Climate change by numbers

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A note on how the video was produced

First, a PowerPoint presentation, with animations, was produced. Each slide was then put into its own PowerPoint file. Unfortunately, when it comes to producing videos from PowerPoint, Microsoft and PowerPoint indicate that many things are possible, when in fact they are not. I was using PowerPoint 2016, on Windows 10, and some googling revealed I was not alone in experiencing problems. What is described here is a route that worked, after I had tried a lot of other routes which led to dead ends. I produced the audio for each slide via Insert > Audio > Record Audio. At that stage I simply read from my script (what appears below), without worrying about the animations. Importantly, after producing the audio, one needs to go into the Animations Pane and make sure the audio is the first item, and that it is prompted by a click, and that it continues past the end of the current slide. Next I went to File > Export and Create a Video. I selected Full HD, and then Record Timings and Narrations. I deselected Narrations, ink and laser pointer, and then began the process. During the process, I would click my way through the animations, making sure I timed that with the audio I was hearing. After that was over, I clicked Create Video, selecting .mp4. One major headache I could not resolve was out-of-control animations in slides with many animations. I would look at the mp4 video and realise that after all working well for a while, at one point all the animations would happen in quick succession, not at all in the way I'd recorded. Some testing revealed that the problem did *not* reside in the conversion to .mp4. The problem already existed in the supposed synchronisation within PowerPoint. Testing also revealed that it was not a matter of the slide being too long in terms of time. I narrowed down the problem to one of two things: too many animations, or too many items in the animations pane (for me, there are more of the former than the latter, as one click can animate more than one graphic element). I resolved the problem by splitting up a slide with too much into two slides with less in each, and then producing two .mp4 files. I then used the Video Editor app which comes with Windows 10 to join the two .mp4 videos. I also used Video Editor to trim for instance periods of silence at the start or end in all the videos, before uploading onto YouTube.

GENERAL INTRODUCTION

Slide 1: Introduction

● Hello. I'm * Martin, the producer of this video, a video intended to help you understand climate change. * As suggested by the title, there's a strong emphasis on the numbers, as climate change is a very numbers phenomenon: * percentages of certain gases matter a lot, * there are risks associated with certain temperature increases, and much of the uncertainty is about rates of change.

* Though I am South African, and the video was put together after having looked at the South African secondary school curriculum, the way climate change is inserted in various parts of the curriculum would be similar in different countries. Thus, wherever you are in the world, and whether you are a teacher or a student, you may find this video interesting and useful.

In the description below this video, you will find a link to my blog, which has the full text of the video, references to sources, how I produced the video from an original PowerPoint file, and how I took care not to violate copyright rights when selecting images.

Slide 2: School curriculum

● Climate change, and related environmental and social issues, feature in various places in the South African school curriculum, in particular in the six subjects listed here. * There is a lot in Grade 11. Of course, one is not limited by what the curriculum says. You can bring the issues dealt with in this video into essay-writing in the English class, or the Zulu class, and because so much is about numbers, one can incorporate these issues into mathematics exercises quite easily.

Slide 3: Contents

● * This series of videos is broken up into six main parts. * What the *scientists* measure. * What *environmental accountants* in many countries calculate. * What the *forecasters predict* will happen. * What the *politicians* have put forward as targets. * What activists say we as ordinary people can do to slow down climate change, and how big the effects of those actions are. * And then there's a part with the South African perspective. * After each part, there are three multiple choice questions.

* The background document has a lot of footnotes and references that can help you dig deeper.

PART 1 INTRO: WHAT THE SCIENTISTS MEASURE

Slide 4: Introduction to Part 1

● Okay, let's begin then. In Part 1 we take a look at the things scientists measure in relation to climate change. * I'll discuss three key things the scientists measure: the concentration of carbon dioxide, or CO_2, and other gases in the atmosphere; the average surface temperature of the atmosphere; the acidity of the oceans. We can think of these three areas of measurement as central to understanding how the earth's climate system is changing. We'll look at how these three things are measured. What tools do the scientists use? How serious are the errors in the measurement process? We'll also look at how some people have tried to discredit the scientists, or show they are wrong, * especially as far as the second measure, the average temperature of the atmosphere, is concerned. In looking at this, we'll explore how the politics around climate change can become quite dirty. Some people have basically paid a lot of money to promote the idea that the scientists are wrong and that climate change is not something we have to worry much about. People have done this often in the interests of certain business sectors and political parties.

PART 1.1: CONCENTRATION OF CO_2 AND OTHER GASES IN THE ATMOSPHERE

Slide 5: Concentration of CO_2 and other gases in the atmosphere

●[1] Concentration of carbon dioxide, also referred to as CO_2, and other gases in the atmosphere. The measurement of CO_2 in the atmosphere in many ways centres round one man: ○ Charles Keeling. An American, he was born in 1928 and died in 2005, aged 77. He

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[1] This is the first *content slide*, by which is meant a content-rich slide which works in a particular way. Each of these slides consists of several figures, one relatively big and important one in the middle and then several smaller ones around the sides, the 'postage stamps'. An empty bullet ○ indicates that a figure is expanded and made to cover most the slide, as the figure is described. The description involves adding and removing a lot of bits of information (arrows, highlighting circles, numbers, even new illustrative figures) – each occurrence of this is marked with *. × means that the figure which was expanded is now collapsed back to its smaller size. Bottom line is that *, ○ and × all require a forward click in the management of the slide.

liked music and nature, and almost chose to become a musician instead of a scientist. But fortunately for science, he ended up studying chemistry at university. After completing his studies, he received many good job offers from the new and growing plastics industry. Fortunately for us, Keeling, didn't see his future there. Instead, became a researcher at a technology university. ×

Keeling became interested in measuring the amount of carbon dioxide in the atmosphere. O Nobody at the time was sure how much of this gas existed in the air. * Everyone knew it was very little, but how little? Scientists at the time thought it was between * 250 and 550 parts per million, meaning that out of every million molecules in the air, between 250 and 550 would be carbon dioxide molecules. Keeling wasn't happy with all this uncertainty. He wanted a more precise statistic, in particular because he and all scientists knew that humans were putting a lot of extra CO_2 into the air through burning coal, petrol and other fuels. As will be seen further in another section of the video, CO_2 is the most common gas emitted, or released, by industrial processes. How was one to know what effect industry was having on the atmosphere if there wasn't an accurate way of measuring carbon dioxide in the air? ×

Keeling's solution was to develop O a small device, around half a metre long, to measure CO_2 in the atmosphere. The name of this device was the * IR (or infrared) gas analyser. In a way, this device copied on a very small scale what was happening in the larger atmosphere. To put it simply, * an infrared red light shone into two tubes, * one containing natural air captured from outside, * the other containing air which was normal and natural except for the fact that * all carbon dioxide had been artificially removed. * The infrared light flowed more easily through the tube without the carbon dioxide, *** as carbon dioxide is a greenhouse gas, meaning it blocks some of the infrared light. * At the other end of the tubes were instruments, actually a kind of microphone, which picked up how much of the infrared light was reaching the end of the tubes. Which tube would have more infrared light flowing through it? * The one with*out* the carbon dioxide, of course. By looking at how much of the infrared light didn't get to the end of the top tube, through looking at the difference between the measurements of the two microphones, it was possible to work out how much carbon dioxide there was in the first tube. The greater the difference, the more there was[2]. ×

Keeling's invention resulted in his getting a job in a government programme, linked to the Weather Bureau, that was being set up to measure CO_2 in the atmosphere at the top of O Mauna Loa, a 4,200 metre-high volcano, in Hawaii, in the Pacific Ocean, often considered the world's largest volcano. Why Mauna Loa? This was considered a good place as the plan was to find out by how much CO_2 was increasing as a result of human activities even in very remote places, with almost no human activity. One would expect such a place to be affected, ultimately, by human activities, as air moves around all the time, for instance through wind.

So, Keeling set up his instruments at Mauna Loa. In * 1958 they started producing measurements, every hour, for 48 years, up to * 2006, when the original instruments were replaced. These instruments thus worked for half a century, producing a statistic every hour, resulting in some of the most important data humanity has ever had. ×

So, what did this data show? It showed two fascinating things that no-one had been properly aware of previously.

O Firstly, it showed that the Earth was breathing. In a way, yes, it was breathing. * In around May of each year, CO_2 levels were high, * in October they were relatively low. This is the graph for the year 1959, using data you can download at the following site *[3]. Now why would this pattern exist, of different CO_2 levels at different times of the year? The explanation

[2] From Harris, 2010.
[3] ftp://aftp.cmdl.noaa.gov/products/trends/co2, accessed March 2018.

is that in the early part of the year * there are not that many plants available to absorb CO_2 from the atmosphere. This is the winter in the Northern Hemisphere, and many plants have no leaves. Of course, it is summer in the Southern Hemisphere, but what happens with the plants in the Northern Hemisphere is particularly important as there is more land in the Northern Hemisphere, so this hemisphere has a larger impact on CO_2 levels. During the northern summer, there is a lot of plant growth, which results in CO_2 being absorbed, or sucked out of the atmosphere. This is why by the time one comes to October, roughly the end of the northern summer *, CO_2 levels are quite low. This is repeated every year. These seasonal changes are seen most clearly in the Northern Hemisphere, but even in the Southern Hemisphere one would end up with a very similar graph, because the patterns would be so heavily influenced by what is happening in the Northern Hemisphere[4].

* Here are the CO_2 levels for four years, 1959 to 1962. This brings us to Keeling's second discovery. Though CO_2 levels were moving up and down in a regular way within a year, each year's levels were a little higher than the previous year's ones. * We can see this here. The 1962 levels are a bit higher than the 1959 levels. * In fact, the increase was 0.6 ppm, or parts per million, every year. This trend was so clear that * in 1960 Keeling published a four-page article on this. It was a short article, but it sparked the beginning of a change in the way scientists looked at the industrial world, and its impact on the atmosphere and the climate.

* Now if we look at the trend all the way from 1958 to 2017, what do we see? The amount of carbon dioxide in the atmosphere rises, goes up. But this rise in getting faster. * Around 1960 the level of CO_2 was rising by 0.6 ppm a year. * By 2017, the annual increase was 2.4 a year. So, the increase has been four times as fast in recent years as it was back in 1960. Those are the annual increases. But what are the levels? * In 1959, just after Keeling started his measurements, the level was 315 parts per million. * Recently, in 2015, that level passed the 400 mark. ×

* So, thanks to Keeling, there was no longer this great uncertainty over carbon dioxide in the atmosphere any longer. * We had very precise figures and could easily see how the level of CO_2 was increasing.

Even today, scientists are not absolutely sure what the consequences are of having more CO_2 in the atmosphere. They all agree that this results in temperature rises, but exactly how fast temperatures will rise in future, and what other impacts may arise out of increases in CO_2 levels, is not too clear. One thing scientists have attempted to do is to establish what the CO_2 levels in the Earth's atmosphere have been over thousands of year. If, say, 2,000 years ago there were CO_2 levels similar to the ones we have today, then we could look at what happened to the climate 2,000 years ago to understand what might happen today.

○ The scary thing is that the Earth has not got close to current CO_2 levels for a very, very long time. This we can see in the extended Keeling curve. The curve you see here goes back around 2,000 years. * It's clear that for most of the last 2,000 years, the concentration of CO_2 has remained at around 280 parts per million. But then something happened. The amount of carbon dioxide starting rising, * around 1850, and as we've seen earlier, we now sit at over 400. * So what happened around 1850? The Industrial Revolution happened. For the first time ever, we started burning coal in large quantities, * to run steam engines and industrial machines, and to heat houses. *

How do we know all this if Keeling only started measuring CO_2 in the atmosphere around 1960? How do we know how much carbon dioxide there was 2,000 years ago? We know this

[4] Note titled 'Why are seasonal CO_2 fluctuations strongest at northern latitudes?' at https://scripps.ucsd.edu/programs/keelingcurve/2013/05/07/why-are-seasonal-co2-fluctuations-strongest-in-northern-latitudes (accessed April 2018).

mainly thanks to ice cores. * Ice cores are long cylinders of ice which scientists obtain, using drills, in parts of the world where ice has covered the land for long time, in particular Antarctica. When ice is formed, it traps small bubbles of air. It is these bubbles scientists can use to find out what the air contained 2,000 years ago, even hundreds of thousands of years ago. It is these air bubbles which are used to fill * in this graph for the years before 1960. Scientists have been able to find air bubbles going back to 800,000 years * ago. During all these years, the level of carbon dioxide has remained low, hardly ever going above 300. * This means it is difficult to know exactly what the effects over time will be of the very much higher levels of CO_2 we have today, due to human activity. We could say that the Earth has not been here before. *

This graph is copied straight from the 2014 reports of the * Intergovernmental Panel on Climate Change, or the IPCC[5]. The IPCC is an organisation set up by the United Nations which has been releasing enormous reports every few years on things related to climate change, since 1990. The IPCC brings together thousands of scientists to interpret the data. The scientists do not always agree with each other on everything, which one should expect. The IPCC encourages the scientists to discuss their differences, and then indicates what we can be quite sure about, meaning what almost all scientists agree on, and in what areas scientists disagree. * The Keeling curve, data from the ice cores, the information in this graph, are things virtually all scientists agree on. ×

○ So far, the discussion has been about carbon dioxide, or CO_2. But there are other gases which are becoming more present in the atmosphere, and scientists are worrying about them too. * There's methane, or CH_4. * There's nitrous oxide, or N_2O. And there is more not shown in this diagram. Of these other gases, we are going to focus just on * methane, as after carbon dioxide, this is the gas with the largest impact on climate change. ×

○ Let's look at a few numbers that compare CO_2, or carbon dioxide, and CH_4, or methane. These numbers can be a bit confusing. Getting to understand them can help guide the actions people must take to reduce emissions. * First, we should note that though CO_2 makes up very little of the atmosphere – we've already seen it's just 400 parts per million, which is the same as 0.04 per cent – * methane makes up even less. Methane is just 1.8 parts per million, or 0.00018 per cent. We can think of it as follows. * If you have a city with a million people, representing the parts of the atmosphere, then only * two people out of the million would be representing methane. Can such a small fraction really make a big difference to the climate? As we'll see, in fact it can. * Here is the annual increase in the concentration of the two gases. * This comes to an annual increase of 0.6% year. * This comes to an increase of 0.3% – this is the increase that has been occurring in recent years. So, the growth in methane seems slower than the growth in CO_2. However, one should bear in mind that methane increases have changed a lot over time. They go up and down. In the 1980s the annual increase in methane was * three times this, and it is possible that it will go up again in future. * Global warming potential, or GWP *, is a statistic the scientists have come up with to compare the impact of CO_2 emissions to the emissions of other gases. These figures mean that, say, a kilogram of methane emitted into the atmosphere causes * 34 times as much warming of the atmosphere as a kilogram of carbon dioxide *over a period of a hundred years*. So, the GWP figures referred to here are actually * GWP100 figures. Usually, calculations are made which consider the impacts over 100 years. But one can use different time periods, and the results can be rather different. For instance, * GWP20 would be the impact over 20 years, and that would be much higher. In fact, * it would be 86, meaning the impact of a kilogram of methane would be 86 times as bad as the impact of a kilo of carbon dioxide[6]. Why does the years we consider make such a difference? The answer is that methane does not stay in the atmosphere as long as carbon dioxide. Over time, it breaks up into water, or H_2O, and, actually, carbon

[5] Intergovernmental Panel on Climate Change, 2013: 493.
[6] Intergovernmental Panel on Climate Change, 2013: 714.

dioxide, CO_2, so when we look at the impact of methane on global warming, we're looking both at methane as a greenhouse gas, and the carbon dioxide it eventually becomes. * Whatever the number of years we focus on, we can conclude that while much less methane is emitted than carbon dioxide, even small amounts of methane have large effects. Once one takes into account all the factors, and using * GWP100, so impacts over 100 years, ** we can say that while carbon dioxide is increasing at 2.4 parts per million, or ppm, per year, the *CO_2-equivalent* figure for methane would be an annual increase of 0.6 ppm's per year[7]. In other words, the problem of human-induced emissions of methane is around a quarter as large as the problem of our carbon dioxide emissions. * If we look at effects over just the * next twenty years, then the damage done by methane is almost as large as the damage done by carbon dioxide. In fact, there are scientists who say we have been worrying too little about methane, relative to carbon dioxide, and that we shouldn't only focus on what the impacts of emissions are over 100 years[8]. So, according to the scientists, what human activities contribute towards methane emissions? * Just under a third of these emissions come from leakages of methane produced long ago, and stored underground. The leakages come about when we for instance mine coal. * Most human-induced methane emissions come from agriculture, and the biggest cause here is ruminants. Farm animals such as cattle, sheep and goats are ruminants. They emit large amounts of methane, mainly through their mouths, because of the way they digest food and continually burp. * And their numbers have been increasing, though not as fast as for humans[9]. * One sometimes reads that the * farting of farm animals produces methane. That is true, but most of the methane these animals emit is through their mouths. * Note that when we burn methane to cook or generate energy, we emit mainly carbon dioxide, not methane, into the atmosphere, because methane is converted to carbon dioxide when we burn it[10]. ×

[7] While the value of 2.4 for CO_2 is readily available, the impact of methane in terms of CO_2-equivalent ppm is not seen in the literature. However, the 0.6 given here is defensible insofar as it is relatively clear in the literature that recent emissions of CH_4 have a quarter of the impact of emissions of CO_2 (using a 100-year impact). In particular, in Intergovernmental Panel on Climate Change (2014: 123) is clear that the impact of CH_4 is a quarter of that of CO_2 (here emissions are expressed in CO_2-equivalent tons). Yet the methane numbers can be confusing and should be explained better. One thing making methane effects difficult to understand is the fact that methane emissions move up and down in ways carbon dioxide emissions do not. Before 1990 rises in methane levels were higher than in the decades after 1990 (see for instance Figure 8.6 in Intergovernmental Panel on Climate Change [2013: 677]). What are very useful are the IPCC's simple carbon cycle and methane cycle diagrams, each of which follow the same format (Intergovernmental Panel on Climate Change, 2013: 471, 474).

[8] Ocko *et al*, 2017.

[9] Data for cattle from data querying facility of the Food and Agriculture Organization (FAO).

[10] Intergovernmental Panel on Climate Change, 2013: 507.

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