as in Antarctica, the glacier can end up reaching the ocean and either melts there or breaks away and form icebergs.

Moraines are formed where the glacier ice melts. The rocks and debris gouged from the sides and floor of the valley are carried down within the moving ice and finally dumped. This material forms a wall across the valley. The appearance, when you actually look at one, is like a long river of ice suddenly ending as a wall of rocks.

For example: in rare cases, in some wide valleys, a glacier will form walls on either side of itself and have the appearance of an elevated ice freeway with rock sides, sometimes 60 feet (20 m) high running down the centre of an otherwise flat valley floor. These moraines can be miles long with an ice-free valley floor visible on either side. All these dumps, in their various forms, are called glacial moraines.

The flow speed of a glacier can be as slow as a few inches a century as in Alaska and Antarctica, or as high as 16 feet (3 m) per day for the Fox Glacier near Mount Cook on the South Island of New Zealand. The Fox Glacier must undoubtedly be one of the fastest moving glaciers in the world.

You can actually hear it moving.

When significant and long-term climate changes occur and temperature rises become well established, the glacier retreats, relatively abruptly, back up its valley to a new stable location. At the old location is the moraine containing the debris of sometimes thousands of years of deposition. It forms a wall, and as silt and other debris arrive, they eventually form a seal between the rocks and boulders and other debris and a lake is formed. The existence of such lakes is quite common throughout the world. The formation of these glacial moraine walls created most of the many lakes in the southern island of New Zealand and most of the lakes in other parts of the world at similar latitudes.

The positions of the end of glaciers in valleys are dependent on average temperatures prevailing over the time the moraines were forming. Knowing the altitude of a particular moraine we can determine what those prevailing temperatures might have been.

The very existence of these lakes dramatically evidences the existence of past variations in world atmospheric temperature patterns and the effects they create. They also show that the climate periods were much longer and more stable than the one our Global Warming is initiating.

Other clues to world temperature changes and their magnitude include the rise and fall in the altitude of snow lines. These lines are indicated by fossilized and semi-fossilized vegetation deposits on the mountain sides.

When all the information is collected from these and other sources, it indicates that the variations in average world temperatures in the biosphere, causing or resulting from the establishment and termination of ice ages, is less than 5ºC or about 9ºF. Additionally it is generally thought that tropical sea surface temperature changes are a good two degrees higher still. Temperatures over continents can double that again.

These temperature changes may not seem important, especially as in our daily experience we see changes varying by much more than that in just a few minutes. However we are talking about world averages. And they are very important.

Sunspots are also often mentioned as a possible influence on our planet's weather. Sunspots are round cooler patches on the surface of the Sun. They are like volcanoes, only they erupt intense magnetic fields, not ash or carbon dioxide or lava like terrestrial volcano do. Sunspots don't cover a substantial area of the sun. In photographs they look like half a dozen small grapes in a large flat fruit bowl.

The well known eleven-year sunspot cycle seems to be half of a twenty-two year solar magnetic cycle in which the magnetic polarity of sunspots reverses each eleven years. Sunspot activity, very slightly affects the 1,370 watts per square metre solar constant. Also there is a slight cyclic variation in total solar emissions over periods of less than 100 years. In the longer term therefore, these effects do not seem to be related in any significant way to glacial cycles and ice ages as they tend to average out over their relatively brief cycle.

In the short-term however, they can affect human activities and civilizations. An increase in total solar activity between the years 1100 and 1250 did appear to coincide with relatively warmer weather in Northern Europe. It was this added warmth that encouraged the migration of Vikings to Greenland, and even on to North America.

Likewise the thermal energy released from catastrophic volcanic activity is totally insignificant when considering Global Warming and world climates. A volcano does however spew out dust, and sometimes the dust is in sufficient quantities to alter the optical characteristics of the atmosphere. That is the only possible way a volcanic eruption can affect total world weather, but even then it can only be for a short period, just while the dust settles.

There is now absolutely no doubt that the recent warming of the Earth that has occurred in the last forty years cannot be blamed either on orbital changes, nor on sunspot activities, nor on overall solar emissions. Nor can this warming be blamed on any Milankovic glacial cycle, for the reality is that according to their postulated long-term effects, the Earth should be very, very slowly cooling; not rapidly warming, as it is.

Neither does the internal heat of the Earth, soaking up through the mantle have any significant effect on our weather and climate. Just below the Earth's crust, temperatures do soar to thousands of degrees, and yet the influence of all this internal planetary heat has less than a tenth of a percentage point effect on the Earth's surface temperatures. In other words, the temperature of this entire planet, from one side all the way through to the other is, in the long term, determined by the heat of the sun and the related greenhouse phenomenon. A massive planetary phenomenon that we are rapidly changing.

The climates and the weathers of this planet are ultimately determined by the amount of heat that comes to us as sunshine. The amount of heat-energy, arriving as sunshine in our part of the Solar System is called the "solar constant". The solar constant is an incredible 1,370 watts per square metre. Where most people on Earth live, it drops to about 1,000 watts per square metre mid-day, mid-summer, depending on the clarity of the atmosphere. That's like a 100-watt light bulb per square foot. Or for the whole world, it's like 130,000,000,000,000 electric radiators, each a thousand watts, and all shining down on the Earth's surface. That's 130 trillion of them.

That is the energy that drives our entire weather system. That is the energy that powers the flows of the giant ocean currents. And a little of it is the energy that powers virtually all living things.

The greenhouse effect is an entirely optical phenomenon. Technically it's an electromagnetic phenomenon. That's why these things are so important and why we need to know some of the relevant details.

The energy from the sun comes to us as sunshine, and sunshine is light. So what controls our weather is the optical characteristics of our atmosphere. Some things are transparent to light at only certain wavelengths (or colours). Some things are partially transparent. Some things are totally transparent. A layer of some materials, no more than one or two atoms thick, can block out sunlight completely. A piece of black paper, a thin film of plastic, a sheet of aluminium foil, the chrome plating on a car, a blush of spray paint, a linen shirt, all can totally prevent sunlight getting through.

Light coming to us from the sun is a mixture of a whole range of colours. We see these colours in a spectrum or in a rainbow. The mix of colours in natural sunlight is extremely consistent, and we have evolved so we don't notice the mix at all, nor can we differentiate the component colours. When we hear a mixture of sounds we can hear the mix of different pitches, or frequencies, that make up the sound. When we see a mixture of colours we only see the final mix. What we see as green may not be green light at all, but a particular mix that seems green to us. Green light appears green, but sunlight appears to have no colour at all and is described as "white light".

At both ends of the colour range there is just a little bit of sunlight that we can't see. At one end there is infrared, i.e. just beyond red. At the other end there is ultraviolet, or just beyond violet. Some night hunting animals can actually "see" the infrared coming from warm-blooded prey. Others creatures are sensitive to some of the ultraviolet wavelengths.

All objects radiate some light energy, whether visible or not. As they cool they radiate less. If not too hot, radiation is generally infrared. We may not see infrared radiation ourselves, but we can feel it. We feel it as warmth. Above about 600ºC many surfaces start to glow red. Objects are then described as "red-hot" and we can see the radiation.

The actual surface of the sun is around 6,000ºC and at this temperature it's much hotter than "red-hot"; it glows "white-hot". It is very much hotter in the deep interior where nuclear reactions are continuous. Temperatures there are in the millions of degrees.

Light is a wave of electric and magnetic fields, a so-called electromagnetic wave, but if you think of it like a wave on the surface of water you won't go far wrong. All waves have some common properties: wavelength (the distance between the crests), frequency (the number of crests passing per second) and velocity (how fast the crests move). The wavelength, frequency and velocity are thus interrelated. In a vacuum, (and pretty much in air), all light waves travel at the same speed and we need only consider either the wavelength or frequency. The wavelength multiplied by the frequency always equals the velocity of light so either term can be used.

A nanometre is one billionth of a metre. The wavelength of ultraviolet light ranges from 280 to 400 nanometres. Visible light, i.e. violet, indigo, blue, green, yellow, orange and red lights have wavelengths ranging from 400 to 760 nanometres. The infrared wavelengths go from 760 to 50,000 nanometres. Gamma rays and X-rays are also electromagnetic waves and have wavelengths of less than 200 nanometre.

Above a wavelength of 50,000 nanometres we have "microwaves". Longer than a wavelength of about 80,000,000 nanometres or 8 cm, we get into the radio wave band. Radio waves are generally described by their frequency, instead of their wavelength. Longer wavelengths correspond to lower frequencies. In the electromagnetic spectrum a wavelength of around 8 mm is called EHF (extra high frequency), then descending comes SHF (super high frequency), UHF (ultra high frequency), VHF (very high frequency), HF (high frequency), MF (medium frequency), LF (low frequency), and VLF (very low frequency). With ULF (ultra low frequencies), frequencies are around 100,000 cycles per second and have wavelengths around 10 kilometres long. Wavelengths can be virtually any size, up to light years long, but these would be almost impossible to detect.

Waves that convey radio signals can generally pass through wood and bricks and plastic. Electromagnetic radiation in the visible spectrum, will penetrate water and glass and petrol to a certain extent, but not thick oil. Infrared radiation hardly penetrates solid materials at all.

The electromagnetic frequencies of raw sunlight cover a fairly wide spectrum, but a good forty percent arrives as visible light. Gamma rays, X-rays and ultraviolet rays amount to about ten percent. The remaining fifty percent is composed of a broad spectrum of infrared radiation.

The light absorbing characteristics of our tiny and vulnerable atmosphere control the quantity of energy we receive from the sun and it controls how much of that energy is re-radiated back into space. The optical characteristics of our atmosphere decide the climate and the weather of the world we live in by balancing the amount of energy coming in and going out. Normally, changes in our atmosphere occur only slowly, usually over many thousands or even millions of years.

However, major changes in the Earth's optical characteristics can occur rapidly, often after dramatic geological events. The air then becomes loaded with dust. The input-output heat balance rapidly changes. This occurred most noticeably with the eruption of Mount Pinatubo in the Philippines in July 1991. Generally within months and rarely more than within a few years the particles settle and the atmosphere clears. The original heat balance is restored. There is little permanent disruption to life and to ecosystems. With the Pinatubo eruption the average world surface temperatures dropped by over 0.5ºF (0.3ºC) for two years, but in complete contrast, and because of polar air circulation; in the high northern latitudes warming actually occurred.

After an impact with a large extraterrestrial object, say a few kilometres in diameter, things are different. The atmosphere does not revert to "normal" in a matter of months. The world changes totally. Massive global extinctions occur. The world's ecosystems are altered forever. Eventually a totally new world environment forms, and a new heat balance becomes established.

A stable heat balance is the only thing that establishes stable climatic systems, which in turn controls our weather and determines the energy and power of our ocean currents. Ultimately that balance is the factor that decides whether we will be surviving in an ice age or living in an interglacial period; as we are now.

Massive changes in climate are O.K. and can be, and are tolerated, but only over geological timescales. For most advanced life forms, changes can only be tolerated when long periods of time are available for adjustment or evolution. Only very primitive life forms can survive on a world in a constant state of erratic and unpredictable change.

Humans can adapt. Animals can adapt. But only so long as there is time to adapt. But the rate of adaptation certainly cannot be sped up a thousand fold, and a thousand fold increase in adaptation rate is what would be needed to adjust to current fossil carbon induced Global Warming.