Chapter One

The Absolute Basics

Draft Version: June 2022

INTRODUCTION

Recognising Our Limits

An adult brain is the size of a decent melon and weighs over a kilo. It is filled with about 100 billion neurons[1], and each neuron has thousands of synaptic connections with other neurons. This astonishing piece of biotechnology consumes around 20% of the total body energy budget as it processes a vast stream of data. But despite the remarkable power and complexity of our brains, there are some things that are just out of our natural reach.

Right now, as you hold these pages, there are pet dogs tracking smells that we could never detect, there are domestic cats alerted to sounds that lie well beyond our range. There are millions of quarks passing imperceptibly through the Earth… and there are galaxies (far, far away) in which Supernovas are spilling out their enriched guts into the universe.

There are many more dimensions to reality than those that we are used to in our everyday lives. To get a fuller understanding of what is going on around us we have managed to develop high-precision scientific technology. The modern A to Z of scientific instruments is a curiously diverse collection, from Absorptiometers to Zymosimeters, and hundreds of others in between. We can now look out into the deepest past of our universe and zoom down into the whacky world of quantum entanglements.

Climate change is a reality that is known through science. For example, the Mauna Loa Observatory in Hawaii has been measuring the monthly mean atmospheric CO_2 level since 1958 to an accuracy of one molecule per million[2]. In March 2016, the reading went over 400ppm for the first time[3]; by March 2022 it reached 420ppm[4].

So what, you could ask? Perhaps as you absent mindedly stared at your box of Cornflakes in the morning, you might have noted that there are 5.4 μg of Vitamin B12 in every 100g. A high-precision reading, but that measurement did not make you suddenly choke in shock and awe. You would not feel compelled to share this nutritional fact on your phone. It certainly would not flip your worldview upside down and transform the way you see your future.

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[1] PNAS June 26, 2012 109 (Supplement 1) 10661-10668; first published June 20, 2012

[2] To be precise, the reading is taken as the mole fraction of dry air. The results are published in ppm, parts per million, but the instrumentation is sensitive up to ppb (parts per billion).

[3] https://keelingcurve.ucsd.edu/

[4] https://gml.noaa.gov/ccgg/trends/weekly.html

The truth is that a reading of over 420ppm CO_2 particles in the atmosphere should cause you to choke on your morning cereal. This reading is the key measurement of a dimension of life on this planet that lies beyond our immediate senses. This reality is understood comprehensively by thousands of lines of scientific enquiry. It is called climate change, and these modules will expose and explore why it is all so astonishingly and fundamentally important.

A clear understanding of climate change is a brutal shock to the system. It is an offence to our common sense of the world. The sheer size and scope of the problem is hard to wrap your head around. Indeed, in many ways we just can't. We are humanoid. We are mammals. We are geared to respond to immediate threats - we are wired to react to loud bangs, not graphs. But the graphs do not lie. Our ability to use reason to join up dots of evidence provides us with access to something that is going on above our heads.

Despite the abstractness of these conclusions, the truth is that this reality will impose itself on human life with an intolerable level of violence and disruption. Global warming is a brute fact, whether we are willing to look at it or not. The earlier we engage with it, the earlier we deal with it, the better chances we have of avoiding its most destructive effects.

Living in Flatland

The English school master Edwin Abbott Abbott [sic] was very, very [sic] aware of the limits of human perception. Being a good teacher, he wanted to pass this ignorance on to his students.

He wrote about his limited understanding in a short little book named "Flatland" (1884). This book is narrated by "A Square". Taken at surface value, it is about a two-dimensional shape who gets into real difficulties when he visits different dimensions. Firstly, A Square has a disturbing dream about a visit to "Lineland" in which no-one can recognise who he truly is because they just see him as a sequence of dots. In fact, the monarch of "Lineland" feels so threatened by the absurd notion of an extra dimension, that an attempt is made to kill him.

Then, after waking up from this awful dream, things become more disturbing.

A Square encounters A Sphere. And so, in a shocking twist, the problem is reversed. No matter how hard A Square tries, he just cannot understand what A Sphere is talking about. A Sphere tries to show the depth of the 3-dimensional world that he comes from, but all A Square can see is a series of linear circles and ovals.

That is until he visits Space Land.

In Space Land he comes to understand how limited his previous experience was. After seeing the deeper dimensions to existence, he returns to his native Flatland. Predictably, his insights are not accepted and suppressed by those in power. However, A Square cannot unseeunsee what he has seen, and he insists that his claims about a third dimension are true. Towards the end of the novella, A Square tries to convert his Grandson to the 'Gospel of 3 dimensions' but

his attempt to explain the radical difference between going 'Up' and going 'North' is a futile one, as he cannot point to it in two-dimensional space.

The 'Grand Council of Flatland' eventually arrests him for his subversive attempt to challenge the *status quo*. It is during his imprisonment that "Flatland" is written, in the hope that it "may stir up a race of rebels who will refuse to be confined to limited Dimensionality".

AlthoughAbbott's book is quite funny, it was not just a bit of mental acrobatics about lines, shapes and dimensions. There were psychological and political angles to his book. He was offering a critique of the rigid social hierarchies of Victorian England. Yet, the book was largely ignored after its publication in 1884[5].

Abbott was a teacher, and he wanted his students to confront the limits of their common sense of the world. Climate change first demands humility. Knowledge and understanding are not simply acquired by the intellect. It requires courage to think outside of our normal boundaries. Within an individual, just like within society, there is often a fight for control over what is permitted to be known.

Conclusion

The situation we are in demands that we become fully human. We need to think and act beyond just our basic instincts and sensibilities. Indeed, there is a major upside to the climate crisis: it will force us to be our true selves. A full response to climate change will make us deeply human. We are wonderfully, beautifully, multi-dimensional creatures. The transformation of human society ahead will either be catastrophic or simply wonderful. Either way, it will not happen without struggle.

Questions

- When have you felt dwarfed by science? Or an experience?
- What was your response to that feeling?
- Why is it difficult to challenge the *status quo*?
- What are the main psychological blocks to getting a clear view of climate change?

[5] There was just a bit of spike in interest in "Flatland" after Albert Einstein's *Theory of General Relativity* was published in 1915, because the Austrian genius radically shook up our common sense understanding of what space and time …were. and then in 2007, "Flatlands: The Movie" came out.

Main Text:
The Absolute Basics

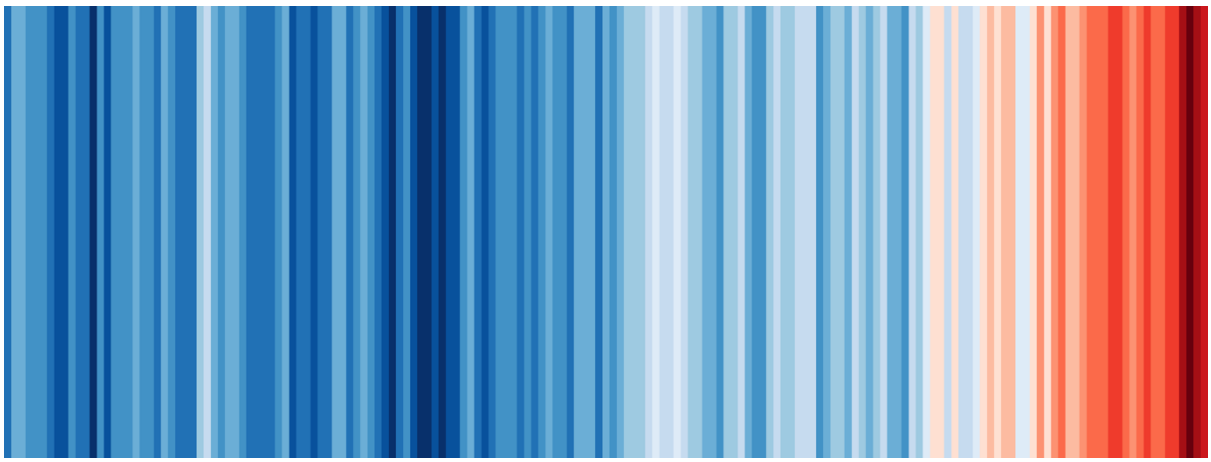
Let's be frank[6].

There is no point investing any further time reading this book, or engaging in any urgent efforts to fix the climate crisis, if there is no such crisis (or if it is already much too late to do anything significant about it). We all have other stuff we could be getting on with. The basic science of our situation must be very robust; getting the evidence straight is fundamentally important. This respect for data and the latest conclusions of mainstream science avoids two dangers: it prevents us from being too casual about the severity of the crisis we are in, and it prevents us from undue alarmism.

Any book worth the effort on climate change must therefore be written on a rock-solid scientific base. Not only that, a decent book on climate change has to provide a proper landscape of the situation. It is easy to get lost in the details, it is easy to miss what the central conclusions are. This opening module will put this important frame in place.

There are two absolutely basic issues to address here: global warming, and greenhouse gases (GHG).

1. **Global Heating**



It is easy to understand why A Square found it difficult to see the hidden depths of A Sphere. Although the suppression and punishments that A Square suffered are clearly not to be applauded, it is easy to understand how whacked out his claims must have seemed to everyone in Flatland. Likewise, there are significant psychological and political obstacles to seeing the reality of climate change. These will be given their proper attention in the Module 10.

But honestly, there is not much excuse for any kind of hesitation – look at the chart above.

[6] Apologies for just stating the obvious if you are actually called Frank.

These "Warming Stripes"[7] demonstrate just how radical the shift in the average global temperature has been since the start of the industrial revolution. The first stripe of colour, on the left, represents the average global temperature for the year 1850; the last stripe of colour, on the right, represents the latest thermal data.[8] The contrast between the cool blue on the left and the hot reds on the right is vivid. Behind every stripe of colour there is a huge store of raw data collected from various scientific instruments.

Things are getting hotter. Given the complexity of our Earth climate systems it is not a surprise to see that the pattern of change is irregular. However, the acceleration of change in recent decades is emphatically clear. The climate crisis is very real.

We are bipedal mammals, living day to day. It is true that in our normal everyday experience of walking outside in the wind, the rain or the sunshine, it is impossible for us to get a reliable picture of long-term changes. A problem compounded by the fact that we can only be in one place at once. This has often been likened to the difference between a tree and a forest. When you are in the middle of a forest you can only see the trees around you; each tree is like a weather event. By contrast, the whole forest remains out of sight. Not only can you not see the trees hundreds of miles away, but the forest has been around for hundreds, thousands or perhaps millions of years. The forest, in this fullest aspect, is like the climate. One dead tree does not signify anything about the forest, you need to be able to look at the bigger picture. One flood or storm, one cold or warm winter, does not signify anything about the climate. You need to have much deeper and wider data to be able speak scientifically[9].

Thankfully, Science can make the reality of the climate crisis crystal clear. It can summarise a vast amount of data, from different times and different places, into a small space on a page for our eyes and brains to see it.

So things are getting hotter.

Why is this such a problem?

The scale of the problem led 196 nations of the world to sign up to "The Paris Agreement" in 2015. They agreed "to **limit global warming** to well below 2°C, **preferably to 1.5°C**, compared to pre-industrial levels".

A rise of 1.5°C, or 2°C might not sound like a big deal. We might have recently planned a trip outdoors and checked the forecast again in the hope that it would have notched up a bit. In winter months, we have probably given the thermostat a little nudge for a bit of extra comfort. What's the big deal? A rise of 2°C does not naturally trigger loud alarm bells in the

[7] Thanks to the clarity of mind of the climate scientist Ed Hawkins.
[8] The colours are rooted in the HadCRUT4 gridded dataset of global historical surface temperature anomalies relative to a 1961-1990 reference period. Earlier data sets are available for each month, since January 1850, and can be found in the collaborative work of the Met Office Hadley Centre and the Climatic Research Unit at the University of East Anglia.
[9] Fudging the difference between the climate and the weather is a common tactic used by sceptics to undermine the climate science. It is also true that whilst extreme weather events are typical of what climate change looks like, some people engaged in climate activism can lack a bit of nuance by asserting a certain link between a weather event and a climate trend without qualification.

public imagination. It would not be that surprising to think that the human impacts of climate change might be fixed with a bit more suntan cream.

However, a raised temperature is a big deal. It is a systemic problem. Anyone who has had a fever for a few days at 39°C will know how lethargic and grumpy it can make themfeel. Moreover, doctors inform us that if an elevated temperature is not treated for several weeks, then vital organs can start to break down. In fact, a 4°C rise for humans is a medical emergency; vital organ damage occurs, and death will follow if the temperature is not lowered quickly. It is called hyperpyrexia.

All life has similar difficulties with movements in temperature outside of their tolerance zone. The parallel between ecological systems and the human body is only a metaphor, given that different organisms experience heat stress differently. However, it gives a good approximation of the deadly consequences that await human civilisation. Shockingly, we are on track to lock-in such dangerous high temperature rises by the end of this century, if not well before. It is crucial to not underestimate the systemic dangers of escalating levels of greenhouse gases in the atmosphere.

In 2019, global average temperature was 1.2°C higher than the pre-industrial level. Since 1980, each decade has been warmer than any preceding one since 1850.[10] The seven warmest years on record have all been in the past seven years[11]. To illustrate this trend, Furnace Creek in Death Valley (USA) set a new record when it recorded a temperature of 54.4°C in 2020 [12] (and again in 2021) [11.] Temperatures so hot, the chickens in Inyo County (CA) were actually laying hard-boiled eggs for over a week[13].

Almost all the media attention on climate change is zoomed in on particular events – most typically, floods, storms or forest fires. These events are profoundly tragic for those who get caught up in them and deeply affecting for those who observe them from a distance. Of course, it is entirely appropriate to report on them and highlight the suffering and issues involved. However, when the media only covers climate change like this it misses the fundamental problem of the global heating that is speeding up: *its systemic impact*.

The heatwaves, droughts, floods and storms are the most vivid signals of the increasing stress. These events hit our senses with force. They illustrate the gap between the ambitions of human civilisation and the pathway that the natural world is on. The dots of natural disasters that put increasingly large blots onto the record books of meterologists and insurance companies are important moments in the dot-to-dot of climate change.

However, a wider zoom is needed to really have a clear view of the dangers ahead. This wider zoom requires us to think in more abstract terms, it needs the work of science. It needs the long reach of scientific research. This extra level of abstraction and reasoning is why it gets less media attention, but this view of the biggest cogs of the Earth's systems are where the critical action is actually taking place. From the vantage point of climate science,

[10] World Meteorological Organization: Statement on the state of the global climate in 2019.
[11] World Meteorological Organization: State of Global Climate 2021, provisional report
[12] National Ocean and Atmospheric Administration: State of the Climate (August 2020)).
[13]Just testing that you are paying attention. There is (of course) nothing scientific about this claim, it is just a lame joke.

there are things which the scientists can see that sometimes keep them awake at night (and this is not simply a metaphor).

Climate science is attentive to some huge interlocking cogs that are in place around the planet that define how the whole of life works. If any one of these cogs is disturbed the consequences will play out in radically chaotic ways. These cogs define the grammar, not just the vocabulary of life. They are the fundamental principles, not the details.

For example, we have permanent ice at both poles, these in turn fix the configuration of the Polar Front. The Polar Front jet stream is one of the major ribbons of very strong winds (up to 200kmh) that flow around the globe in entrenched patterns, hundreds of kilometers wide. A destablisation of this monumentally large pattern of energy transfer would be catastrophic.

Let's be honest, any consideration of the forces that dwarf our humanoid perspective of things is difficult – both psychologically and emotionally. It is probably one reason why Education, like the media, has been shy and reluctant to handle it. It is material that is not appropriate to teach to younger children. But can we honestly consider ourselves well educated if we did not know that the real damage caused by rising temperatures has the potential to cause the collapse of human civilization? If students attending university were not really aware of who Adolf Hitler was or if they did not really know what Google was, there would be serious questions to ask about their basic awareness of the world. Yet, how many university students have a clear understanding of the depth and severity of the climate crisis? How many would be able to explain why climate change is so much more of a threat to human life than the issues arising from plastic waste?

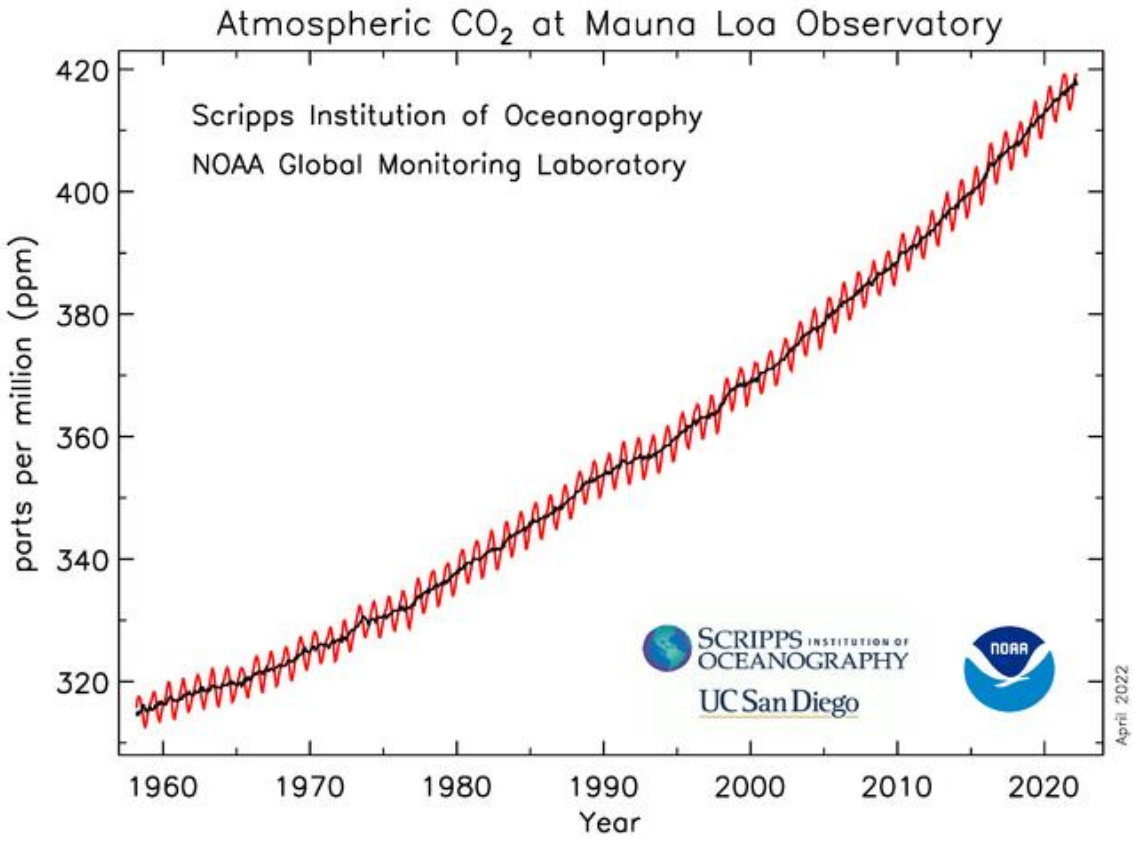
There are lots of ways to express the serious negligence of our current educational standards. Is it like forgetting to mention on your Tinder profile that you are actually a vampire. It is like loosening the wheel bolts of your high-spec Porsche before driving for a blast down the A7 Autobahn. Or, perhaps most appropriately, if you are still in primary school (and not able to read this yet), it is like you are being very careful to not knock over a glass of your favourite juice at the family dinner table, whilst some mad uncle is sawing away at the table leg.

The consideration of these interlinking big cogs of our planet deserves its own space in a later module, "Chapter 10: Tipping Points." But for the moment, it is simply enough to state that temperature, even if it is a seemingly small adjustment of 2°C, is a really big deal.

2. Greenhouse Gases

The extra heat energy that we have to cope with comes from the escalating concentrations of greenhouse gases in the atmosphere. Science has known of the greenhouse gas effect since 1824, through the work of French physicist Joseph Fourier. In 1856, Eunice Foote provided the first key chemical details of this effect when she established that H_2O and CO_2 trap heat.[14]

Modern science can measure, in a remarkably precise manner, which particles make up the atmosphere above our heads. As noted above, the Mauna Loa Observatory in Hawaii has been measuring the concentration of atmospheric molecules, expressed as parts per million (ppm). This data has been plotted onto a graph known as 'The Keeling Curve', so named after the scientist Charles David Keeling, who set it up. The Mauna Loa reading at the time of writing (March 2022) signalled that there were 420 particles of CO_2 in every million (420 ppm).[15] Nitrogen (N) makes up over three-quarters of the rest with 780,900ppm, alongside Oxygen (O) that occupies 209,500 ppm.



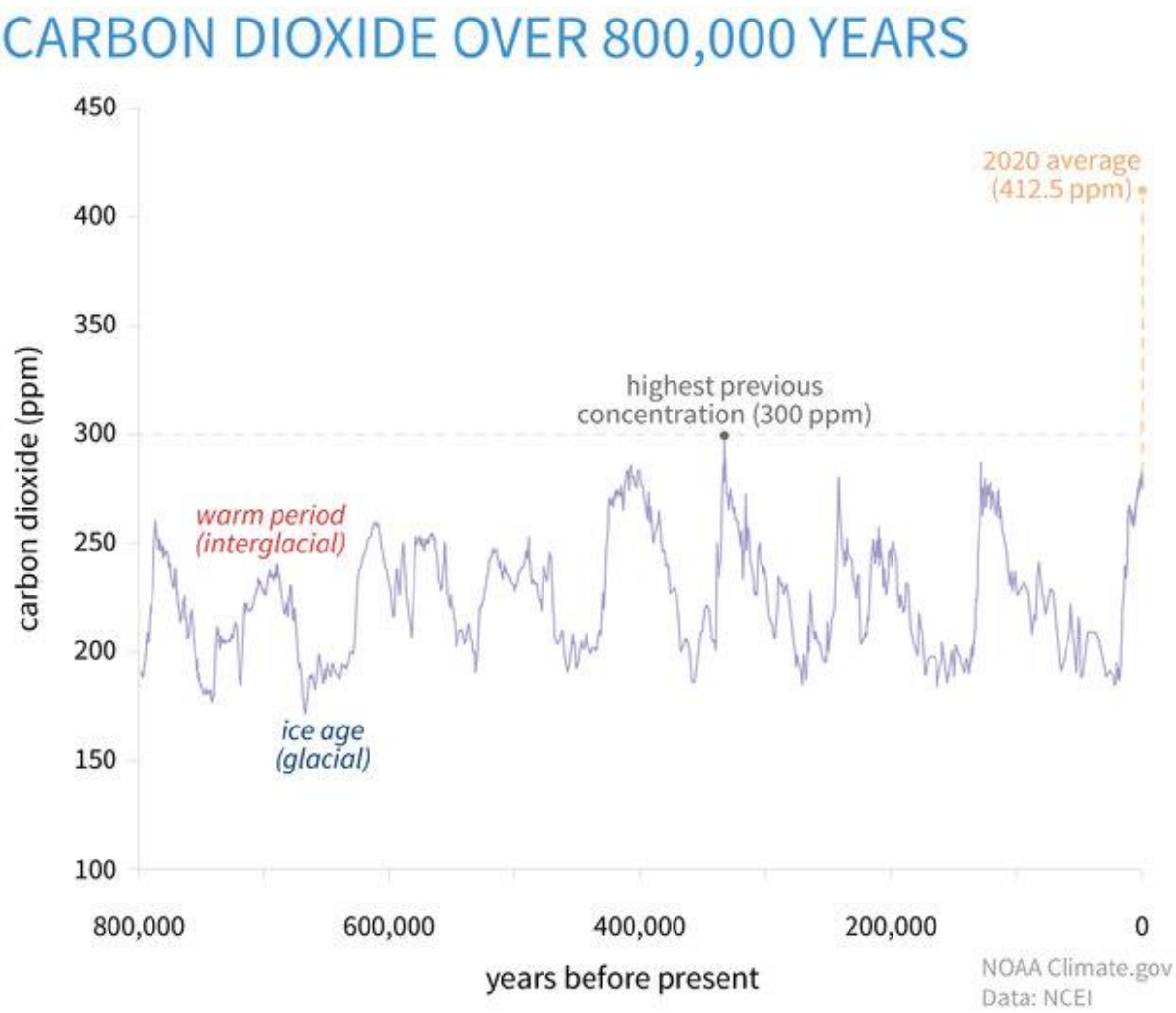
[14] Foote E., "*Circumstances affecting the Heat of the Sun's Rays*". Read before the American Association, August 23d, 1856. It is common to credit John Tyndall for this discovery, but his lecture to the Royal Society lecture was delivered three years later on June 10th, 1859.

[15] Source: https://www.esrl.noaa.gov/gmd/ccgg/trends/monthly.html

420 parts per million[16] does not sound like a lot, it is only like a can of coke sat in the corner of a classroom. However, a carbon reading of 420 ppm informs us that we have bumped up the level of CO_2 by almost 50% since the start of the Industrial age.[17]

This is a concentration of CO_2 that is unprecedented in around 4 million years and when geologists look back in time to previous epochs that had the same levels of CO_2 they do not see a world which is compatible with human civilisation as it is now: "Current levels of CO_2 correspond to an equilibrium climate last observed 3-5 million years ago, a climate that was 2-3°C warmer than today, and sea levels that were 10-20 m higher than those today."[18]

It will take us into an utterly alien world for our species. This is a kind of situation that is very hard for us *homo sapiens* to even think about.



One problem we have is that because the climate has been so temperate and accommodating in the past,it is hard to imagine that the whole system could switch so dramatically to become

[16] To be exact, the global average for 2021 was 416ppm. The 420 ppm that was measured in Mauna Loa is a reading taken at a particular moment in the annual zig-zag of concentrations caused by the four seasons.
[17] These figures do not include the other greenhouse gases like methane (CH4), nitrous oxide (N20) and halogens.
[18] *World Meteorological Organization Greenhouse Gas bulletin 2017.*

such a dangerous enemy. Indeed, human beings have just experienced an unusually balanced and warm climatic period known as the 'Holocene' that lasted from 11,700 BCE until the modern day. This calm interglacial pocket of time provided the favourable conditions that helped Neolithic *homo-sapiens* to grow up, and then served as the background for our more immediate ancestors' development in the Bronze and Iron Ages.

Science also enables us to look much further back over our shoulder further into the distance.

Beyond the Holocene, the hominoids who lived in the last 800,000 years of the Palaeolithic Age, lived on an Earth with wider swings in the patterns of climate. From this wider perspective, we can see the effects of planet Earth's slowly drifting patterns of orbits, spins and wobbles (more eloquently known as the Milankovitch cycles). These huge rhythmic pulses can be seen throughout this age, a regular beat that comes to an unusually long, warm pause in the Holocene. This background climate of this Pleistocene epoch is cooler and rougher, but it was the world that the primates evolved in and it had a firmly rooted pattern.

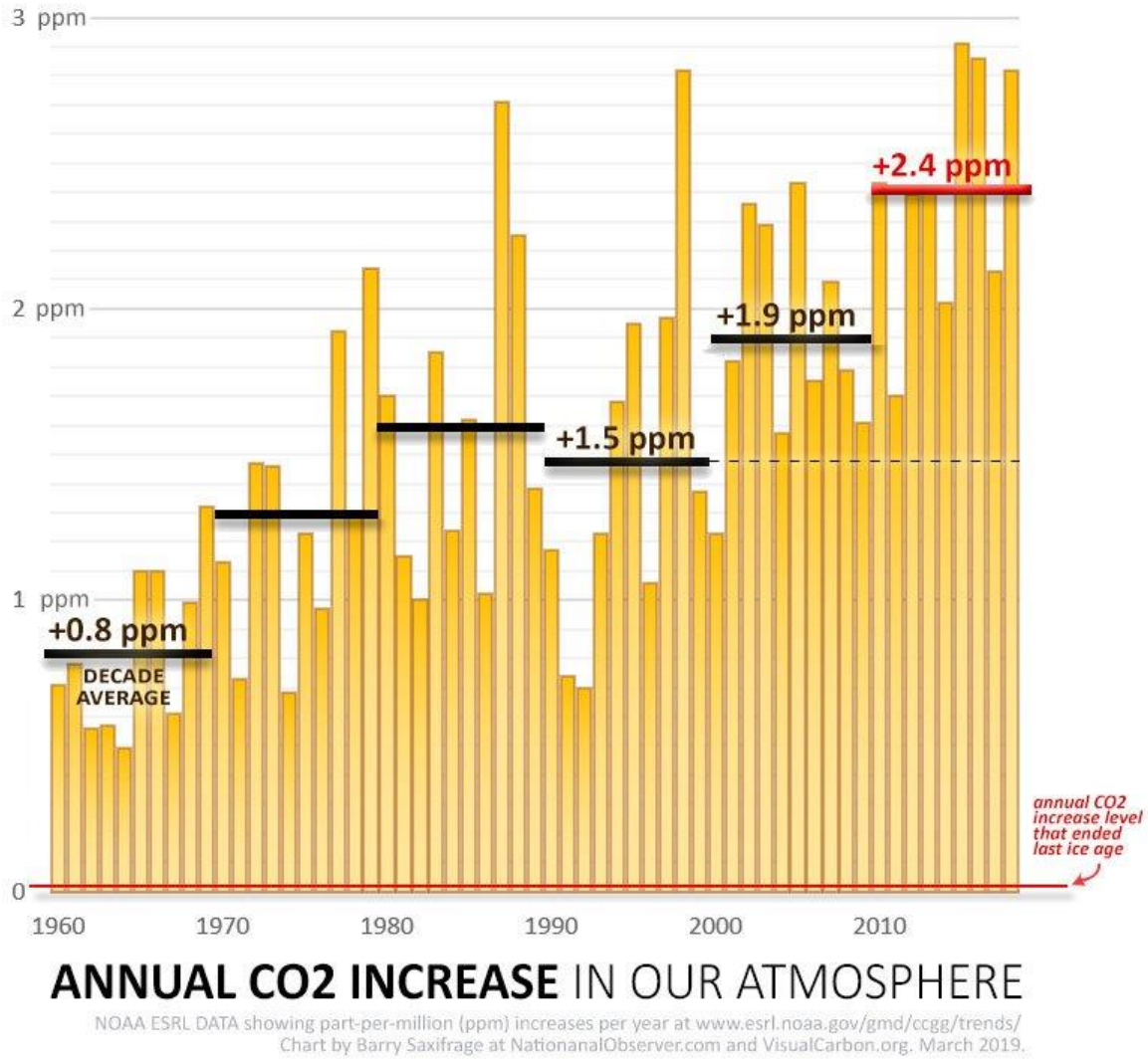
What is shocking, is that we have exited both the cosy Holocene and this settled long-term rhythm in a sudden and massive surge upwards. Through the burning of fossil fuels on a monumental scale (especially since 1950), we have booted the climate into unchartered territory. The level of CO_2 has been entrenched in a stable range of between ~180ppm and ~280ppm for well over a million years.[19] Therefore, a reading of over 420 ppm is not a historic level; it is a profoundly prehistoric level.

Throwing our whole ecological system out of its long-entrenched equilibrium is unimaginably foolish. The entire biosphere that we are part of has evolved over millions of years into forms of life that are perfectly adapted to this current environment. Anthropogenic climate change is happening at breath-taking speed, 0.2°C per decade, and it is accelerating.[20] There might be more solar panels and wind turbines around, but do not be misled, our booming population and consumption is driving emissions faster and faster. We have not slowed anything down yet. Overall, the speed we are travelling at is about 20 times faster than the average rate of ice-age recovery warming.[21] We have already driven ourselves into a minefield of dangers, and not yet found the brake pedal.

[19] *World Meteorological Organization Greenhouse Gas bulletin 2017.*

[20] Intergovernmental Panel on Climate Change, Global Warming of 1.5°C (2018) Executive Summary

[21] Nasa Earth Observatory: "As the Earth moved out of ice ages over the past million years, the global temperature rose a total of 4 to 7 degrees Celsius over about 5,000 years." That is about 0.008 to 0.014°C per decade; in other words, current climate change is 14 to 25 (average 20) times faster than the average rate of ice-recovery warming.



The science is emphatic. Pushing greenhouse gas concentrations and (thereby) global temperatures into entirely new territory will not end well for us. The graphs are vertiginous.

To conclude, what we are doing is comparable to suddenly upping the voltage on the power supply to your laptop, on which you have all your work, family photos, bank account details and personal files stored. Why would you wilfully do that, especially when there is no back up?

Videos:

Neil de Grasse Tyson, "The most astounding fact".

https://www.youtube.com/watch?v=kl0J6Le5MpM

"There is something wrong with the world"

https://www.youtube.com/watch?v=XoaPFPBQhww

Further reading:

"This Changes Everything" (Naomi Klein)

"Bankrupting Nature" – Club of Rome