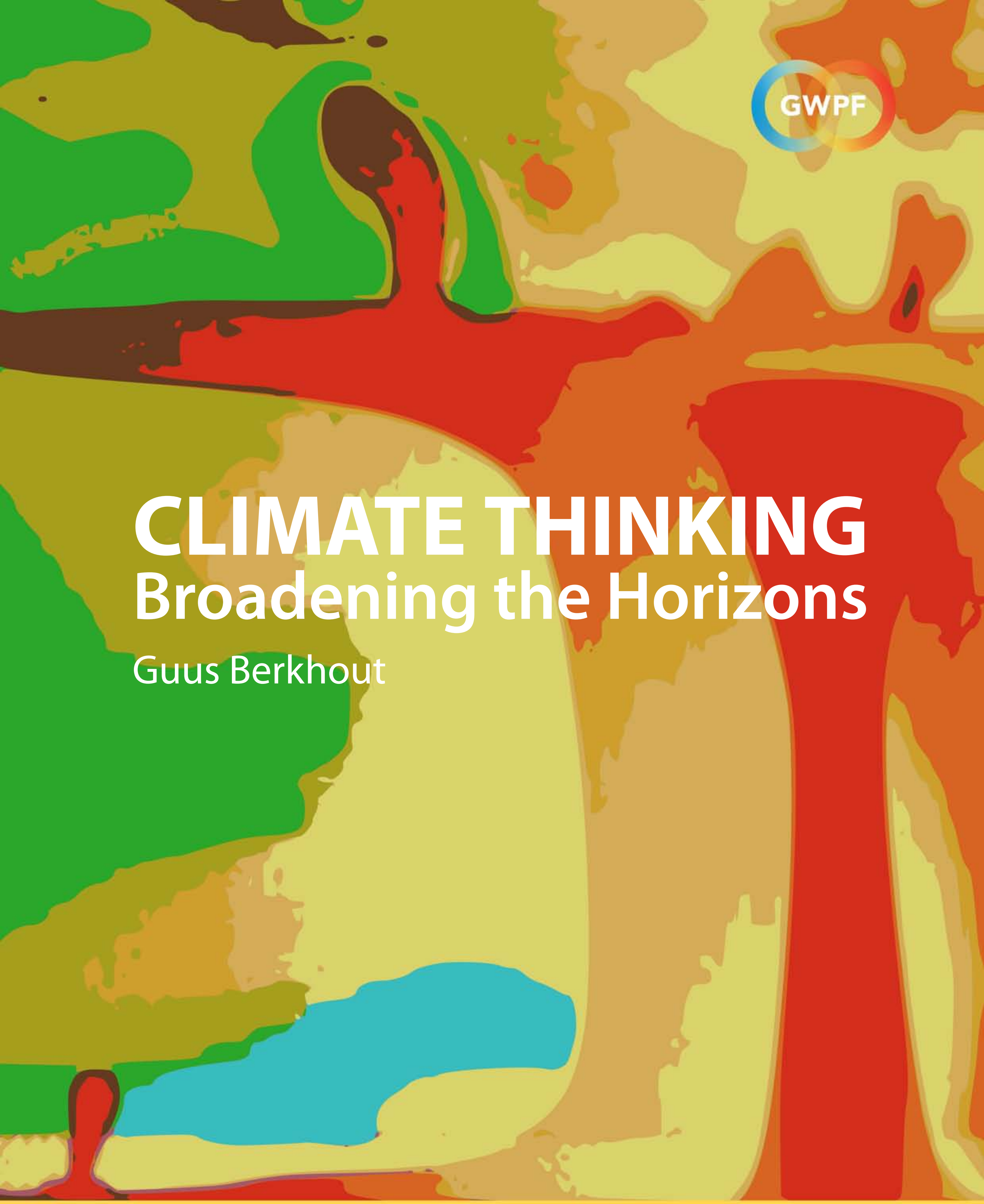


CLIMATE THINKING
Broadening the Horizons

Guus Berkhout

The Global Warming Policy Foundation
GWPF Essay 7

CLIMATE THINKING
Broadening the Horizons

Guus Berkhout

About the author

Guus Berkhout is emeritus professor in physics and seismic imaging at Delft University of Technology, The Netherlands. He is the founding director of the Centre for Global Socio-Economic Change (CFGSEC), a member of the Royal Netherlands Academy of Arts and Sciences (KNAW), and a senior member of the Netherlands Academy of Engineering (AcTI).

CLIMATE THINKING

Guus Berkhout

1 Summary: Realism above wishful thinking

Climate change is a fact. It is not a modern phenomenon but has always been with us. There has never been anything resembling a constant climate on our planet. Our climate has been continuously on the move. The Earth's history tells us that very cold periods ('glacials') have always alternated with very warm periods ('interglacials'). Travelling from a very cold to a very warm period and vice versa was not a smooth, predictable ride but a chaotic bumpy one. About 20,000 years ago we lived through the most recent ice age. Remains of this long, global winter are still visible. Today, we are living in a period of global warming; 'business as usual' in terms of the natural pattern of glacials and interglacials. It would be foolish to deny that.

The existence of climate change is beyond any doubt. The big question is: 'What is the principal cause of today's global warming? Is it mankind, or is it the natural system?' Without knowing the answer to this question, mankind could end up like a modern Don Quixote, fighting a foolish and pointless battle. Current climate policies are based on the conviction that 'the science is settled' and that mankind is the principal cause of global warming. It is also believed that our technological capabilities will enable us to shape the Earth's climate. But is there any scientific evidence for such a bold statement and for such an unconditional belief?

This essay gives an up-to-date overview of what we know and what we don't know about climate change. It is primarily meant for the millions of interested laymen who are desperate to hear a truthful story they can understand. These people have become suspicious of being misled by climate alarmists. As a group, they have the potential to put pressure on politicians to stop the use of poorly validated models and to focus on evidence-based climate policies.

The first message of the essay is that we can distinguish four principal causes of climate change (the so-called 'CCL' system):

- changes in the solar radiation and cosmic rays that reach the Earth's atmosphere;
- changes in the Earth's orbit and the orientation of the Earth's axis;
- changes in volcanism and heat convection from the hot inner Earth;
- changes in the emission of climate-affecting gases, produced both by Mother Nature and by mankind.

Note that the first three causes are entirely natural; only the fourth is a mixture of nature and man. The simultaneous interaction of these four phenomena with our turbulent atmosphere and oceans is extremely complex. Note also that planet Earth is unique in the solar system, having a surface that is 70% water. This property makes water a leading actor in the variations of the Earth's temperature. In addition, unlike carbon dioxide (CO_2), water occurs in three phases on our planet – gas, liquid and solid. Any change of phase causes an exchange of heat with the direct environment. It is not single-phase CO_2 but multi-phase water that is by far the most important influence on the climate in our atmosphere. This dominance of a multi-phase material brings extra complexity to the climate system.

The second message is that the Intergovernmental Panel on Climate Change (IPCC) has focused on only part of one component – emission of manmade CO_2 – from all influences

in the climate system. This narrow view makes the credibility of the IPCC's computer simulations highly debatable. Why focus on manmade CO_2 in this way? Why put aside all of the natural sources of climate change? Looking at the Earth's rich climate history, large changes occurred before mankind started to produce significant amounts of CO_2. Taking this hard fact into account, can we seriously claim with more than 90%(!) certainty that all natural causes of climate change are insignificant compared to the human-produced CO_2? In this essay we argue that – despite the excellent scientific work that is being done in the IPCC's working groups – the current lack of knowledge of the climate system does not allow us to draw such firm conclusions.

The IPCC's computer simulations cannot explain the significant climate changes that took place prior to mankind appearing on our planet; their work primarily refers to the last 150 years, a fleeting moment in the 4.6-billion-year history of the Earth. There is currently no theoretical or empirical evidence that the simplifying assumptions in the IPCC models are justified. On the contrary, there is increasing evidence that simulation of the real climate system is far beyond our current capabilities.

The third message is that scientific progress requires the availability of open databases with reliable measurements. After all, in professional research processes, theoretical models need to be tested and updated by comparing simulated measurements with real measurements ('model validation'). When measurements cannot be trusted, any reference to the truth is lacking and meaningful progress is prevented. Unfortunately this is exactly what happens in climate science, because of the poor state of global temperature databases. In many countries there is no information available about how temperatures have been measured, how the environment of measurement stations have changed over time (think of urbanization and/or industrialization), or how measurement stations themselves have been changed (new equipment and/or new locations). But, even worse, it also frequently turns out that raw measurements cannot be retrieved because databases have been lost or that data correction methods are not disclosed. Bear in mind, the mother database of climate science – the Global Historical Climatology Network – is used by all research organizations worldwide, but it suffers from all of the above shortcomings. This means that all of climate science is affected by unreliable measurements. Why has this alarming state of affairs not been taken in hand by the IPCC? Climate science must seriously consider starting all over again, giving priority to professional measurement technologies.

The fourth message of the essay is that we need to stop making predictions with the oversimplified and poorly validated IPCC computer simulations. Instead, it is proposed that climate scientists should put all their efforts into building a big picture of the climate system, involving all of the principal causes and interactions. To realize this huge ambition, we should take advantage of the current revolution in system modeling and digital measurement technology.

Future climate research should make use of reliable databases and validated theoretical models. Evidence from other scientific areas, such as astrophysics – related to items 1 and 2 of the CCL model – and geophysics, related to item 3, should play a more prominent role in climate science. This hopefully will bring about less arrogance in the climate community ('we know it all') and more curiosity to search for the truth. Such a renaissance will lead us to a better understanding of the Earth's climate past and present, making us ready to say something meaningful – albeit still subject to uncertainty – about the future.

The last, but not the least, message is that in recent years we have seen that the output of climate models have made a huge impact on society at large. This gives an extra responsibility to climate scientists: they are not only responsible for the scientific quality of their research but also for what society is doing with them. Of course, climate scientists don't need to explain the ins and outs of their models but they are morally obliged to make clear what the underlying theoretical assumptions are, what simplifications they have made and, above all, what this all means for practical policymaking. To prevent a huge waste of public money, climate scientists must resist any misinterpretation of their theory and any misuse of their models by politicians and activists. In that respect, IPCC has been of little help and the Paris Agreement of 2015 was a lost opportunity.

In this essay we will argue that 'the science is not settled at all' and that it is most premature to make a far-reaching agreement, as was done in Paris. When the future reveals that it is not manmade CO_2 but the natural system that is the principal climate-driving force, society will be very unforgiving to the scientific community, and they will be right to be so.

2 Climate change: mankind or Mother Nature?

It is far from clear to what extent mankind can influence the climate in any way that is significant in comparison with natural changes. Such a comparison has never been shown in the global temperature simulations! The climate models of the IPCC assure us that the increasing emission of anthropogenic CO_2 – particularly after World War II – is the prime cause of global warming. But so far, convincing proof is lacking.

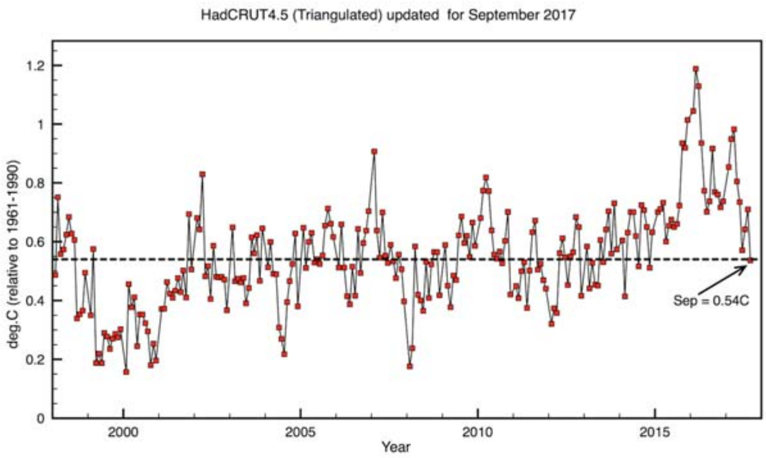
Figure 1 illustrates the issue. Figure 1a shows surface temperature measurements for the past 20 years. The moving average is rather constant, with a dip around 2000, and an El Niño peak around 2016. However, the IPCC models tell us that an alarming temperature rise must be taking place. This rise is caused by the strong positive CO_2-temperature relation that is implicitly built into the IPCC models.

Figure 1b shows that after the end of the Little Ice Age (ca. 1900), there were two short periods of temperature increase (1915–1945 and 1980–1995) and two stable periods (1945–1980 and 1995–present). Again, this picture shows that there is more going on than just the effect of CO_2.

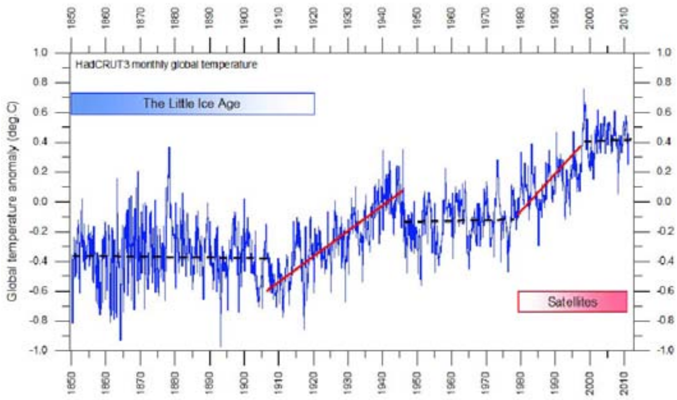
Figure 1c shows the long-term temperature record based on the Vostok ice core. It suggests that temperature changes on Earth are a cyclic phenomenon (from glacials to interglacials). Climate change was therefore a fact long before mankind had any impact on planet Earth. Note the erratic course inside the cycles. Note also that there exists a natural temperature boundary on the low as well as the high side.

The three examples above indicate that it is necessary to look at temperature variations over a long timespan ('context') before any sensible conclusions can be drawn about recent events. It is clear that research focusing on just a few decades will miss the broader context. Any conclusions drawn may therefore be incorrect and the resulting predictions will be misleading.

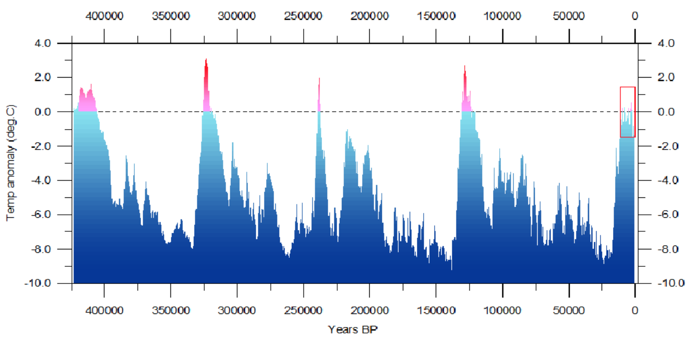
The data examples in Figures 2 and 3 illustrate the IPCC's struggle with reality.[1] In Figure 2 we see the continuously increasing CO_2 concentration in our atmosphere. There is no debate about the validity of this graph. In Figure 3, the temperatures are shown as computed and as measured.[2] We can indeed see that the alarming IPCC trend is not visible in the temperature measurements at all. Moreover, we can see that the IPCC's temperature predictions are highly correlated with the increasing CO_2 concentration. This does not mean that anthropogenic CO_2 does not play a role at all, but it appears that the IPCC is significantly overestimating the influence of CO_2.



(a)



(b)



(c)

Figure 1: Surface temperatures per HadCRUT (a) for the past 20 years; (b) for the last 160 years; (c) for the past 450,000 years, from the famous Vostok ice core.

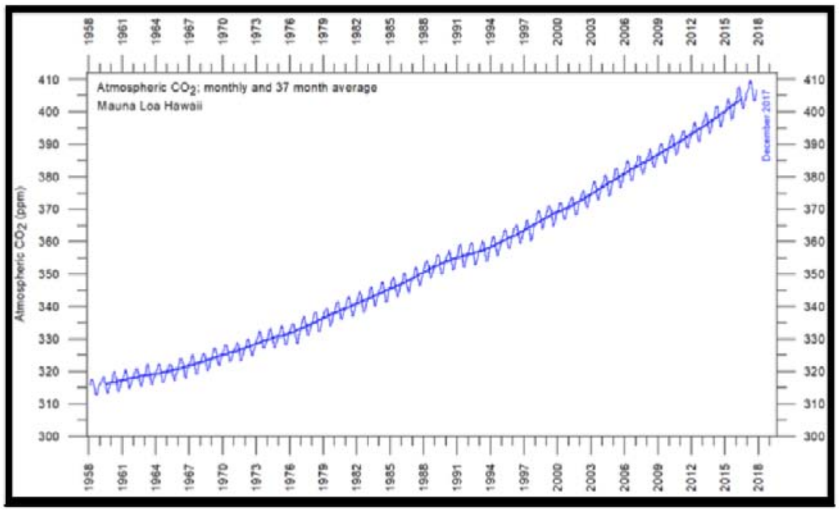


Figure 2: Carbon dioxide concentrations rise.
Concentration of atmospheric CO_2 (1958-2018) measured at the Mauna Loa Observatory, Hawaii. The thin line shows the monthly values, while the thick line is the simple running 3-year average.

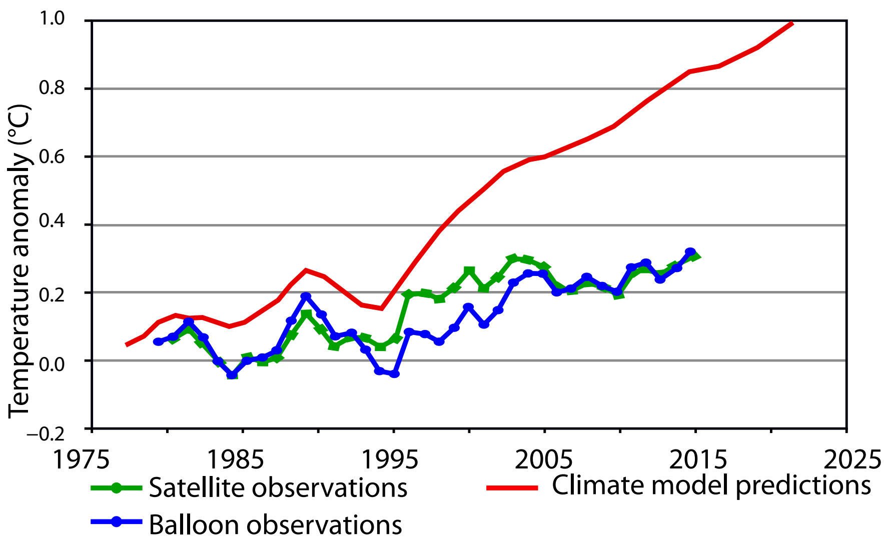


Figure 3: Temperature predictions versus observations.
IPCC modelling results (1975-2025) show that IPCC theory is not consistent with measurements. Note the strong correlation with the CO_2 trend. This is anchored in the IPCC's theory (more CO_2 means a higher temperature). After John Christy, (University of Alabama-Huntsville).

These results suggest that the essence of IPCC modelling is translating global CO_2 concentrations into global temperature. Both common sense and measurements suggest that the reality is a lot more complicated. Physically, there is much more going on in the climate system than global warming by manmade CO_2. This will be further discussed in the next section.

3 A big picture of the climate system

The problems the IPCC's climate models have in simulating the past, matching the present and predicting the future are not a surprise, as the complexity of the climate system is a world away from the IPCC's simplifications. Powerful natural forces from outer and inner Earth interact with the atmosphere, geosphere (continents) and hydrosphere (oceans) of the Earth in ways about which we often know little. These effects are therefore largely unpredictable if we are aiming at timescales beyond that of the weather (a few days). Note that the complexity of these interactions is further increased by the influence of living organisms (biosphere). Figure 4 shows the so-called 'circular climate' (CCL) model, which summarizes these interactions schematically. It gives a pictorial overview of the prime physical phenomena in the climate system, telling us that there are many more factors affecting global temperatures than the carbon dioxide content of the atmosphere.

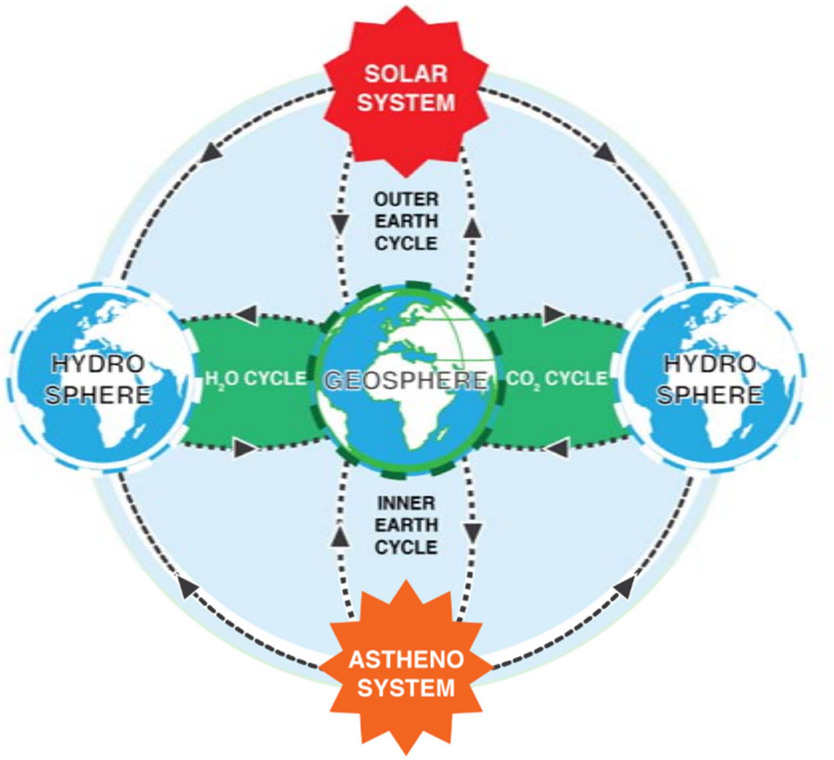


Figure 4: The CCL model.

The Earth's climate is determined by complex interactions between four phenomena: (i) solar and cosmic radiation (from above); (ii) heatspots and volcanism (from below); (iii) the water vapour cycle; (iv) the carbon dioxide cycle. Both cycles are essential for a green Earth. Note also that arrows mean flow of heat and/or climate-affecting factors.

Starting at the top of the model, the sun delivers enormous amounts of energy by radiation: every second the Earth receives 712,000 TJ. This impressive heat flow is absorbed and reflected by the atmosphere and surface, and stored, released, radiated and transported (convection currents in air and water). Complex positive and negative feedback processes are at work in, on and along the Earth's surface (land and water) as part of the water vapour and carbon dioxide cycles. These cycles may involve other factors that affect the climate, for example aerosols (suspensions of small particles in the atmosphere). These are depicted on the left- and right-hand sides of the model.

In our solar system, the Earth is unique, as 70% of its surface is covered in water. Therefore, oceans play a central role in determining the climate (see dual position of the hydrosphere in the CCL model). For instance, they are enormous reservoirs of water and carbon dioxide molecules. These molecules are released when the water temperature is rising and are stored when the water temperature is falling.

Note that the Moon is at about the same position as the Earth in our solar system and, therefore, the two bodies are more or less equally exposed to solar and cosmic radiation.[3] However, the Moon has no atmosphere. Let us compare their temperatures. We know that on the Moon the temperature varies consistently between about −130°C and +130°C. On Earth, extreme temperatures range on average from −40°C to +40°C. Our atmosphere makes the difference. As the exposure from space is approximately the same, the water and carbon dioxide cycles must be responsible for moderating the temperature range. Together, they represent an effective natural control system, with positive and negative feedback loops that keep temperatures within tolerable bounds. It may therefore be better to consider water and carbon dioxide to be thermostatic gases rather than greenhouse gases, and not separately but in combination.

As already mentioned, the surface of our blue planet is 70% water – the so-called 'hydrosphere' – and only 30% land; the 'geosphere'. Water is unique because it occurs in three phases (gas, liquid and solid) on our planet. In a warming period, energy is extracted from the environment during evaporation and melting. Similarly, in a cooling period, energy is released to the environment during condensation and freezing. This means that each phase change is working against a temperature change; in other words it is a 'negative feedback'. The temperature influence of the multi-phase water cycle is many orders more complex than that of the single-phase carbon dioxide cycle.

In similar vein, consider also the influence of cloud cover on temperature and humidity at the surface. Recent research results show that cosmic rays may play a key role in cloud formation.[4] Can we really generate a representative model of the climate when our understanding of variables such as solar and cosmic radiation, volcanism, and hotspots from inner Earth is poor?

Apart from their temperature function, water vapour and carbon dioxide are also key components in forming the building blocks of life (carbohydrates) and therefore both are also indispensible for a flourishing biosphere. Hence, the combination of water and carbon dioxide not only regulates temperatures, but it also causes the Earth to become and stay green. Shortage of water and carbon dioxide causes a loss of natural green and this leads again to a disturbance of both cycles.[5] Deforestation – not just for agriculture and for building materials, but increasingly for energy – has devastating consequences.[6] It is therefore hard to understand why 'green' climate policies have degenerated into a crusade against CO_2. Carbon dioxide is for plants and trees what oxygen is for humans and animals (Figure 5).

Figure 5: A poster from a recent academic symposium on 'toxic gas CO_2'.
Note that today's average CO_2 concentration in the atmosphere is 400 parts per million (ppm), in city air 700 ppm, in city air inside houses 1400 ppm, in exhaled air 40.000 ppm (about 4%). Below about 150 ppm, vegetation will disappear (also meaning that no oxygen will be generated). About 97% of CO_2 emissions is absorbed by the oceans; part of this absorbed CO_2 is transformed into 'young fossils'.

Finally, at the bottom of the CCL model, there is the effect of the heat flows from within the Earth. In the semi-fluid mantle ('asthenosphere'), temperatures are several thousands of degrees centigrade, and this causes material and heat to flow just below the Earth's crust. The moving rock exerts so much force that the Earth's crust moves ('continental drift'), and causes mountain ranges and volcanos to form. This not only causes earthquakes but also changes the position and shape of continents and, therefore, the ocean–continent distribution. This again causes changes in the nature of the oceanic currents and thus the heat distribution across the planet. At the same time, there are places where the inner heat flow reaches the Earth's surface ('hotspots'), locally melting ice sheets and warming up oceans from below. The influence of the forceful asthenic system on the Earth's climate may be seriously underestimated.

In the next section it will be explained that the rocks near the Earth's surface ('lithosphere') hide an impressive archive of the geological history of our planet. We will see that Earth scientists can decipher what happened in a distant past, including climate changes.

In summary, the CCL model shows us that climate change is a very involved process, caused by highly complex phenomena: the interaction of the driving natural sources (upper and lower part of the CCL model), with water and carbon dioxide loops in the Earth's atmosphere (left- and right-hand sides of the CCL model). Hence, to understand the climate system, we need to know the properties of these natural sources of climate change and their impact on the Earth's natural cycles.

In system terminology, this impact is referred to as the 'source response'. Hence, in this essay, climate is described as 'the response of a system that is excited by external sources'. Unfortunately, in the current debate, the idea of a source response is hardly mentioned. We passionately discuss small details of the carbon dioxide issue (at the level of differential equations), but the overall picture of the climate system – in terms of driving sources with related

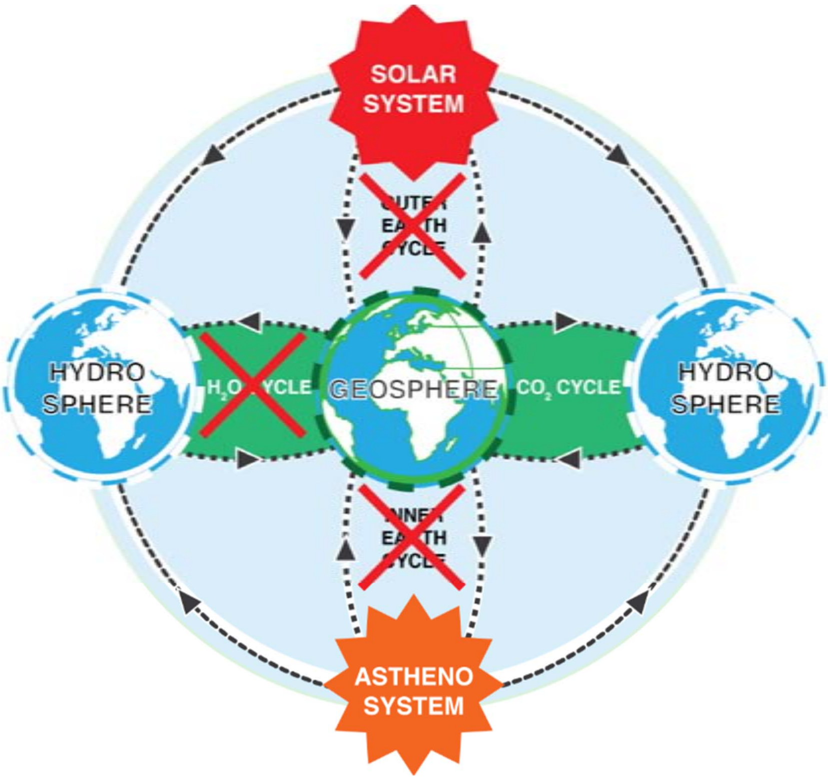


Figure 6: What IPCC models miss.
In today's IPCC climate models the carbon dioxide cycle plays a central role and manmade carbon dioxide ('anthropogenic CO_2') is indicated as the prime cause of global warming. In this way, climate policy is narrowed down to a 'war on CO_2', with big consequences for global energy policy.

system responses – remains out of view. Therefore, dealing effectively with the climate question is not only a matter of more research; we also have to change our mindset and think in terms of a heat control system: the natural sources as external disturbances, the oceans as immense reservoirs of heat and carbon dioxide, the atmosphere as a complex pathway with positive and negative feedbacks, and living organisms (including human beings) as users and producers. In this way we can separately analyse the role of the driving sources and the properties of the different system components that together create the response.

The schematic presentation of the CCL model in Figure 6 suggests that the IPCC is looking at the climate system through a CO_2 keyhole and over a very short timespan as well. This narrow approach does not add much credibility to their overconfident statements about the future of the Earth's climate. Reality is much more complex than is implied by this fixed focus on carbon dioxide levels. Climate science must open its eyes to a world that is wider than that portrayed in general circulation models.

As we mentioned earlier, climate models should at least be able to explain the past. Here, indirect measurements from different disciplines play a crucial role (see Figures 1b and 1c). When we understand the past, we can interpret today's direct measurements in the proper context (Figure 1a). Only when that is achieved are we in a position to say something meaningful about the future. Given the huge complexity of the climate system, we are only at the initial stage of developing predictive climate models. If we want to speed up progress, we need to broaden the IPCC approach. New methods and players in Working Group 1 are very much needed (see below). This is no surprise: in scientific circles, awareness is growing that when studying complex phenomena one needs to take down the walls that separate different knowledge areas.

In this respect, to minimize the endless debate about the physical meaning of averaging temperatures on a global scale and using this global average as a key indicator for climate change (traditional approach), let us use the concept of global heat content (GHC) instead. Unlike global average temperature, GHC is a meaningful physical quantity (expressed in Joule) that depends on the specific heat capacity, the density and the temperature in each grid point of the medium (air, water) under consideration. Note that by using GHC we implicitly apply a very smart temperature-averaging process that is physically and mathematically fully correct. In addition, we can easily quantify that oceans are key, not only because they represent a huge volume but also because the heat capacity of oceans is several thousand times larger than that of the atmosphere.[7] Figure 7 shows the implementation of heat content in the CCL model.

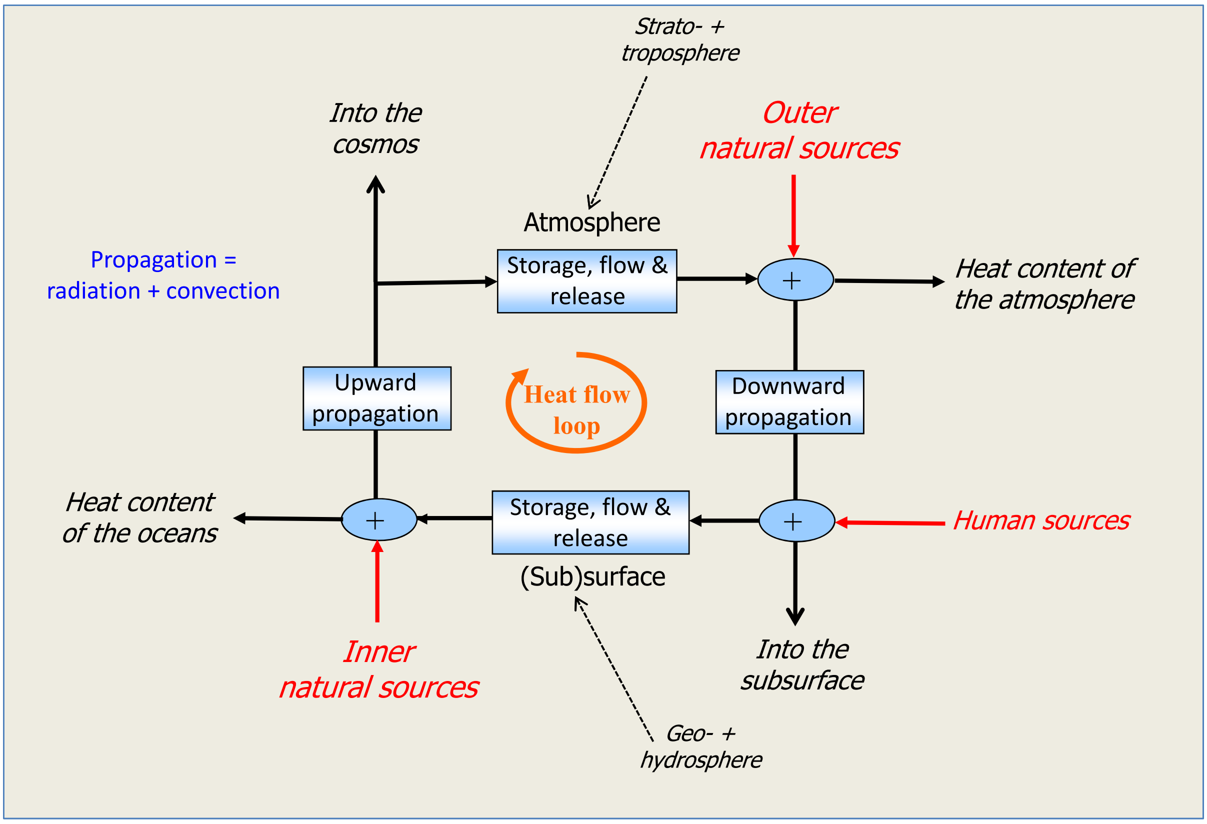


Figure 7: System description of the CCL model.

The figure shows the climate-driving sources and the different system components. These sources drive the complex physical processes that generate the heat flows in the loops. The principal output consists of heat content in the oceans and the atmosphere at each moment.

For readers who are interested in a little more detail, the diagram of the CCL system separates the climate-driving natural sources (outer and inner) and human sources (CO_2, aerosols and heat) from the system components. Each system component is represented by a matrix operator. It propagates the system variables, being represented by a vector, during their trip in the circulation loop. The principal output is heat content at each grid point and each moment of time. Together they form the output vector at each moment of time. Note that the gradient of the heat content equals the heat flow vector (in joules per second). Under simplifying conditions, the heat flow vector is determined by the Navier-Stokes equations.

For the same readers, a most interesting numerical experiment would be to show the influence of different feedback assumptions (positive and negative) on climate sensitivity. Another highly informative experiment would be to keep the manmade contributions constant. In this specific situation the changes in the output variables are exclusively due to the natural sources. According to IPCC, these changes would be insignificant, but is this just an assumption? And if so, based on what? The IPCC has never shown simulation results that compare temperature curves, with and without manmade contributions, for the past, the present and the future. Note that simulations of the past would be particularly interesting as they represent automatically changes without the influence of mankind. Note also that by continuously comparing the simulated output vector with the measured output vector, the source and system parameters are updated. In this way we create a *learning* climate system.

As we already mentioned in this essay, today's global temperature databases are rather messy. In many countries there is no information available about how temperatures have been measured, how the environment of measurement stations have changed over time (think of urbanization and/or industrialization), how measurement stations themselves have been changed (think of new equipment and/or new locations), and so on. But it also frequently turns out that raw measurements cannot be retrieved because databases are lost and/or data correction methods are kept secret. Bear in mind, the mother database of climate science – the Global Historical Climatology Network (GHCN) – is used by all research organizations worldwide, but it suffers from all of the above problems. This means that all of climate science is infected by sloppy measurements. In my own research institute (CFGSEC), we are working on the following recommendations:

- *Apply array technology:* Don't use traditional point measurements, but design measurement stations (on land and at sea) that consist of a spatially distributed array of multifunctional sensors, measuring density, pressure, velocity, temperature, humidity, aerosol concentrations, CO_2 content, etc. In this way, location noise becomes visible, a quality factor can be assigned to the array output, and the local heat flow vector becomes available as well.
- *Calibrate satellite measurements:* Implement the high-quality output of the station arrays for satellite calibration purposes, aiming at translating satellite measurements into surface data. This means that satellites take care of the fine coverage, allowing scientists to position the calibration stations at ideal locations only (stable meta-data).
- *Utilize independent proxy data:* Due to the high complexity of the climate system and the imperfections of proxy data, analyse independent measurement series. Conclusions must be consistent across all data sources used.
- *Create green laboratories:* We invest in laboratories for research on many problems, but for climate research computer modeling appears the only tool. Why not make controlled environments to study the many complex feedback properties in the climate system. For instance, modern greenhouses are loaded with measurement and control equipment. They are perfect 'laboratories', with well-defined climates and well-defined biotopes, for the study of the complex interaction between atmosphere and biosphere. There are millions of these 'laboratories' in the world.

Current plans in CFGSEC also include analysing the direct and indirect measurements by higher-order statistics in terms of full probability distributions, not only globally but also for the different climate zones.[8] We think that working with just global averages (global first-order statistics) is not the way to continue.[9] We need distributions for each individual zone.

We also focus on auto- and cross-relationships for the determination of predictive components in the driving sources and in the system response. This actually means that we are looking at minimum-phase components in the data.[10] Minimum-phase systems have the unique property that their future behaviour is fully predictable from the past (think of the trajectory of planets in our solar system). If an algorithm claims that it can predict the climate future from the past with high certainty, it actually assumes that the climate system is a minimum-phase system. That is a bold assumption, and in reality probably only applies to the world they modelled and not the world we live in. Causal predictions of system behaviour with a mixed-phase property lead always to a hockey-stick outcome. A further discussion on predictability is beyond the scope of this essay.

4 Climate stories

In the following, a plea is made to get a wider description of the CCL system by giving Earth scientists and astrophysicists a more prominent role in IPCC's Working Group 1.

The climate story of Earth scientists

Earth scientists will continue to provide an important contribution to data-driven discoveries regarding the history of our climate. They have already convincingly shown that climate change was happening (far) before man evolved. Earth scientists are geological detectives, able to reconstruct the past on the basis of the rich geological archive of our planet.[11,12] This spectacular past – a series of small and large cold periods with brief warm periods in between – is hidden in the complex geological layers of the lithosphere, representing a 'natural 3D print'. Worldwide, Earth scientists are mapping these layers, and their work has resulted in many insights about cause and effect.

Earth scientists can also use the geological archive to reconstruct sea-level change over time.[11] At the beginning of every ice age we observe an impressive worldwide sea-level drop (over 100 m), which is followed by a similar sea-level rise when entering the next warm interglacial. The archive shows a series of these cycles. Temperature and sea-level anomalies are fully consistent. At the present time the sea level is rising at a small and constant rate. We measure some 18 cm per century over the last few thousand years (about 1.8 mm per year). This fits with our current move to the next interglacial. Note that in many deltaic areas the manmade land subsidence is much larger (in the Jakarta area, subsidence is about 2 cm per year). Sea-level rise and subsidence are often confused and climate change is then claimed to be the culprit.

As we saw in the system description of the CCL model, Earth scientists also look below the lithosphere into the asthenosphere (Figure 8). We have mentioned already that enormous forces, caused by the heat convection in this part of the subsurface, are able to create mountain ranges and move the continents. These primordial forces also cause (submarine) earthquakes and (submarine) volcanic eruptions. Is it possible that they are (partly) responsible for climate change, perhaps by way of recurring phenomena like La Niña and El Niño?

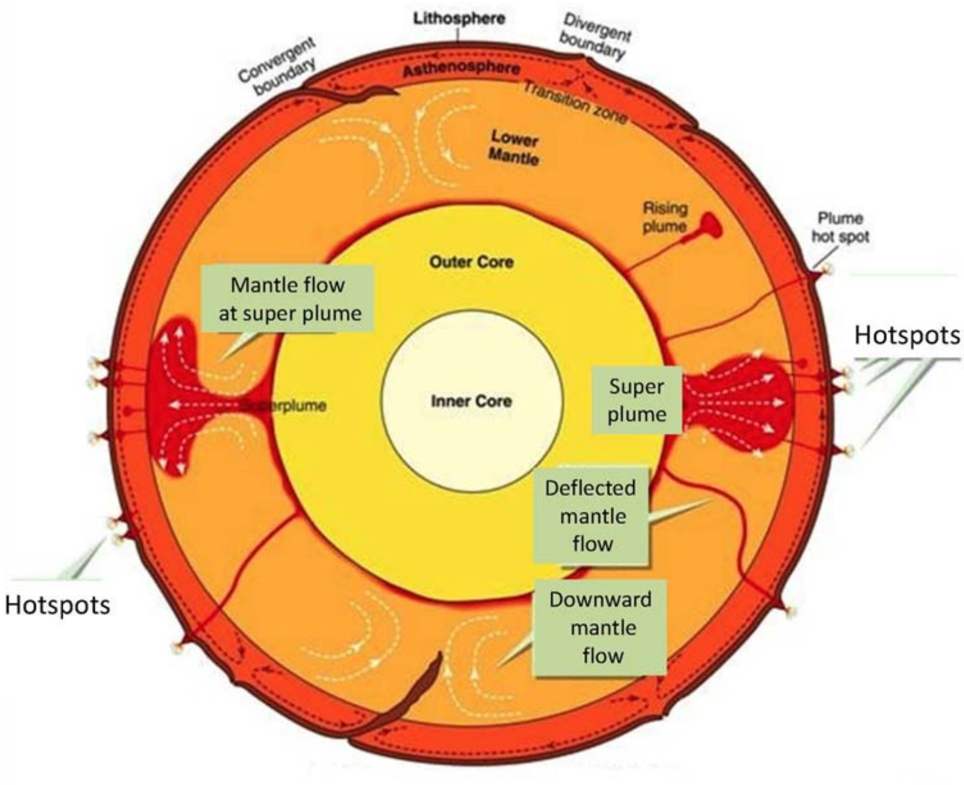


Figure 8: The mantle plume is a column of melted rock that rises through the mantle and the lithosphere to the Earth's surface and may cause volcanism and hotspots. Little is known of mantle plumes that flow out into the oceans. This also applies to the mantle plumes under the kilometres-thick ice sheet of Antarctica.

A recently published study from NASA lends support to this 'mantle plume' hypothesis.[13] The study indicates that the instability of the Antarctic ice mass observed in 2017 may be caused by pulsating volcanic activity deep below these ice sheets. In early 2018, researchers from the Arctic Research Centre of Aarhus University published a paper that showed that the deep bottom water of the north-eastern fjords of Greenland is being warmed by mantle plume hotspots.[14] This natural heat source triggers the sliding of glaciers from the ice sheet towards the sea. This natural phenomenon reminds us that heat not only comes from above (solar radiation) but also from below (mantle convection). Also, this heat source from below is beyond human control.

Another item of great significance is that in the geological archive one finds that CO_2 concentration variations in the atmosphere follow the temperature variations with a noticeable time lag (see Figure 9). This is a critical empirical finding when trying to answer the question of causality: 'Are the observed variations in atmospheric CO_2 levels caused by mankind (the justification of present climate policy) or are they effects of changes in the driving natural sources?'. In other words, we may need to turn the question around. Rather than: 'Is the increase in temperature caused by a higher CO_2 concentration?' we could also ask: 'Is the higher CO_2 content of the atmosphere due to a global temperature increase, and if so, with what time lag?' Until now, measurements do not reveal any clear indication for a dominant anthropogenic origin (note that in this discussion the concepts of causality and correlation

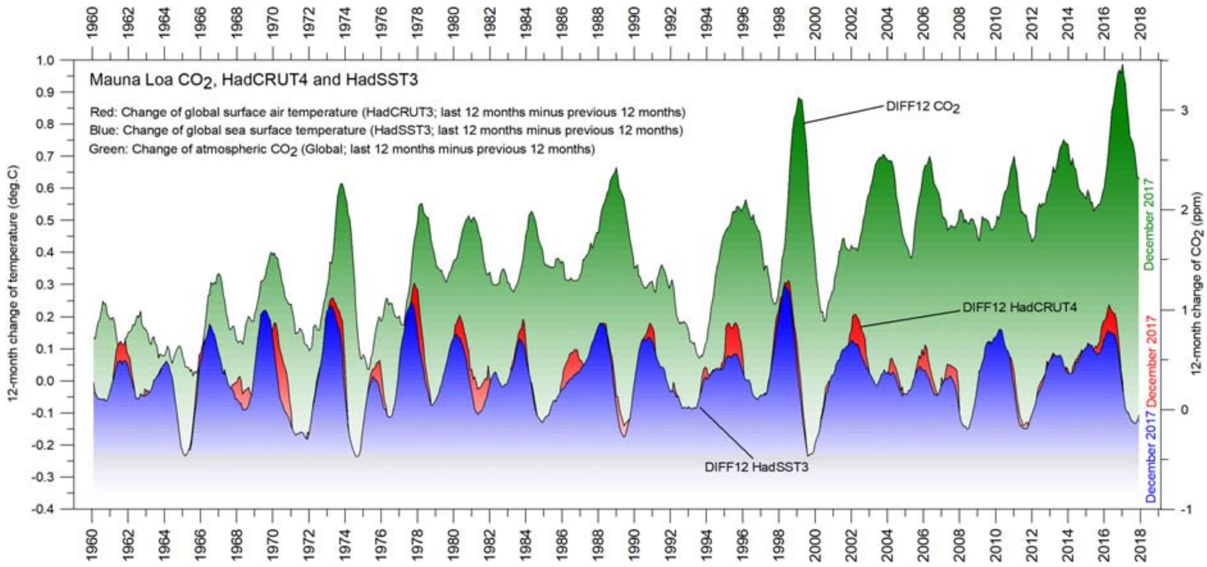


Figure 9: Differential CO_2 concentration (Mauna Loa; in green), global sea surface temperature (HadSST3; in blue) and global surface air temperature (HadCRUT4; in red).[1]

Note that the graphs show that the CO_2 concentration has a delay with respect to the temperature curves. From Humlum 2018.

are regularly intermixed by climate activists). IPCC scientists in Working Group 1 should explain more convincingly why these measured time differences are the opposite of what they use in their models: time advances instead of time delays.

The climate story of astrophysicists

The Sun has a dramatic influence on the Earth. We all experience that in our daily life (and this does not take a degree in astronomy):

- The Earth is a planet rotating on its axis, which causes the circadian (day-night) rhythm. The differences in insolation cause day and night temperatures to differ by 10°C, or under clear skies, more than that. Think about the desert climate.
- The Earth orbits the Sun, and the axis of rotation is tilted with respect to the orbit around the Sun. This causes the seasonal variations in temperature, which can amount to several tens of degrees. As we know, this happens every year.
- The orbit around the Sun has an elliptical shape. However, the eccentricity of the ellipse changes in cycles lasting about 100,000 years (the big Milankovic cycles). Because the influence of insolation is so large, it is no surprise that small fluctuations in the orbital shape have a large influence on temperatures on Earth. The geological archive shows crystal clear how the large cold ('glacial') and warm ('interglacial') periods on Earth are in sync with these big Milankovic cycles.[11,15,16] Some geological outcrops allow these cycles to be seen with the naked eye![11] Hence, what astrophysicists predicted, is confirmed in the geological archive when read by the geoscientist. It represents a beautiful illustration of how science can flourish through cooperation of different knowledge areas. Geologists have observed ten such cycles in the last one million years. Extreme hot and cold periods are not singular and random, they are

repetitive and cyclic. There is no indication that these cycles will not occur in future, implying that we are on our way to the next interglacial.

Combining knowledge about Earth dynamics with the study of the geological archive gives more important clues on factors influencing temperatures. Because the axial tilt of our planet is not constant, but slowly changes its angle, and the Earth also shows precession movements, Milankovic predicted two smaller temperature cycles, with periods of 43,000 and 21,000 years respectively. These are also observable in the geological record.

Recently, more cyclic variations with smaller periods have been discovered. These are caused by variations in solar activity,[17] cosmic radiation[4] and variations in warm and cold ocean currents.[18] Hence, the erratic fluctuations in temperature we observe are a sum of many more or less periodic components. Using classic Fourier analysis ('spectral analysis'), we can retrieve the cycle duration and magnitude of the principal periodic components from a measured temperature series. Note that long periods require long temperature series!

In summary, a major contributor to climate change is the variation in Earth's orbit around the Sun (cycles of about 100,000 years), followed by variations in tilt of the Earth axis (about 43,000-year cycle), those in the precession of the Earth around its axis (about 21,000 years) and in addition – with decreasing global impact – the countless smaller drivers such as solar dark spots, cosmic radiation, volcanic eruptions, terrestrial hotspots, La Niña and El Niño, etc. While the long cycles have a worldwide impact on climate, the short cycles may be responsible for local changes only. For the very short cycles, we should not refer to 'change of climate' but to 'change of weather'.

Let us introduce a new time unit: climate year, being 100,000 calendar years. Hence, in one climate year we move from the global winter (glacial) via the global spring to the global summer (interglacial) and via the global autumn back to the next global winter. Note that the age of planet Earth equals 46,000 climate years. A climate analysis over 10 calendar years means an analysis over 54 climate minutes only. It shows the ultra-shortness of such a period on the global climate scale. Analysis windows in the order of 10 calendar years are debatable for valid conclusions on climate change (10 calendar years is not even one climate hour).

We often see extreme weather being thought of as a sign of climate change (Figure 10). Measurements show, however, that in a particular climate period the weather may jump up and down (Figures 1a–c), not only along the time coordinate but also along the spatial coordinates (e.g. compare the very warm winter in Spitsbergen and the very cold winter in the USA early 2018). Averaging temperatures is an art in itself, particularly when measurement positions are very irregularly distributed. Today, small temperature changes are discussed by looking at double averages (temporal and spatial) without knowing anything about the underlying statistics. We have argued already that double averages are not very meaningful and should be replaced by quantities that are related to heat content.

5 Common sense versus poorly-validated algorithms

The general public knows from personal experience the enormous influence of the Sun. We feel the difference in temperature between night and day and summer and winter. Spectacular differences between summer and winter in the Arctic and Antarctic regions are beautifully visualised in the nature documentary *Frozen Planet*. Common sense suggests that changes in heat flow due to changes in solar radiation, whatever the reason, must be part of any climate model.

Figure 10: Snow in the Sahara in 2017.
This illustrates that within one climate zone the weather conditions may change significantly. It also tells us that an extreme hot summer does not mean that the global warming theory is correct. Similarly, an extreme cold winter does not mean that we are on our way to a new ice age.

Most people have little knowledge about the hypothetical IPCC models, but they are getting increasingly suspicious. Why are changes in solar radiation ignored? In the Earth's history, they were always responsible for major climate changes. For instance, people know of the existence of the last ice age. And the general public also knows about the large effects of the water cycle by experiencing the temperature effects of a cloud cover: less warming during the day, less cooling during the night. However, clouds cannot be properly modelled in the IPCC circulation models and they have to be 'parameterised' instead. Changes in solar radiation, changes in cloud formation, changes in hot and cold ocean currents, and the changing influence of hotspots on ice sheets are of little interest to climate alarmists. Only short-term changes in the manmade CO_2 concentration get their attention. Their message is embarrassingly one-sided and primarily focussed on fear: 'If we don't get rid of CO_2 soon, we will be toasted, roasted and grilled'. This is not science; it is politics. Using a little common sense and taking into account the system uncertainties involved, the IPCC's one-dimensional causal relationship between carbon dioxide and temperature seems less and less likely.

We have already discussed that independent areas in science tell us that changes in the inner and outer sources of the natural system are responsible for the large climate cycles (sequence of global winters and global summers) over millions of years. There is no evidence that these driving natural sources have stopped being active today. This means that we are surfing on a big natural climate wave that is bringing us, via a bumpy journey, to the next global summer (interglacial). We should not fight this wave like modern Don Quixotes; instead we should adapt to it and, even better, try to use it to our advantage. In other words:

‘How can we benefit from the next interglacial?’

However, despite the significant influence of the climate-driving sources in the natural system, climate alarmists and politicians are still convinced that if we ban manmade CO_2 we can control the Earth’s climate. Consequences of such a conviction are dramatic. For instance, let us look at the energy plans to fight CO_2. Today, the energy consumption of 7 billion people amounts to 11 Gtoe per year.[19] In 2050, it is estimated that 10 billion people will consume at least 16 Gtoe per year (if future poverty-reduction programs are very successful, it will be more). If we aim at a 50% share of fossil fuel in 2050 (today it is 80%), then 8 Gtoe has to be generated from nonfossil sources. This is entirely unrealistic.[20] Some environmentalists have even come up with the idealistic goal of a 10% share of fossil fuel in 2050. Why do they refuse to use their common sense?

Note that the level of wealth is highly dependent on the security of supply of affordable energy.[8] Pushing an ideology with embarrassingly unrealistic energy transition goals will certainly lead to a significant loss of wealth. Socio-economically, that is a very unsustainable policy.

We should ignore the IPCC’s predicted CO_2 apocalypse, reject the half-baked energy transition plans and buy time by aiming at a longer fossil fuel transition, say by replacing coal by clean natural gas. This would already be a huge achievement, with invaluable benefits for our natural environment.[21] Meanwhile we can improve electricity storage technology and, last but not least, search for new energy sources. We must acknowledge that wind turbines and solar panels alone will never be able to secure the energy needs of future generations.

In conclusion, the next interglacial is on its way. Therefore, let us change our mindset about climate change and stop all these miserable apocalyptic stories. Instead, let us be positive and think about how we can benefit from the next interglacial.

6 Epilogue: could we start again, please?

What would have happened if the ‘Intergovernmental Panel on Climate Change’ had started as an open ‘Interscientific Panel on Climate Change’? And what would have happened if the mission of this Interscientific Panel had been to determine the causes of climate change with an open mind, in other words with no specific assignment to find out whether the cause could be manmade CO_2. In addition, what would have happened if this Interscientific Panel had given a high priority to the reliability of climate measurements and the validation of their models?

The Intergovernmental Panel was managed by key officials from governments that had a firm grip on the coordinating lead authors. From the beginning, they has little interest in improving measurement technology. Instead, building computer models appeared to be their prime objective. In addition, validation was low on their priority list, They also made it clear that finding evidence for a manmade cause (CO_2 emissions) was considere good news. Unsurprisingly, this encouragement led to an extra bias in the focus on research. Favourable evidence was preselected and computer models were constructed that confirmed the anthropogenic cause. These models even claimed that they had could make predictions out to the year 2100. As a result, predictions were (and are) very alarming, and stated with increasing certainty.[22] Alternative views were (and still are) not welcome. Model falsification was (and is) considered a hostile act. At some universities we even see what amounts to a regime of ‘climate-marxism’. The theme of this essay is that we still know very little about the climate.

The time of the Intergovernmental Panel – with all the scandals at its top – can be seen as a dark period in the history of climate science. My plea is: 'Could we start again, please?', this time with a sincere *interscientific* panel that searches for the truth, operating with an open mind, with interdisciplinary teams, with an emphasis on repeatable multidisciplinary measurements, with model verification as an obligatory research routine, and with an honest story to tell to society. Would that not be wonderful?

We have the privilege to live on a miraculously beautiful planet, unique in our solar system. Let us use all our knowledge and means to make the right choices to keep our planet as unique and beautiful as it is. I sincerely hope that the views in this essay will contribute to that goal.

7 Acknowledgements

Special thanks go to Ir. Kees de Groot for the many discussions about the fascinating world of paleoclimatology and the great impact thereof on the present day climate research. I also like to thank my colleague Prof. Dr. Ir. Dick Thoenes for his insight in the complex physical and chemical properties of the atmosphere. Finally my thanks go to Dr. Ir. Leo Ongkiehong for his critical review and editorial assistance in making this essay readable for the non-expert.

Notes

1. Ole Humlum, 2018, The State of the Climate, GWPF Report 30.
2. Due to the polluted databases of GHCN, these temperature measurements are under debate. For instance, measurements may not be properly corrected for the effects of urbanization and industrialization ('urban heat island effect').
3. As the Moon orbits the Earth, variable gravitational forces influence ocean tides and currents, causing changes in weather conditions (*Climate Change, The Facts*, 2017, Chapter 4).
4. Svensmark H and Calder N (2003) *The Chilling Stars, A new Theory of Climate Change*, Totem Books.
5. For example, Justdiggit is an organisation that makes a plea for a greener Earth by better utilization of the water vapour cycle, www.justdiggit.org
6. Annie Proulx (2017) *Barkskins*. HarperCollins; see also www.waterparadigm.org.
7. The use of ocean heat content was already advocated by Roger Pielke in 2003 in a paper in BAMS.
8. Berkhout G and Poliakov E (2016) First World Prosperity Outlook, Center for Global Socio-Economic Change, The Hague.
9. Using higher-order statistics is common practice when analysing processes in the economic system. Compare income in economics with temperature in climatology.
10. Berkhout G (2018) Closed-loop multiple scattering imaging with sparse seismic measurements. *Geophysical Journal International*, January 2018.
11. Kroonenberg S (2006) De Menselijke Maat, Atlas Uitgeverij (also available in English).
12. Carter R (2010) *Climate: the Counter-Consensus*, Stacey International
13. Seroussi H and Ivins E (2017) Influence of a West Antarctic mantle plume on ice sheet basal conditions, *Journal of Geophysical Research*, August 2017.
14. Rysgaard S (2018) Heat loss from the Earth triggers ice sheet slide towards sea, *Journal of Geophysical Research*, January 2018.
15. Hays, Imbrie and Shackleton (1976) Variations in the Earth's orbit: Pacemaker of the ice ages. *Science*; 194: 1121-1132
16. Ruddiman, W.F., 2001, *Earth's Climate: Past and Future*. Freeman & Co.
17. Climate Change, 2017, Institute of Public Affairs, Melbourne, Chapter 3; see also the excellent summary by Dick Thoenes at www.climategate.nl
18. Moffa-Sánchez P and Hall, IR. (2017) North Atlantic variability and its links to European climate, *Nature Communications*; 8: 1726.
19. 1 toe = 1 tonne of oil equivalent = 11.6 MWh.
20. See also de Groot, K (2018) www.climategate.nl/2018/03 (in Dutch)
21. Should we not give priority to the alarming degradation of our natural environment, instead of spending lots of money on reducing human CO_2, the result of which is very uncertain?
22. In the IPCC's reports, certainty on 'human CO_2 being the cause of global warming' was qualified by the terms 'likely' (second report), 'very likely' (third report), 'most likely' (fourth report) and 'almost certain' (fifth report).

About the Global Warming Policy Foundation

The Global Warming Policy Foundation is an all-party and non-party think tank and a registered educational charity which, while openminded on the contested science of global warming, is deeply concerned about the costs and other implications of many of the policies currently being advocated.

Our main focus is to analyse global warming policies and their economic and other implications. Our aim is to provide the most robust and reliable economic analysis and advice. Above all we seek to inform the media, politicians and the public, in a newsworthy way, on the subject in general and on the misinformation to which they are all too frequently being subjected at the present time.

The key to the success of the GWPF is the trust and credibility that we have earned in the eyes of a growing number of policy makers, journalists and the interested public. The GWPF is funded overwhelmingly by voluntary donations from a number of private individuals and charitable trusts. In order to make clear its complete independence, it does not accept gifts from either energy companies or anyone with a significant interest in an energy company.

Views expressed in the publications of the Global Warming Policy Foundation are those of the authors, not those of the GWPF, its trustees, its Academic Advisory Council members or its directors.

GWPF ESSAYS

1	Nigel Lawson	The Trouble With Climate Change
2	Peter Lee	Ethics and Climate Change Policy
3	Matt Ridley	The Climate Wars and the Damage to Science
4	Richard Lindzen	Global Warming and the Irrelevance of Science
5	Clive James	Mass Death Dies Hard
6	Garth Paltridge	Four Questions on Climate Change
7	Guus Berkhout	Climate Thinking: Broadening the Horizons

For further information about the Global Warming Policy Foundation, please visit our website at www.thegwpf.org. The GWPF is a registered charity, number 1131448.