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# What does it mean, what does it take, and why is it important to understand climate change?

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What kind of cognitive state occupies the central stage in our interest in the phenomenon of climate change? What exactly is required to achieve this cognitive state? This paper addresses these questions from a purely conceptual footing by delving into the recent philosophical literature on the nature of understanding. As it will be argued, given the cognitive benefits associated with this state and the (mostly) practical concerns underpinning it in this context, understanding is what we are after, at a cognitive level, when we are interested in climate change. Knowing this is important because it can be used to further determine (in a purely conceptual way) what is required to achieve this cognitive state as well as who can achieve it. Much of the discussion in this paper is devoted to showing that understanding climate change is a highly demanding cognitive state that can be achieved to different degrees and that requires different things depending on what we take 'climate' and 'climate change' to mean. The most important implication of this discussion concerns the level of understanding of this phenomenon that is achievable by laypeople: even though gaining a basic degree of understanding of climate change isn't above laypeople's capacities, when it comes to making the connection between climate change and the kind of phenomena that can negatively impact our society (e.g., extreme weather events), laypeople cannot do better than to trust the scientists.

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## Introduction

Climate change is one of the most important phenomena of our time. It interests people from all walks of life (teachers, farmers, artists, doctors, scientists, politicians, journalists, etc.), and of all ages (Ritchie, 2024; Vlasceanu et al., 2024; Andre et al., 2024). But the reason for this interest is mostly, and justifiably, practical and action-related. That is to say, this concern mostly arises because of climate change's impact on our society. They are not intellectually curious or fascinated by the phenomenon but are, primarily, worried about how it will impact our livelihood and are interested in the prevention, mitigation, and adaptation actions that can be taken to deal with it. This is significant because, as will be made clearer shortly, given the special cognitive benefits associated with it, it places 'understanding' at the centre of most people's cognitive interest in climate change. What I mean by that is that when people are interested in this phenomenon, what they are interested in is either to understand it or at least to know how much understanding can be claimed to have been achieved (by the relevant people) regarding it. The genuine interest in the latter is evidenced by the existence of an international organisation tasked with assessing the progress made in understanding climate change. As stated in its guiding principles, the role of the Intergovernmental Panel on Climate Change (IPCC) is to "assess on a comprehensive, objective, open and transparent basis the scientific, technical and socio-economic *information relevant to understanding* the scientific basis of risk of human-induced climate change" (IPCC, 2018, my emphasis).

But why is it 'understanding' and not some other cognitive state such as, for instance, (non-explanatory) knowledge, belief, or acceptance, that occupies the most prominent cognitive position in people's interest in climate change? Why is it more important to understand climate change than it is, for instance, to know that climate change is real? And, assuming that understanding climate change is indeed more valuable than just knowing about it, what does this involve? Why do we need to have understanding rather than mere (non-explanatory) knowledge about climate change?

## 'Understanding' and climate change

To answer these questions, we must delve into the recent philosophical discussion about (scientific) understanding. The first thing to note is that philosophers are divided on the question of the nature of understanding. Some philosophers consider understanding to be a kind of knowledge, while others take it to involve a specific kind of ability (for more on this, see the papers in Grimm et al. (2016) and Khalifa et al. (2023)). This debate notwithstanding, there is widespread agreement in the recent philosophical literature that understanding is a *highly demanding cognitive state*. What this means is that, compared to (other species of) knowledge, something more is required of the epistemic subject to achieve understanding. This distinctive feature of understanding is usually codified in the literature with concepts such as *grasping* or *cognitive control*.

For example, in a highly influential paper, Alison Hills argues that understanding why something is the case requires *cognitive control* (Hills, 2016, p. 664), where 'cognitive control' means a set of abilities that allows the epistemic subject to (mentally) manipulate the relationship between the phenomenon of interest and the thing(s) it depends on. This feature, in Hills's opinion, distinguishes understanding from knowledge. However, even philosophers who take understanding to be a kind of knowledge (namely knowledge of an explanation, or explanatory knowledge), such as Kareem Khalifa, agree that understanding "frequently involves impressive exercises of cognitive ability" (Khalifa, 2017, p. 51). However, in Khalifa's case, the abilities characteristic of understanding are the same as those required for acquiring scientific knowledge of an explanation.

To have a more concrete idea about what this means, let us consider an example. Suppose you do not know anything about the complex aerodynamics involved in flight, but you are curious about what goes on when planes fly (Trout, 2002, p. 222; de Regt, 2017, p. 25). To find out, you search the web and read some information about the phenomenon of lift. As a result, you can now claim that *you know* that the fact that aeroplanes can fly has something to do with Bernoulli's principle, aerofoils, and the upward force generated by the difference in air pressure. This information may be sufficient (depending on the person) to satisfy one's curiosity. But it is far from being enough to claim that *you understand* why such heavy objects can fly. To achieve understanding, you also need to piece things together, that is (to use the philosophical jargon) you need to *grasp* the following complex relationship between aerofoils, air speed, air pressure, and lift: aerofoils split the incoming air into two streams (one that goes over the upper surface and travels faster, and one that goes beneath the wing and travels slower) as the aeroplane moves forward and, according to Bernoulli's principle, this results into a difference of pressure: higher beneath the wing and lower above it. The pressure difference generates an upward force known as lift. Only if you genuinely grasp this relationship can you claim that you are in cognitive control of this phenomenon or that you have knowledge of its explanation. This last point is important from the perspective of our discussion because its possession (no matter what one chooses to call it) is associated with several *cognitive benefits*. For instance, only someone who genuinely understands why aeroplanes can fly can (given the right context) build a plane, explain to someone else why planes fly, determine why a particular plane fails to take off, repair a plane by fixing its wings, etc.

The moral of this discussion is that while (non-explanatory) knowledge is sufficient (in some situations) for satisfying one's intellectual curiosity, it falls short of providing the cognitive benefits associated with understanding. Most importantly, there seems to be a stronger relationship between understanding and one's ability to do things than there is between knowledge and the same ability. As is clear from our example, a person who understands the aerodynamics of flight can do a lot more things (such as assess if a particular device is flight-able or not) compared with one who merely knows some things about aerofoils and Bernoulli's principle. This is significant for the purposes of our discussion. This is because if it is correct that our cognitive interest in the phenomenon of climate change is underpinned by practical concerns with the way climate change impacts our lives, then what we are interested in is either having the kind of cognitive control of this phenomenon associated with understanding it, or at least knowing whether the right people (e.g., scientists and policymakers) have such cognitive control.

Returning to the claim that understanding is at the centre of most people's cognitive interest in climate change, we can now see that the cognitive benefits associated with understanding are exactly the sort of things that are important for most people interested in climate change. Now that this has been established, let us move on to determining what needs to be done to acquire an understanding of climate change.

## What do 'climate' and 'climate change' mean?

The first thing that we need to do is to determine exactly what is meant by 'climate' and what people have in mind when they talk about 'climate change'. For the former, perhaps the best place to start is the IPCC's latest assessment report. According to the IPCC, we can distinguish between two meanings of 'climate':

> "*Climate in a narrow sense* is usually defined as the average weather, or more rigorously, as the statistical description in terms of the mean and variability of relevant quantities over a period of time ranging from months to thousands or millions of years. The classical period for averaging these variables is 30 years, as defined by the World Meteorological Organization (WMO). The relevant quantities are most often surface variables such as temperature, precipitation and wind. *Climate in a wider sense* is the state, including a statistical description, of the climate system" (IPCC, 2023, p. 2222, my emphasis).

This definition allows us to distinguish between two (interrelated) perspectives on climate change: a narrow and a wide one. Seen from a wider perspective, climate change has to do with the long-term changes in the dynamics of the climate system (or the alterations in the interactions and feedback between the components of the climate system) due to both natural and human-induced factors. More will be said about this below where it will be made clear that, if we look at climate change from this perspective, understanding it turns out to be a highly cognitively demanding undertaking.

If we focus only on the narrow sense of 'climate', and we take the relevant quantity to be temperature, climate change can be taken to concern the change in the global average temperature as a result of the increase in anthropogenically generated greenhouse gases. This way of conceiving of climate change corresponds to the common usage of the term, where climate change is associated with *global warming*. To better capture what is required for understanding climate change from this perspective, it is important to say a few words about another important and widely agreed upon feature of understanding. This is that understanding is gradable, i.e., it usually comes in degrees. What is meant by this is that one person can have a better understanding of some phenomenon than another, or that the same person or even a community of people can experience an increase in their understanding of some phenomenon over time. For instance, in its latest assessment report, the IPCC frequently claims that the climate-science community's understanding of some aspect of the climate system has improved since the IPCC's last report (i.e., over seven years). This is important for our discussion because, as I hope to demonstrate shortly, depending on the scientific models used, we can have different degrees of understanding of climate change.

## Understanding global warming

So, returning to our question: what is required to understand climate change if by climate change what we have in mind is global warming? A closer look at this question reveals that it is ambiguous, and this is for two important reasons. First of all, it doesn't take into account the fact that understanding comes in degrees, that is, it fails to specify the level of understanding one is interested in. Secondly, it doesn't make clear whether 'required' is supposed to refer to some aspect of the system of interest or the scientific tools used to study it. A better question, then, is this: what exactly do we need to grasp about the climate system to acquire a basic level of understanding of the phenomenon of global warming? The short answer to this question is that what needs to be grasped is the greenhouse effect and the role played by Earth's atmosphere in regulating the planet's temperature.

But how can we gain such an understanding? With the appropriate models. When scientists are trying to understand some phenomenon, they usually use theories and models. What scientific models are and how exactly they work are questions that have generated a sizable body of philosophical literature (Magnani and Bertolotti, 2017; Frigg, 2022; Nguyen and Frigg, 2022), so addressing them here will require too much space and will take us too far off-topic. What I can say, though, is that models are used in science to represent selected parts of the world that scientists are investigating, and that constructing models is an essential part of scientific practice (Frigg and Nguyen, 2020, p. x). Some scientific models are physical objects (e.g., Watson and Crick's metal model of DNA, or the fruit fly and other model organisms in biology), but most of them are abstract/mathematical objects (e.g., Bohr's model of the atom, the Lotka-Volterra model of predator-prey interaction, the Newtonian model of the solar system).

When it comes to understanding global warming, there is an important model that stands out: the greenhouse model of Earth's atmosphere. This model was discovered more than two hundred years ago by Joseph Fourier and further refined by John Tyndall. Fourier focused on understanding heat transfer processes on Earth. One of the questions that interested him was why the Earth's surface is warmer than what would be expected based solely on the amount of energy it receives from the Sun. Fourier suggested that the atmosphere allows sunlight to penetrate and warm the Earth's surface, but it also traps some of the outgoing heat, preventing it from escaping directly into space. He likened this effect to the way a glass covering over a greenhouse traps heat. Later, John Tyndall discovered that it was primarily water vapour and carbon dioxide in the atmosphere that provided the warmth.

The greenhouse model of Earth's atmosphere makes the relationships between the global average temperature on Earth, its atmosphere, and the greenhouse effect caused by some gases (which are commonly known as greenhouse gasses), explicit. Grasping these relationships together with the fact that human activities, such as burning fossil fuels (like coal, oil, and natural gas) and deforestation, have significantly increased the concentration of greenhouse gases in the atmosphere, provides a good basis for understanding global warming. This understanding is basic, though. The reason for this has to do with the amount of cognitive control it yields over the phenomenon of climate change. If this is the degree of understanding one has about climate change, one cannot, for instance, answer very important questions about this phenomenon. For example, how sensitive is the Earth's temperature to changes in greenhouse gas concentrations? Or, how fast will the climate system reach a new equilibrium if we suddenly double the concentration of $CO_2$ in the atmosphere and then keep it constant?

Before moving on to the issue of what generates a higher degree of understanding, it is important to emphasise that this basic understanding of the phenomenon of global warming is not unimportant. It allows one to identify the source of the climate change problem (i.e., the fact that human activities are dramatically increasing the level of greenhouse gases in the atmosphere) and to come up with an important solution to this problem (i.e., to drastically reduce the anthropogenic greenhouse gas emissions). So, although basic, this understanding does provide one with some cognitive control of the relationship between human activities and the thermal properties of the atmosphere.

To gain a higher degree of understanding of the recent change in Earth's global average temperature, we can use more sophisticated climate models that incorporate and simulate more adequately the key thermodynamic processes that influence Earth's climate. Two such (types of) models are the energy-balance models and the radiative-convective models. The energy-balance models focus on the balance between incoming solar radiation and outgoing infrared radiation to determine the equilibrium temperature of the Earth, while the radiative-convective models focus on simulating the complex interactions between radiative processes and convective processes within the atmosphere. With the help of these models, we can achieve greater cognitive control over the phenomenon of global warming. We can provide detailed answers to the previous questions about the quantitative aspect of the relationship between the $CO_2$ level and the increase in the Earth's average temperature. In addition, these models reveal important features of the climate system such as the existence of tipping points and climate thresholds.

While these models are the simplest (full-fledged) climate models that can be used to gain a more significant degree of understanding about the climate system, it is important to note that they cannot be mastered by laypeople (unlike the previous model discussed above). This is because they require significant mathematical abilities and command of physics (such as, the first law of thermodynamics, the Stefan-Boltzmann law, radiative and reflective processes, and the heat capacity of objects). What this means is that enhancing one's understanding of some phenomenon is a very demanding process, i.e., the more we want to understand, the greater the *cognitive effort* that we have to make.

## Understanding the climate system dynamics

The last point made in the previous section becomes even more significant if we look at climate change from a wider perspective. As mentioned, from this perspective, climate change has to do with the long-term changes in the dynamics of the climate system. Such a study relies on building general circulation models and Earth system models. Using these models to understand the climate system is incomparably more *cognitively demanding* than using the energy balance and the radiative-convective models. We will see shortly why this is so, but first, let's address an important preliminary question about the importance of looking at the phenomenon of climate change through this lens.

Why do we need this different perspective? Isn't looking at it from the narrow perspective on climate change enough to understand what has been going on recently with Earth's climate? Actually no, it isn't. If the change in the global mean temperature captured all there is to climate change, then this phenomenon would not have been that scary. Some people living at northerly latitudes could have even seen it as beneficial. What makes climate change such a threatening phenomenon is the changes in components of the climate system (such as the atmospheric and oceanic circulation patterns) associated with the increase of the global average temperature. These can lead to extreme weather events, to the intensification of tropical cyclones, to shifts in monsoon patterns, to ecosystem shifts, to the collapse of the Atlantic meridional overturning circulation, etc. These are the most significant aspects of climate change and therefore, the ones we need to have under cognitive control to take the best prevention, mitigation, and adaptation actions. But understanding these threats requires not only a consideration of the thermodynamic aspects but also of the intricate interactions and feedbacks captured by dynamical climate models such as the general circulation models and the Earth system models.

The big problem is that the cognitive effort needed to use these models is among the highest possible. These models depend on discretising onto a grid and then numerically solving the equations that represent the basic laws governing the behaviour of all the subsystems composing the climate system (e.g., the atmosphere, the ocean, the ice, etc.). This task cannot even be performed by scientists; it requires the use of supercomputers. The best way to appreciate the difficulty of this task is by looking back in the history of meteorology at the first attempt at predicting weather using numerical methods by the British mathematician and meteorologist, Lewis Richardson (in the early 20th century). This effort ended up in complete failure. It took Richardson six weeks of labour-intensive manual calculations to produce a 6-h forecast that predicted an atmospheric pressure change of ~150 hPa. The actual pressure change was ~3 hPa.

## Conclusions

My aim in this paper was to make clear two important things. The first concerns what exactly we are really interested in, from a cognitive perspective, when we are interested in the phenomenon of climate change. As I hope to have shown, understanding is the kind of cognitive achievement that is above all others important in the context of our interest in climate change. This is for two reasons. Firstly, it is because most people's cognitive interest in this phenomenon is underpinned by practical concerns regarding how climate change impacts our lives, rather than by intellectual curiosity. Secondly, as a cognitive achievement, understanding comes with a bunch of benefits that, in the right circumstances, can allow one to have cognitive control of the phenomenon of interest.

The second thing I tried to make clear is that understanding climate change comes in degrees and can involve different things depending on what we take 'climate' and 'climate change' to mean. At a basic level, understanding climate change requires understanding the change in the global average temperature and can be achieved with the help of the greenhouse model. Taking climate change to be equivalent to global warming presents an important advantage, but also a great disadvantage. The important advantage of this approach is that achieving an understanding of climate change is not very cognitively demanding from this perspective, and so, even laypeople can achieve it. The disadvantage is that, if we take climate change to concern *only* this aspect, it can be considered not much of a threat. This can be avoided if we take a wider perspective on climate change. From this perspective, climate change concerns the alterations in the interactions and feedback between the components of the climate system. There is a clearer link between these alterations and the kind of phenomena that can negatively impact our society (e.g., extreme weather events), and so this perspective makes it as clear as possible why climate change is such a threatening phenomenon. It doesn't come without disadvantages, though. An important problem is that understanding the dynamics of climate requires a lot of science, and so, laypeople cannot possess this understanding for themselves, but must instead rely on science and trust scientist's testimony. Fortunately, there is an organisation that can help with that. This is the IPCC whose main objective is to inform people about the progress made in science in this respect.

## Data availability

This paper does not involve the collection of empirical data, and so there are no specific datasets or materials associated with the study. All information and arguments presented in the paper are based on existing literature and the author's analysis.

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## Additional information

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