Identifying Flawed Reasoning in Contrarian Claims about Climate Change

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Abstract

While climate change grows as an environmental and societal emergency, misinformation about climate change continues to hinder necessary action and democratic decision-making. An important step towards neutralizing climate misinformation is identifying the rhetorical techniques and logical fallacies used to distort climate science and confuse the public. We expand on previous critical thinking research, developing a detailed methodology for deconstructing and analyzing real-world misinformation. We apply our extended methodology to a comprehensive taxonomy of climate contrarian claims, finding reasoning fallacies in all the analyzed claims. The most common fallacies were *slothful induction*, *cherry picking*, and *oversimplification*. Contrarian claims regarding climate solutions, while more nuanced than explicit science denial, are still rife with misleading fallacies. 91% of the analyzed contrarian claims required additional hidden assumptions which, upon reconstruction, revealed reasoning fallacies., This underscores the difficulties of conventional fact-checking. The ubiquity and complexity of misinformation in online spaces and public discussion necessitates holistic, interdisciplinary solutions that can be scaled up to meet the immensity of the problem. This research is an example of such an interdisciplinary approach, building on existing natural language processing research with critical thinking, climate science, and climate solutions scholarship. Our results are presented as a resource for countering contrarian claims, particularly useful in automated applications that detect and fact-check online climate misinformation in real time.

1. Introduction

Climate change is arguably the most pressing social, economic, and environmental problem facing society (Abbass et al., 2022; Gasper et al., 2011). Despite overwhelming scientific agreement on the reality of human-caused global warming (Oreskes et al., 2004; Doran & Zimmerman, 2009), and growing concern about climate change, nevertheless, some still remain confused about the issue with 22% of the public doubtful or dismissive of climate change (Leiserowitz et al., 2025). A contributing factor to this problem is the propagation of climate change misinformation (Chen, 2024; McCright & Dunlap, 2011). While concern for climate change has been rising steadily over the past 20 years among Americans (Gallup, 2023), climate misinformation has caused a range of negative impacts delaying public support for climate action (Cook et al., 2017).

Climate misinformation (false information) and disinformation (intentionally false information) (Treen et al., 2020) cast doubt about the reality or severity of human-caused climate change and the efficacy of climate solutions, which can reduce acceptance of climate change (Taddicken & Wolff, 2023) and delay public support for climate action (Lamb et al., 2020). It reduces climate literacy (Ranney & Clark, 2016) and accentuates public polarization along political lines, having a disproportionate effect among political conservatives (van der Linden et al., 2017). This polarizing effect is strongest with misinformation that targets climate solutions or attacks climate scientists (Lieu et al., 2026). It has a subversive effect on how scientists report their results (Lewandowsky et al., 2015) and whether people discuss climate change with family and friends (Geiger & Swim, 2016). It poses significant challenges for science communicators and educators by reducing the effectiveness of their attempts to share accurate information (McCright et al., 2016; van der Linden et al., 2017). Exposure to a conspiracy video about global warming results in people being less likely to sign a petition to reduce global warming and less likely to donate to a charity (van der Linden, 2015), while exposure to a conspiracy theory about climate scientists reduced peoples' intention to reduce their carbon footprint or engage in politics (Jolley & Douglas, 2014).

Climate misinformation has been recognised as "complex and interconnected, involving the interaction of politics, culture, psychology, and technology." (Cook, 2024), necessitating holistic solutions to address the immensity and complexity of the problem (Lewandowsky et al., 2017). Recognising the interconnected nature of climate misinformation, the 4D framework (Detection, Deconstruction, Debunking, Deployment) was developed to offer an interdisciplinary approach to understanding and countering misinformation, combining computer science, critical thinking philosophy, psychology, and public engagement and communication (Cook, 2024). The four stages are defined as follows:

1. *Detection* draws upon computer science techniques, identifying and classifying existing misinformation (Coan et al., 2021; Rojas et al., 2024). This approach typically uses machine learning or artificial intelligence to automatically detect climate misinformation, with the ultimate purpose of providing timely, automated responses. However, an important element of this stage is understanding the broad landscape of arguments used in climate misinformation, which is achieved through developing a taxonomy of contrarian claims (Coan et al., 2021).
2. *Deconstruction* involves assessing the quality of reasoning in misleading arguments[1], identifying logical fallacies[2]. This approach is known as logic-checking and can address

[1] In this context, the term argument is used in its formal sense, meaning a connected series of statements used to establish a definite proposition (Chapman & Python, 1989).
[2] Within some domains, logical fallacies refer to formal fallacies (e.g., affirming the antecedent and denying the consequent) while reasoning fallacies refer to informal fallacies of the type typically identified in our analysis.

some of the limitations inherent to fact-checking (Ryan & Hammerton, 2025). Logic-checking can be achieved using a critical thinking methodology that breaks up claims into an argument structure, consisting of premises and a conclusion, facilitating the identification of fallacious premises (Cook et al., 2018; Samoilenko & Cook, 2024b). While argumentation more broadly involves more than the formal mechanics of analytical reasoning or simple rule-following, understanding of basic argument structure can be applied to significant effect (Cook et al., 2022). In this approach we begin with basic logic and reasoning structures that are generally applicable and accessible. The emphasis is on the inferential pathways of arguments and involves establishing argument validity and evaluating the quality of inferences.

3. *Debunking* research is increasingly exploring logic-based corrections as an attractive alternative to fact-based approaches. Unlike factual approaches, they generalise across topics, avoid polarization, and are robust to the cancelling out effect found with factual explanations (Christner et al., 2024; Cook et al., 2017; Cook et al., 2020; van der Linden et al., 2017; Vraga et al., 2020).
4. *Deploying* corrections at-scale to audiences that are targeted by or vulnerable to misinformation is technically challenging, given the capacity for misinformation to spread on social media networks (Vosoughi, Roy, & Aral, 2018). This theme seeks to apply the findings from the previous stages to devise scalable public engagement strategies (Cook et al., 2022; Hopkins et al., 2023; Lewandowsky et al., 2017).

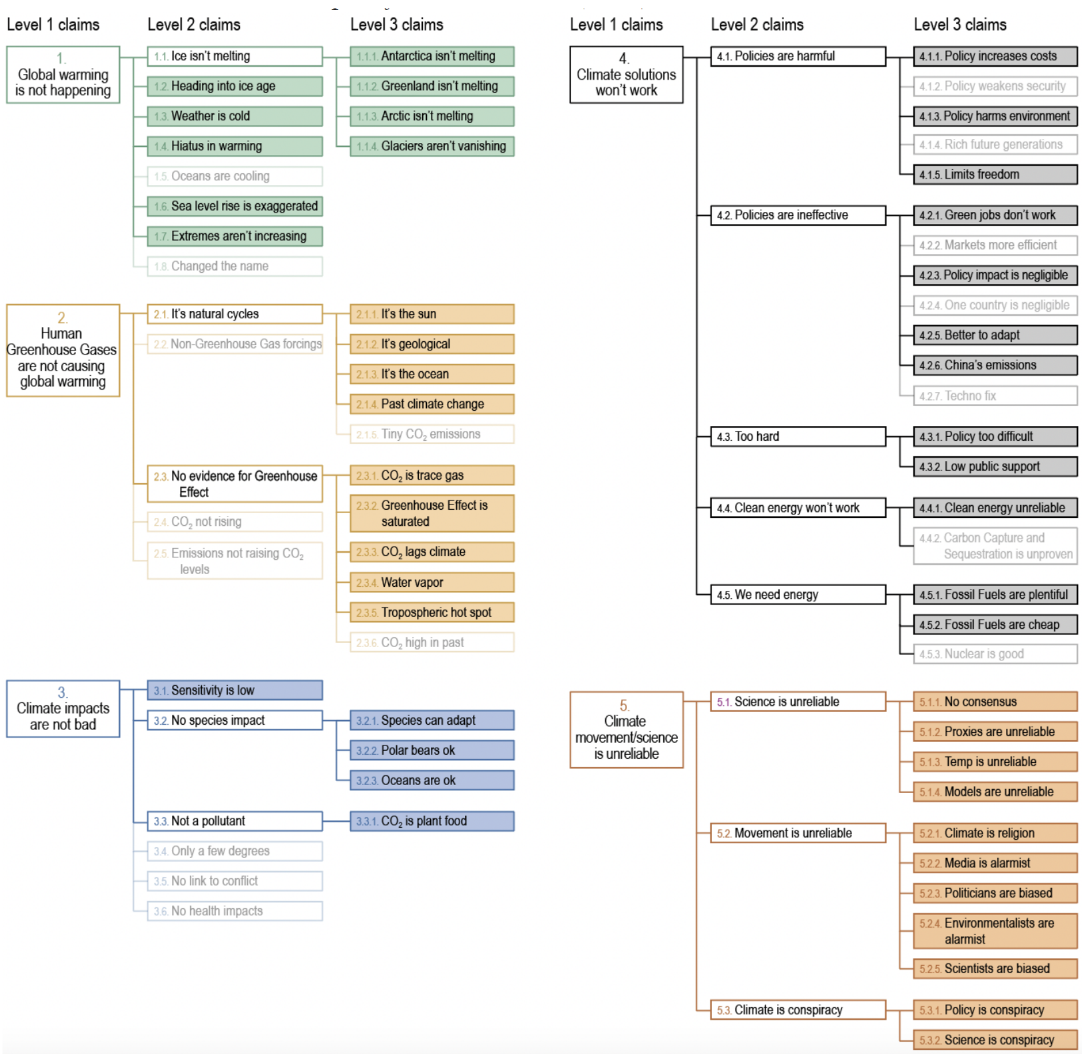
Given that public perception of the term logical fallacies has broadened, we shall in this paper use both terms interchangeably, with each referring to include both formal and informal fallacies structures.

The research undergirding the 4D framework emphasizes the important role that logic-checking and logic-based corrections play in countering climate misinformation. However, there is a dearth of research identifying the logical fallacies and misleading rhetorical techniques in climate misinformation required to develop logic-based interventions. This study will deconstruct a comprehensive taxonomy of contrarian claims about climate change, in order to i) assess the veracity of the claims, and ii) identify the logical fallacies employed in climate misinformation.

Detecting and mapping climate contrarian claims

Previous analyses of climate misinformation have identified misinformation targeting scientific topics (Rahmstorf, 2004), climate policy (Bonds, 2016; Capstick & Pidgeon, 2014; Lamb et al., 2020), and attacks on the reliability of climate scientists or climate science (Samoilenko & Cook, 2024a). Synthesising these disparate perspectives, Coan et al. (2021) developed a comprehensive taxonomy of climate contrarian claims (Figure 1). The CARDS (Computer Assisted Recognition of Denial & Skepticism) taxonomy grouped contrarian claims under five main categories: "global warming is not happening", "global warming is not caused by humans", "climate impacts are not bad", "climate solutions won't work", and "the climate movement is unreliable".

Figure 1. ***The CARDS (Computer Assisted Recognition of Denial & Skepticism) taxonomy of climate contrarian claims adapted from Coan et al. (2021).***



Note. *Only "childless claims" (claims with no sub-claims) were deconstructed in our analysis, indicated by solid color boxes."Parent claims" (claims with sub-claims) were excluded from deconstruction, indicated by boxes with no coloured fill. All level 1 claims are parent claims, while all level 3 claims are childless claims. Grayed-out claims were excluded from this analysis due to insufficient example paragraphs (see Table S3 in Supplementary Material for paragraph quantities). We reiterate the point expressed in Coan et al. (2021) that the claims in this taxonomy are not necessarily misinformation (hence the need for deconstruction).*

This taxonomy was developed as the first stage of an effort to automate fact-checking of climate change misinformation, a goal described as the "holy grail of fact-checking" (Hassan et al., 2015). Coan et al. (2021) used the taxonomy to detect specific contrarian claims using supervised machine learning, laying the foundation for automatic fact-checking of climate misinformation. This was achieved by sampling content from 20 prominent conservative think-tank websites, a prolific source of climate misinformation identified in previous literature on organized climate contrarianism (Al-wari et al., 2021; Boussalis & Coan, 2016; McCright & Dunlap, 2000) as well as denialist blogs (Sharman, 2014; Table S2). They compiled a training dataset of 7,134 paragraphs mapped to relevant contrarian claims.

Deconstructing climate contrarian claims

The scope of Coan et al. (2021) was limited to documenting and detecting claims made by climate contrarians without testing the veracity of the claims. Not all claims in the CARDS taxonomy were necessarily misinformation, with a claim such as "carbon capture and sequestration is unproven" (4.4.2) being a topic of legitimate scholarly debate. Each claim in the taxonomy required further assessment to identify which were misleading.

Cook et al. (2018) developed a critical thinking methodology (deconstruction) to analyze arguments about climate change to ascertain whether it is misleading by identifying reasoning fallacies. Argument analysis plays a crucial role in deconstructing logical fallacies within climate myths, providing a systematic approach to identify, critique, and correct misleading arguments. Walton's (1996) argument schemes, for example, offer a structured framework for analyzing arguments by outlining common patterns of reasoning. These schemes provide a toolkit for identifying logical fallacies by revealing the underlying structure of arguments, including their assumptions and implied premises (Walton et al, 2008). Cook et al.'s approach involved diagramming the process of argument construction, which clarified the relationships between premises, conclusions, and counterarguments. This method enhances critical thinking by making the reasoning process explicit, thereby enabling users to spot logical inconsistencies and unsupported claims. It also allows for a more precise critique of claims, including climate myths, systematically exposing where the reasoning fails and why certain arguments are misleading. Pedagogically, explicit attention to argument structure and how reasoning may deviate from established norms delivers measurable rewards (Cullen et al., 2018; Van Gelder et al., 2004).

The argument analysis and deconstruction approach of Cook et al. involved 1) breaking down claims into an argument structure consisting of one or more statements (called premises) used to establish the truth of another statement (called the conclusion), 2) identifying whether the argument is logically valid, 3) if invalid, adding hidden premises to restore logical validity, then 4) analyzing the truth of the premises. Cook et al. (2018) applied this deconstruction approach to a number of common climate myths, identifying reasoning fallacies in all cases.

Fallacious arguments have been identified in misinformation across a range of scientific topics (Jacobson et al., 2007), with Diethelm & McKee (2009) identifying the five denial techniques commonly found in science misinformation—*fake experts, logical fallacies, impossible expectations, cherry picking, and conspiracy theories*—summarized with the acronym FLICC and expanded into a more comprehensive taxonomy of denial techniques (Cook, 2020; see Table 1 for definitions). The deconstruction method has also been applied to *ad hominem* attacks on climate actors (Samoilenko & Cook, 2024b). *Ad hominem* attacks on climate actors have been found to be a prominent form of climate misinformation on social media (Rojas et al., 2024), Congressional hearings (Cloud, 2020), and media coverage of climate change (Gunster et al., 2018).

Beyond fact-checking: the strengths of logic-checking

To date, most work on misinformation-countering interventions has focused on fact-checking (Ecker et al., 2022; Koch et al., 2023). However, there are a number of challenges associated with fact-checking both from a communication and an epistemological point of view. Birks (2019) argues that a fact-checking approach should focus on what is useful for people to make informed decisions—such as whether a claim is misleading—rather than define what counts as a ‘fact’. Similarly, Lim (2018) argues that fact-checkers should report the logical fallacies in claims without necessarily assigning scores to these observations. Analysing the rhetorical techniques used in climate misinformation offers insights into how contrarians manufacture the appearance of legitimacy and discredit opposing viewpoints (Bloomfield & Tillery, 2019).

This points to logic-checking—identifying the presence of reasoning fallacies—such as that outlined in Cook et al. (2018) as an alternative or complementary approach, addressing some of the limitations of conventional fact-checking. Misinformation commonly relies on hidden assumptions, as misinformers often leave premises unstated to avoid being held to account (Birks, 2019). The critical thinking methodology from Cook et al. (2018) addresses this limitation by systematically uncovering hidden premises in arguments to identify the full reasoning behind the claim.

Assessing claims based on the presence of reasoning fallacies can also sidestep the problem of verifying statements about the future, which are difficult to fact-check when there is no reality which the claim could be compared to (Nieminen & Sankari, 2021). Predictive claims such as "we're heading into an ice age" should be checkable if they contradict scientific research (Feulner & Rahmstorf, 2010). Similarly, hypothetical policy predictions such as "a specific policy will have a negligible impact on climate" might be strictly correct but still misleading because they commit the fallacy of *impossible expectations*—demanding that a lone policy will single-handedly solve climate change.

Another challenge for fact-checkers is how to handle the rhetorical technique of paltering or cherry picking—the use of truthful statements to convey a misleading impression (Lewandowsky et al., 2016; Rogers et al., 2017). A climate example is focusing on a single growing glacier while ignoring the majority of glaciers that are shrinking due to warming temperatures. It might be true that a single glacier is growing but such focus paints a misleading impression by ignoring the full body of evidence. Similarly, greenwashing messages use truthful statements about pro-environmental activities of a company while failing to mention their activities that are damaging to the environment (Naderer & Opree, 2021), a rhetorical technique that is effective in bolstering positive attitudes towards fossil-fuel companies (Friedman & Campbell, 2023). The logic-checking approach appropriately tags paltering text as misleading, even if the cherry picked evidence is factually true.

Table 1. ***FLICC framework fallacy definitions.***

Key Fallacies	***Definitions***
Ad hominem	Attacking a person/group instead of addressing their arguments.
Anecdote	Using personal experience or isolated examples instead of sound arguments or compelling evidence.

Cherry picking*	Carefully selecting data that appears to confirm one position while ignoring other data that contradicts that position. Emphasis is on a lack of confirming evidence rather than on ignoring disconfirming evidence.
Circular reasoning	Relying on an argument's conclusion as a premise, while failing to provide external evidence or reasoning.
Conspiracy theories*	Proposing that a secret plan exists to implement a nefarious scheme such as hiding a truth.
Fake experts*	Presenting an unqualified person or institution as a source of credible information.
False choice	Presenting two options as the only possibilities, when other possibilities exist.
Hasty generalization	Drawing a sweeping conclusion based on insufficient evidence or a small sample size, without considering other relevant factors.
Impossible expectations*	Demanding unrealistic standards of certainty before acting on the science. For scientific arguments, this applies to standards of proof. For policy, it applies to the effectiveness of policies. For environmental arguments, this applies to expectations of physical reality.
Logical Fallacies*	Arguments where the conclusion does not logically follow from the premises. Also known as a non sequitur.
Misrepresentation	Misrepresenting a situation or an opponent's position in such a way as to distort understanding. Differs from oversimplification which can represent part of a system accurately but omit important details in a misleading way, whereas misrepresentation represents part of a system falsely.
Oversimplification	Simplifying a situation in such a way as to distort understanding, leading to erroneous conclusions. Differs from cherry picking in that oversimplification focuses on an aspect of a system while cherry picking focuses on an aspect of a body of evidence.
Red herring	Deliberately diverting attention to an irrelevant point to distract from a more important point.

Single cause	Assuming a single cause or reason when there might be multiple causes or reasons.
Slothful induction	Ignoring relevant evidence when coming to a conclusion. Emphasis is on a lack of disconfirming evidence rather than on cherry picked confirming evidence.
Straw man fallacy	Misrepresenting or exaggerating an opponent's position to make it easier to attack.

Note. *The five techniques of science denial encapsulated in the acronym FLICC (Cook, 2020) are marked with an asterisk (*). For the extended list see S1: Figure 1. and Table 1.*

While Cook et al. (2018) deconstructed a subset of climate contrarian claims, the CARDS taxonomy in Coan et al. (2021) documented a broader set of contrarian claims without specifying which claims were misleading. In this study, we offer a detailed overview of our "logic-checking" methodology and how we assessed the claims found in the CARDS taxonomy. Next, we summarise the frequency of logical fallacies found in climate contrarian claims. Last, we discuss the implications of our findings and how our findings can inform future interventions designed to neutralize misinformation.

2. Methods

Our approach adapts and extends the deconstruction methodology of Cook et al. (2018) and applies it to the comprehensive taxonomy of climate contrarian claims developed by Coan et al. (2021). Specifically, drawing on data from Coan et al. (2021), we 1) collected a sample of exemplar[3] paragraphs for each claim outlined in the CARDS taxonomy, 2) deconstructed these claims into an argument structure[4] consisting of underlying premises and a conclusion, and 3) employed a streamlined version of the methodology in Cook et al. (2018) to determine the

[3] Exemplars here are considered using the technical meaning of the term as "typical examples".
[4] We refer to arguments and/or logical structures as argument structures.

presence of any logical fallacies (see Table 1 for a list of logical fallacies with definitions). This is the first study to employ methodical deconstruction to real-world examples of climate misinformation distributed across the entire CARDS taxonomy.

As the Coan et al. (2021) taxonomy of contrarian claims attempted to cover the entire landscape of climate misinformation, a single claim could represent a variety of arguments. For example, the level 3 claim "clean energy is unreliable" (4.4.1) included examples such as "solar power doesn't work at night", "wind turbines kill birds", and "renewables can't deliver baseload power". As these examples might represent a variety of argument structures and different reasoning fallacies, we developed a methodology for devising an argument that reasonably represented the diversity of examples within each claim.

First, exemplar paragraphs for each contrarian claim were sampled from the Coan et al. (2021) training dataset. This dataset was sampled from a list of 20 US-based conservative think-tanks and blogs. As previously mentioned, organizations such as CFACT (cfact.org) and the Cato Institute (cato.org) (Cato institute) are known sources of climate misinformation. The Cato Institute headlined an article titled "New figures show that California speed rail won't do much about climate change", while CFACT recently claimed that "climate policies are pointless but costly". In isolation this may be a legitimate claim but underlyingly is an attack on climate solutions. These two sources vary in misleading nature with CFACT spreading more blatant misinformation and the Cato Institute publishing more conservative news pieces that are still misleading.

From the taxonomy of claims we only analyzed "childless claims", meaning claims with no sub-claims (see Figure 1). This meant that a "parent claim" such as "ice isn't melting" (1.1) was not deconstructed as it was sufficiently represented by its "children claims" such as

"Antarctica isn't melting" (1.1.1) and "Greenland isn't melting" (1.1.2). Level 2 claims with no sub-claims such as "there's a hiatus in warming" (1.4) were included in our analysis.

To balance argument variability and time constraints, we sampled 20 exemplar paragraphs per claim according to the selection criteria documented in the Supplementary Material S3. However, some claims occurred fewer than 20 times in our dataset, in which case all available paragraphs were included (see Table S3). Upon inspection, all claims with fewer than 13 paragraphs lacked sufficient argument variability to identify a general argument structure and were excluded from the analysis, leaving us with 46 claims for deconstruction.

Each exemplar paragraph was analyzed using a streamlined version of the Cook et al. (2018) methodology. First, each exemplar was deconstructed into an argument structure consisting of premises[5] and a conclusion. For example, the exemplar text "El Niños and the opposite La Niñas apparently have a significant impact on global temperatures, hence global warming" was deconstructed into a more general argument with the premise "Ocean cycles have a significant impact on global temperatures" leading to the conclusion "Ocean cycles are causing global warming".

Second, the inferential intent of the argument was categorized as either inductive (i.e., featuring probabilistic or provisional claims) or deductive (i.e., featuring definitive conclusions). Climate contrarian claims are typically definitive, making absolute statements about the reality (or lack thereof) of human-caused climate change or the unviability of climate solutions. For

[5] Note that we don't need to know the truth of the premises to evaluate the validity of an argument. For hypothetical claims, if the premises *were* to be true, then the conclusion must also be true.

definitive claims, we applied the deductive deconstruction approach of Cook et al. (2018). If an inductive argument was identified during the deconstruction stage, a new exemplar was selected.

Third, we assessed whether the argument was logically valid. In a deductively valid argument, if the premises are true, then the conclusion must also be true. An example of a valid argument is “all Gronks[6] are green and Greg is a Gronk, therefore Greg is green”. In this example, if both premises are true, then the conclusion must also be true. In contrast, a logically invalid argument looks like “all Gronks are green and Greg is green, therefore Greg is a Gronk”. This argument is logically invalid because even if we assume all the premises are true, it does not logically follow that the conclusion must be true. All Gronks might be green but being green does not make one a Gronk.

If the argument was logically invalid, the next step was to identify the hidden premises required to make the argument valid. Arguments typically rely on unstated assumptions that need to be made explicit to make the argument valid. From the invalid example above, the hidden premise that would make the argument logically valid is "all green things are Gronks”. If Greg is green and all green things are Gronks, then it logically follows that Greg must be a Gronk. This step is often the most important step in the deconstruction process as unstated assumptions in misinformation typically contain fallacies.

After the exemplar paragraphs were deconstructed, we sought to identify the most representative argument for each taxonomy claim. Each claim in the taxonomy could contain varying arguments. For example, the claim “Antarctica isn’t melting” might involve the argument “Antarctica is cooling so global warming is not happening” or “Antarctic sea ice is not

[6] We define a “Gronk” as a mythical creature. The “Gronk” is included to demonstrate that the truth value of a premise is not relevant to the validity of an argument.

melting, so global warming is not happening”. A common argument representing both versions was “Antarctica is cooling or gaining sea ice therefore global warming is not happening”. This is an example of a type 2 deconstruction, where two different arguments were similar enough to be represented by a single argument.

Across the contrarian claims, there was variability in the arguments as summarized by the five deconstruction types in Table 2. Type 1 claims (homogeneous argument) featured exemplars consisting of essentially the same argument. An example of a type 1 claim was “CO_2 lagging temperature disproves the warming effect of CO_2”.

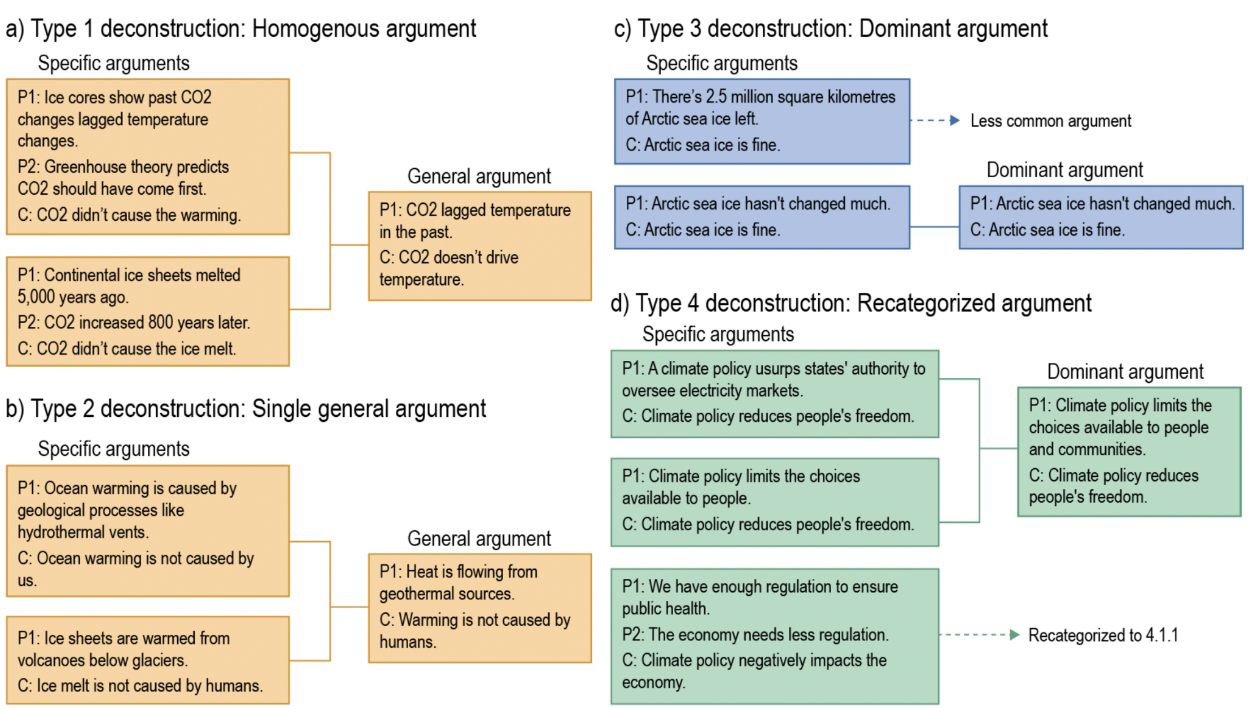
Table 2. *Contrarian claim deconstruction types.*

Type No.	**Title**	**Description**
1	Homogeneous argument	All the exemplars were essentially the same argument.
2	Single general argument	The exemplars were similar enough that they could be represented by a single deconstructed argument.
3	Dominant argument	The exemplars were represented by more than one argument structure but with a single argument dominating.
4	Recategorized arguments	There were multiple argument structures with no dominant argument structure but with one or more of the argument structures belonging to a different claim in the taxonomy.
5	Multiple arguments	There were multiple argument structures that couldn’t be re-allocated to other claims in the taxonomy.

Type 2 claims (single general argument) featured a range of examples that were similar enough that all could be represented by a general argument structure (Figure 2a). For example, the claim “warming is caused by geological factors” took forms such as “ocean warming is due to hydrothermal vents” or “ice sheet melting is due to underwater volcanoes”. These different examples could be represented by the single general argument “geological factors are a source of heat therefore observed warming is caused by geothermal sources”.

Type 3 claims (dominant argument) featured exemplars represented by more than one argument structure but with a single argument dominating (Figure 2b). For example, while the claim “Arctic isn’t melting” included exemplars such as “there’s still a lot of Arctic sea ice”, the majority were of the form “Arctic sea ice hasn’t decreased significantly in recent years”. Type 4 claims (recategorized arguments) included multiple argument structures with no dominant argument but with one or more arguments belonging to a different claim in the taxonomy (Figure 2c). Type 5 claims (multiple arguments) included multiple argument structures that could not be re-allocated to other claims in the taxonomy.

Figure 2. ***Deconstruction types across climate contrarian claims.***



Note. *a) Example of type 1 deconstruction - homogeneous argument (claim "*CO_2 *lags temperature", 2.3.3). b) Example of type 2 deconstruction - single general argument (claim "It's geological", 2.1.2). c) Example of type 3 deconstruction - dominant argument (claim "The Arctic isn't melting", 1.1.2). The dominant argument structure is the "general argument" as it is the argument structure that occurred more than once in the analyzed paragraphs and data set. d) Example of type 4 deconstruction - recategorized argument (claim "Policy is too difficult", 4.3.1). No dominant argument is found, however, one argument structure may be recategorized to another claim within the taxonomy.*

Once a general argument structure was finalized for each claim, we moved on to the final step of the deconstruction process—scrutinizing each premise to identify reasoning fallacies. We used the FLICC framework, featuring a comprehensive list of rhetorical techniques and logical fallacies (Cook, 2020). Figure 3 visualizes our methodology, including a simplified version of the Cook et al. (2018) deconstruction process (steps 1-5).

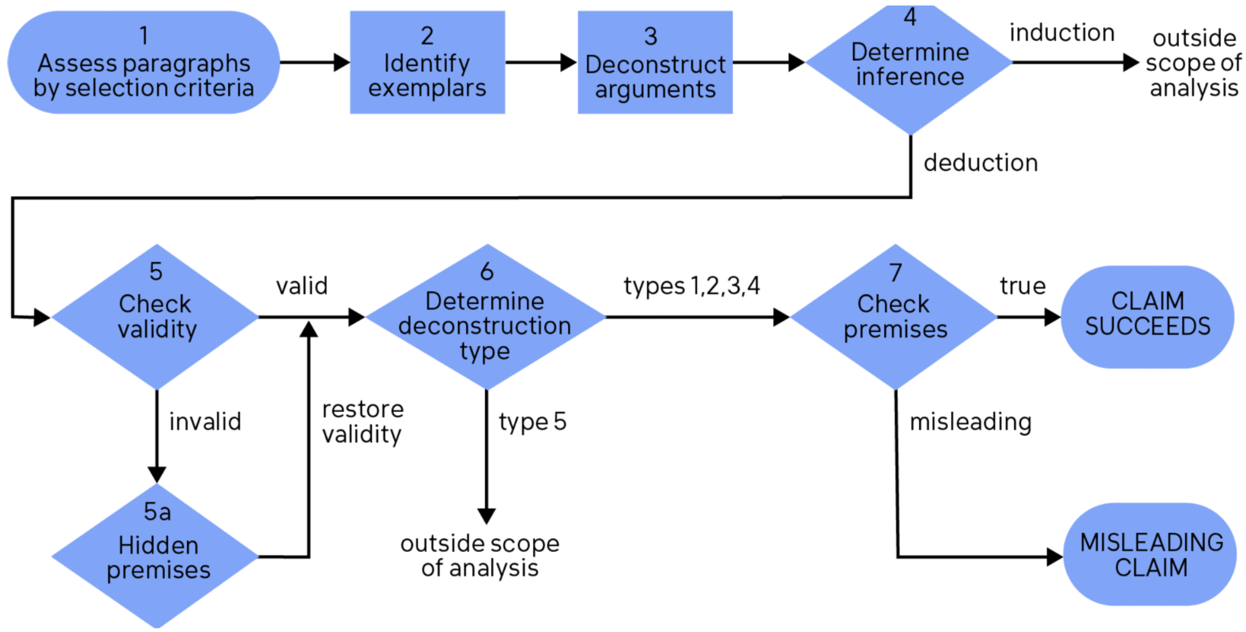


Figure 3. ***Flow chart for deconstructing claims from a dataset of example paragraphs.***

Figure 4 offers clarity between some of the fallacies that conceptually overlap. *Cherry picking* involves actively focusing on select pieces of evidence while ignoring the bulk of evidence that paints a contrary picture (e.g., "some glaciers are growing"). *Slothful induction* is a cousin to *cherry picking* but focuses on a purported lack of evidence. An example of *slothful induction* is "there's no evidence for climate change so the science isn't settled". A more subtle example is "if impacts aren't bad yet, they'll stay that way", where conclusions are made about the future while ignoring any science specifying how conditions will change in the future.

Conceptually, *oversimplification* may seem similar to *cherry picking* as both involve failing to take into account the full picture. The difference between the two is the type of information being ignored. In the case of *cherry picking*, the type of information is scientific evidence while with *oversimplification*, it is scientific models. For example, arguing that human CO_2 emissions are tiny compared to natural CO_2 emissions fails to consider that natural emissions are matched by natural absorptions, ignoring one aspect of the scientific model of the carbon cycle.

Another fallacy targeting scientific models is *misrepresentation*. Conceptually, *misrepresentation* and *oversimplification* are distinct. *Oversimplification* typically makes true statements about a narrow aspect of a scientific model that nevertheless paints a misleading picture because it ignores other aspects of the model (essentially the technique of paltering applied to scientific models). It is true that human CO_2 emissions are tiny compared to natural CO_2 emissions, but a more appropriate comparison is with *net* natural CO_2 emissions, considering natural absorptions. *Misrepresentation* typically makes false statements about part of a scientific model. Misleading comes not from the omission of relevant details but from distortion of the scientific model. For example, claiming that water vapor has a stronger warming effect than CO_2 assumes that water vapor has a forcing effect (e.g., drives climate) when in actuality a feedback effect (e.g., responds to climate).

Misrepresentation of scientific models is a close cousin to the *straw man* fallacy but the two are distinct from each other in structure and intent. The intent of a *straw man* argument is to distort an opponent's position by rephrasing it in a form that is easier to refute. For example, the IPCC conclusion "we have 12 years to halve CO_2 emissions in order to avoid dangerous climate change" was distorted into "alarmists say the world will end in 12 years". Scientific misrepresentations are structured differently, where one scientific concept is misrepresented and presented as a true statement to cast doubt on another concept. For example, the claim "water vapor is the strongest greenhouse gas" misrepresents the nature of water vapor's greenhouse effect, but the intent of the argument is to cast doubt on the significance of CO_2 warming.

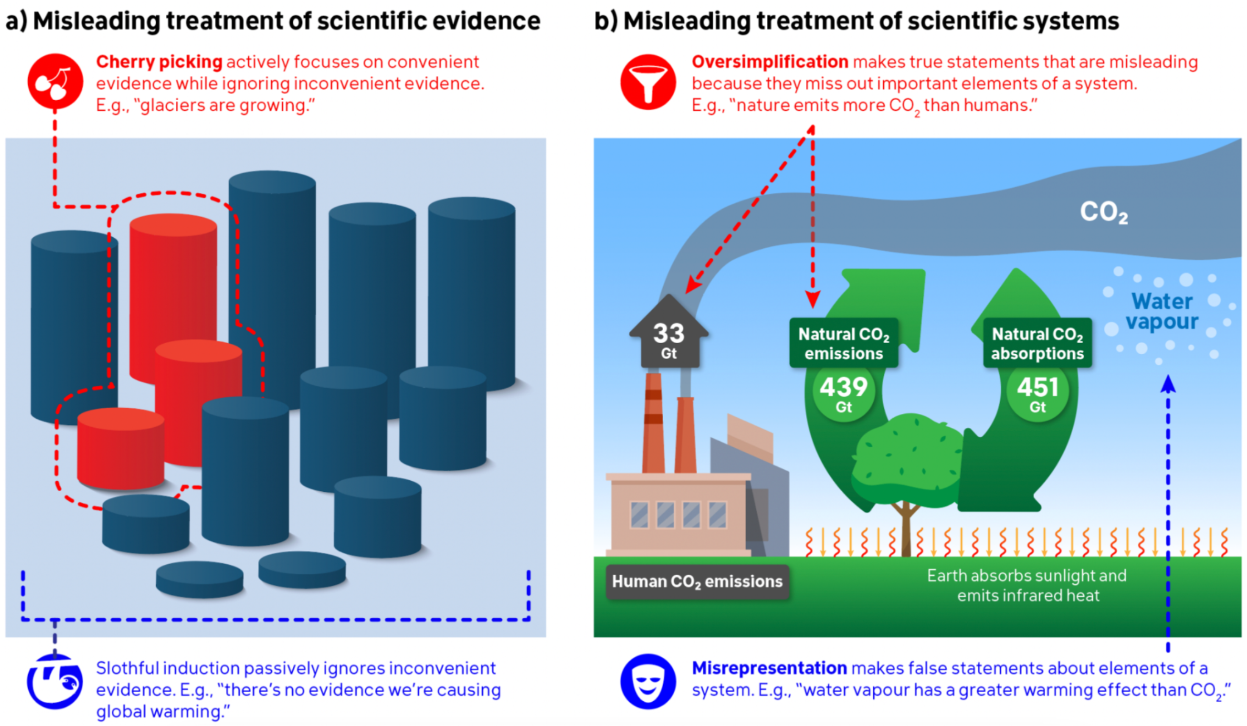


Figure 4. ***Conceptual distinctions between fallacies.***

3. Results

Table 3 summarizes the key results of our deconstruction of the claims in the Coan et al. (2021) taxonomy (for more thorough documentation, see Table S4). Five of the claims supplied insufficient example paragraphs and were excluded from the analysis so our final analysis involved 46 claims. The most common deconstruction type (53%) was type 2 (common argument structure) while the second most common deconstruction type (35%) was type 3 (dominant argument structure) (Table 2). All 46 claims contained reasoning fallacies and were characterized as misleading. Thus, we were successful in extending the work of Coan et al. (2021) by assessing the veracity (or lack thereof) of the contrarian claims in their taxonomy. 31% of the claims contained multiple fallacies, with the average number of fallacies per claim being 1.9. Table 3 includes the deconstruction type, general/dominant argument structure, hidden premise/s, and reasoning fallacies of each contrarian claim.

Table 3. ***Summary of deconstructed climate contrarian claims.***

Claim	Type	General argument structure	Hidden premise	Denial technique
1.1.1. Antarctica isn't melting	2	P1: Antarctica is cooling. P2: Sea ice is increasing. C: Global warming is not happening.	P3: Cooling is the only driver of sea ice gain therefore global warming is not happening.	P1: Cherry picking P2: Slothful induction P3: Impossible expectations P4: Single cause
1.1.2. Greenland isn't melting.	2	P1: Parts of Greenland's ice sheet are not melting. C: Global warming is not happening.	P2: All parts of ice sheets must be melting under global warming.	P1: Cherry picking P2: Single cause, Impossible expectations
1.1.3. Arctic isn’t melting	3	P1: In the short term, Arctic sea ice hasn't changed much. C: Arctic sea ice is fine.	P2: If Arctic sea ice maximum extent hasn't changed much in the short-term, then Arctic sea ice is fine in the long-term.	P2: Cherry picking
1.1.4. Glaciers aren’t melting	3	P1: Glaciers are growing in some regions. C: Glaciers are fine.	P2: If glaciers are growing anywhere in the world, then glaciers must be fine.	P2: Cherry picking, Oversimplification
1.2 Heading into an ice age	22	P1: Current climate change is driven by natural factors. P2: Natural factors are currently having a cooling effect. C: If natural cooling continues, we will experience more cooling in the future.	P3: Greenhouse gasses don't have much of a warming effect.	P1: Cherry picking, Slothful induction P3: Misrepresentation

1.3 Weather is cold	2	P1: Cold weather events are occurring. C: Global warming is not happening.	P2: If global warming was happening, we wouldn't experience cold events.	P1: Anecdote P2: Impossible expectations
1.4 Hiatus on warming	3	P1: There's been no warming over a short period. C: Global warming is not happening.	P2: Short time periods are sufficient to make conclusions about climate trends.	P1: Cherry picking, Slothful induction P2: Misrepresentation, Cherry picking
1.6 Sea level rise is exaggerated	2	P1: Sea levels within a specific time period or region have not shown a dramatic increase. C: Sea level rise is exaggerated.	P2: Results from a narrow set of sea level rise data can be generalized more broadly. P3: Regional factors like subsidence are not a factor in sea level measurements.	P1: Cherry picking P2: Slothful induction P3: Oversimplification
1.7 Extremes aren't increasing	3	P1: Extreme weather happened in the past before recent global warming. C: Global warming is not linked to extreme weather.	P2: If global warming didn't affect past extreme weather, it mustn't be affecting current extreme weather either. P3: The frequency or intensity of extreme weather isn't getting worse.	P2: Single cause P3: Cherry picking
2.1.1. It's the sun	3	P1: There is a link between solar activity and climate. C: Recent climate change is caused by the sun.	P2: If the sun can affect climate, it must be affecting current climate change.	P1: Slothful induction P2: Single cause

2.1.2. It’s geological	32	P1: Heat is flowing from geothermal sources. C: Warming is not caused by humans.	P2: Natural geological processes are the only cause of warming.	P2: Single cause, Slothful induction
2.1.3. It’s the ocean	2	P1: Ocean cycles influence global temperature. C: Ocean cycles are causing global warming.	P2: If ocean cycles affect global temperatures in the short term, then they must affect them in the long term.	P2 Single cause, False equivalence
2.1.4. Past climate change	3	P1: Climate has changed due to natural causes in the Earth's past. P2: Climate is changing now. C: Current climate change must be natural.	P3: Current climate change is similar to past climate change. P4: What caused climate change in the past must be the same as what's causing climate change now.	P3: False equivalence P4: Single cause
2.3.1. CO_2 is a trace gas	2	P1: CO_2 is a trace gas, comprising only a small component of the atmosphere. C: CO_2 cannot be the main cause of global warming.	P2: If there is a small percentage of CO_2 in the atmosphere, its warming potential is low.	P2: Misrepresentation
2.3.2. Greenhouse effect is saturated	1	P1: CO_2 has a diminishing warming effect with higher concentrations. C: Adding more CO_2 to the atmosphere will have a negligible impact on warming.	P2: CO_2 is saturated in all levels of the atmosphere.	P2: Oversimplification

2.3.3. CO_2 lags climate	1	P1: CO_2 lagged temperature in the past. C: CO_2 does not drive temperature.	P2: If temperature affects CO_2, then CO_2 cannot affect temperature.	P1: Slothful induction P2: False choice
2.3.4. Water vapour	2	P1: Water vapor is more heat-trapping or plentiful than CO_2. C: Water vapor contributes more to global warming than CO_2.	P2: The warming of a greenhouse gas depends on quantity or heat-trapping ability.	P2: Misrepresentation
2.3.5. Tropospheric hot spot	2	P1: Greenhouse warming should cause a tropospheric hot spot over the tropics. P2: The hot spot hasn't been observed. C: Global warming is not caused by greenhouse gasses.	P3: If there's a discrepancy between models and observations, the models must be wrong. P4: The hot spot is a unique fingerprint of greenhouse warming.	P2: Slothful induction P3: Misrepresentation P4: Misrepresentation
3.1 Sensitivity is low	1	P1: Negative feedback in the climate system reduces warming. C: Climate sensitivity to CO2 emissions is low.	P2: Negative feedbacks cancel out the positive feedbacks.	P2: Slothful Induction
3.2.1. Species can adapt	2	P1: Species have shown resilience to climate change either now or in the past. C: Species can adapt to climate change.	P2: Species have been resilient to date so they will continue to be resilient in the future.	P1: Cherry picking P2: Slothful induction, False equivalence

3.2.2. Polar bears are ok	3	P2: Polar bear populations are increasing in some regions. C: Global warming is not harming polar bear populations.	P2: Polar bear populations cannot be increasing anywhere under global warming.	P1: Cherry picking P2: Oversimplification
3.2.3. Oceans are ok	3	P1: Coral reefs are resilient against acidification and bleaching. C: Climate change impacts on coral reefs are not serious.	P2: Acidification or bleaching alone are the only negative climate change impacts on coral reefs. P3: If one species shows resilience to climate change, we can assume other species will also be resilient. P4: Current climate change will be no more harmful than past climate change.	P2: Cherry picking P3: Oversimplification P4: Slothful induction
3.3.1. CO_2 is plant food	2	P1: CO_2 is beneficial for plant growth. C: Emitting more CO_2 will be good for plants.	P2: Increased CO_2 only has beneficial effects for plants.	P2: Slothful induction, Cherry picking
4.1.1. Policy increases cost	2	P1: Climate policy increases energy costs. P2: Increased energy costs will have harmful effects. C: Climate policy is harmful.	P3: The cost of climate action is greater than the cost of climate impacts. P4: Climate action doesn't have any positive benefits.	P1: Oversimplification P4: Slothful induction P5: Oversimplification
4.1.3. Policy harms the environment	2	P1: Clean energy has costs on the economy and the environment. C: Clean energy is harmful.	P2: The negatives of clean energy outweigh the benefits.	P2: Cherry picking

4.1.5. Limits freedoms	4	P1: Climate policy limits the choices available to people and communities. C: Climate policy reduces people's freedom.	P2: Failing to act on climate change will have no impact on people's freedom. P3: Regulations only have negative impacts on people.	P2: Oversimplification P3: Cherry picking
4.2.1. Green jobs don't work	3	P1: Green jobs are a small proportion of overall jobs and are growing slowly. C: Green jobs won't work.	P2: The growth rate of green jobs will remain the same over time. P3: Economic factors are all that matter when considering green jobs.	P1: Impossible expectations P2: Slothful induction P3: Oversimplification
4.2.3. Policy impact is negligible	3	P1: A single policy would have a negligible impact. C: We should not have the policy.	P2: If a single policy doesn't solve the problem, then it is not worth implementing.	P2: Impossible expectations
4.2.5. Better to adapt	3	P1: Climate action reduces wealth. P2: Wealth increases resilience to climate action. C: It is better to adapt to climate change than to mitigate it.	P3: Failing to mitigate climate change won't have an impact on our wealth or ability to adapt to climate change.	P1: Cherry picking P3: Slothful induction
4.2.6. China's emissions	3	P1: Developing countries are not doing enough to share the burden of reducing global emissions. P2: One country cutting emissions will make a	P3: One country shouldn't reduce emissions if their action alone won't reduce global emissions. P4: All countries are the same so they should be held	P1: Oversimplification P3: Impossible expectations P4: Oversimplification

		negligible difference to global emissions. C: One country reducing emissions is pointless.	to the same emission reduction standards.	
4.3.1. Policy is too difficult	2	P1: Solving climate change will be difficult and expensive. P2: Making the technical transition or getting global agreement will be difficult. C: Solving climate change is too difficult.	P3: Because emission reduction and political agreement is difficult, it can't be done.	P3: Hasty generalization, Circular reasoning
4.3.2. Low public support	2	P1: Much of the public aren't convinced about the need for climate action. C: Political action on climate change is too hard.	P2: Without public support, climate policy is impossible. P3: Current levels of public support for climate action will stay the same in the future.	P1: Cherry picking P3: Slothful induction
4.4.1. Clean energy unreliable	3	P1: Clean energy has costs on the economy and the environment. C: Clean energy is harmful.	P2: The negatives of clean energy outweigh the benefits.	P2: Cherry picking
4.5.1. Fossil fuels are plentiful	2	P1: There is an abundance of fossil fuel resources. C: We should keep using fossil fuels.	P2: If we have fossil fuels, we should use them rather than other sources.	P2: Slothful induction

4.5.2. Fossil fuels are cheap	2	P1: Fossil fuels are the cheapest form of energy. C: We should use fossil fuel energy.	P2: Cheaper costs are more important than other factors like climate change impacts.	P1: Slothful induction P2: Oversimplification
5.1.1. No consensus	2	P1: There's not enough evidence to know what's happening with climate change. C: There's no scientific consensus on climate change.		P1: Slothful induction, Impossible expectations
5.1.2. Proxies are unreliable	1	P1: Proxy data is affected by non-climate factors and measuring limitations. C: Climate proxies are unreliable.	P2: Scientists don't know how to adjust for limitations and other factors.	P2: Misrepresentation
5.1.3. Temp is unreliable	3	P1: Temperature data is affected by non-climate factors and measuring limitations. C: The temperature record is unreliable.	P2: Scientists don't know how to adjust for limitations.	P2: Slothful induction, Red Herring
5.1.4. Models are unreliable	3	P1: Climate model predictions don't match observations. C: Climate models are unreliable.	P2: If there's a discrepancy between models and observations, the models must be wrong.	P1: Cherry picking P2: Oversimplification
5.2.1. Climate is a religion	2	P1: The climate change movement have some trait in common with religion.	P2: A movement that has any traits in common with a religion is a religion.	P2: Misrepresentation P3: False equivalence

		C: The climate change movement is a religion and unscientific.		
5.2.2. Media is alarmist	3	P1: Media portrayal of climate change supports the mainstream view. C: The media are biased and cannot be trusted.	P2: If the media supports the mainstream view on climate change, they must be biased.	P2: Ad hominem, Misrepresentation
5.2.3. Politicians are biased	2	P1: Governments and politicians support the mainstream view on climate change. C: Governments are biased and untrustworthy.	P2: If governments or politicians support the mainstream view on climate change, they must be biased.	P2: Ad hominem, Misrepresentation
5.2.4. Environmentalists are biased	2	P1: Environmentalists get science wrong as they're not committed to science. C: Environmentalists are biased and unreliable.		P1: Ad hominem
5.2.5. Scientists are biased	2	P1: Scientists act in biased or unethical ways. C: Scientists and their science can't be trusted		P1: Ad hominem
5.3.1. Policy is a conspiracy	2	P1: Governing bodies and corporations act secretly on climate policy. C: Climate policy is part of a conspiracy.	P2: Secret actions by governing bodies and corporations must be for nefarious motives.	P1: Conspiracy theory P2: Conspiracy theory

5.3.2. Science is a conspiracy	2	P1: Scientists have committed a range of conspiratorial actions to defend the mainstream view and suppress dissenting views. C: There is a conspiracy among scientists to deceive the public.		P1: Conspiracy theory

Figure 5 shows the relative prevalence of different fallacies in climate contrarian claims. The most common fallacies were *slothful induction* and *cherry picking*, involving misleading treatment of scientific data. The next two most common categories were *oversimplification* and *misrepresentation*, involving misleading interpretations of scientific models or systems. *Single cause* (a type of *oversimplification*) was the fifth most common fallacy. Note that if *oversimplification* and *single cause* were to be collapsed together, they would amount to the second most common fallacy. *Impossible expectations* was the sixth most common fallacy, with varying applications.

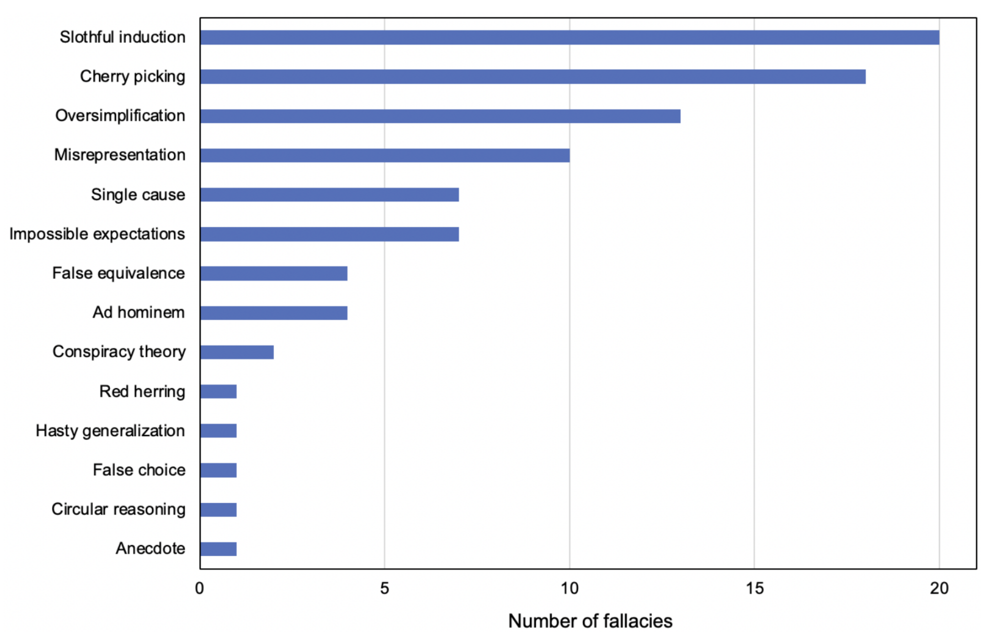


Figure 5. ***Prevalence of fallacies supporting climate contrarian claims.***

Almost every claim was supported by an invalid argument that required the addition of a hidden premise. Among the invalid arguments, every hidden premise resulted in a reasoning fallacy. Only 4 claims out of 46 were supported by a logically valid argument.

4. Discussion

Understanding how climate change misinformation misleads is a crucial step to neutralizing its negative influence. This study aimed to assess the veracity and understand the range of logical fallacies employed across a comprehensive taxonomy of contrarian claims about climate change. We developed a methodology to deconstruct real-world misinformation exemplars. A novel addition was the development of deconstruction types, offering a systematic method of identifying the most representative argument structure for each contrarian claim.

We identified cherry picking, slothful induction, and oversimplification as the most employed fallacies in climate misinformation. These techniques were often found in the same claim, with 20% of claims employing cherry picking/slothful induction in one premise and oversimplification in the other. For example, in the claim "CO_2 is plant food" (3.3.1), the first premise employed oversimplification, while the second premise used slothful induction. Furthermore, some single premises contained two fallacies. In the claim "policy is a conspiracy" (5.3.1), the premise "decision making authorities should always be 100% transparent or otherwise they can't be trusted" utilized both *ad hominem* and *impossible expectations* (Table 3).

This study's findings can be compared to prior work on deconstructing climate denialist claims in order to validate our results. Cook et al. (2018) is the closest comparable study, although it restricted its scope to climate science misinformation found in categories 1 (global warming isn't happening), 3 (climate impacts aren't bad), and 5 (climate science isn't reliable) in the Coan et al. (2021) taxonomy. In most cases, our identified fallacies matched the fallacies identified by Cook et al. (2018). However, two noticeable discrepancies between the two studies were the claims "species can adapt" (3.2.1)—where Cook et al. (2018) identified the use of *misrepresentation* while we identified *cherry picking* and *oversimplification*—and "environmentalists are alarmists" (5.2.4)—where Cook et al. (2018) identified cherry picking while we found *ad hominem* and *slippery slope*. Contributing factors to these discrepancies could be differences in how real-world exemplars were translated into semi-structured premise-conclusion form.

All 46 analyzed claims contained reasoning fallacies, with 42 (91%) specifically containing fallacious hidden premises. This supports the view that unstated assumptions must be uncovered to fully understand why an argument is misleading (Birks, 2019). This also reinforces the value of a critical thinking approach that offers a systematic method for "logic-checking" claims with hidden premises.

The deconstruction of the Coan et al. (2021) taxonomy has benefits for improving the machine learning research that this work was based on. Identifying examples that need reclassifying (e.g., deconstruction type 4) highlighted that there were conceptual ambiguities in the initial coding of paragraphs. The deconstruction process clarified conceptual differences between some claims, which could support further coding and refinement of the machine learning model. The process of deconstructing a diverse range of contrarian claims also added nuance to past critical thinking work. The *impossible expectations* fallacy was previously defined as "demanding unrealistic standards of certainty before acting on the science" (Cook, 2022). This definition was suitable for science-based claims such as "proxies are unreliable" (5.1.2), a prominent argument among the reasons given for climate skepticism (Matthews, 2015). However, the *impossible expectations* fallacy was also found in the solutions-based claim "policy has a negligible impact" (4.2.3), which argued that if a single policy did not fix the problem, then it was not worth implementing. This claim unrealistically demanded that a single policy must comprehensively solve climate change to be implemented (equivalent to arguing "the first step won't get me out of the way of oncoming traffic so I might as well not move"). Applying *impossible expectations* to a policy context demonstrated the limitation of the previous definition of *impossible expectations* in Cook (2020). Consequently, we broadened the definition for *impossible expectations* so that it was applicable in a wider range of contexts (Table 1).

Half of the claims that were logically valid contained the *ad hominem* fallacy, involving a character attack on a person or group who accepts the reality of climate change and/or the need for climate action. This is not to say that all *ad hominem* attacks are necessarily valid arguments (Samoilenko & Cook, 2024a; Walton, 1998). An *ad hominem* attacking a person's trait (e.g., "Al Gore is overweight") might be irrelevant to a conclusion that disregards the person's argument (e.g., "therefore Al Gore's film is not credible") and therefore logically invalid. In the *ad hominem* claims in our analysis, the premises (e.g., "scientists act in a biased or unethical way") were relevant to the conclusion (e.g., "therefore scientists are unreliable") and hence were deemed logically valid. In all the exemplars we examined, the premise accusing a target of being biased or unethical was assessed in the deconstruction process to be false. For example, accusations that stolen emails revealed deceptive behavior by climate scientists have been rejected by multiple investigations (Cook, 2020; Stott, 2021). Nevertheless, a point of discussion of our approach is that we cannot state definitively that in every instance, members of the climate movement are unbiased and ethical. Our approach to this kind of argument was to explain in general terms how *ad hominem* arguments focus on a person's character to distract from their arguments.

A limitation of our study was the coverage of the training data used to harvest exemplars representing each contrarian claim. There was significant variance in the number of paragraphs matching each claim, ranging from 0 to 766 paragraphs per claim. 17 childless claims had less than 20 paragraphs with 8 having zero examples. We considered the number of paragraphs a proxy for the prominence of each claim so concluded that excluding low-represented claims was appropriate. As a result, claims such as "Carbon capture & sequestration is unproven" (4.4.2) and "Nuclear power is good" (4.5.3) were excluded from our analysis. While obtaining more exemplar paragraphs was outside the scope of this study, future research should expand the training dataset targeting underrepresented claims.

An additional characteristic of the dataset was a heavy emphasis on U.S. sources with half of the blogs and nearly all the conservative think-tanks being U.S. based. This is to some degree reflective of the fact that the initial prolific sources of climate misinformation were U.S.-based conservative think-tanks (McCright & Dunlap, 2000), and that public polarization over climate change is greatest in the United States (Hornsey et al., 2018). Nevertheless, it is expected that contrarian narratives will differ across countries (Chen, 2024). For example, U.S. narratives about deregulation emphasize restrictions imposed on the fossil fuel industry while similar narratives in Brazil focus on policies restricting deforestation (Stecuła et al., 2025). Future research should replicate this methodology in other countries and languages, particularly if the work is aiming toward automating responses to misinformation.

Limited resources were available for the deconstruction process so greater resources would facilitate a more detailed analysis. We sampled approximately 20 example paragraphs for each claim. Sampling a larger number of paragraphs would likely result in the identification of more argument structures, which would provide a more comprehensive (albeit complicated) summary of fallacies. A more thorough treatment would enable distinguishing between factual statements such as “the weather was cold somewhere on a certain day” and misleading statements such as “the weather is cold today, therefore global warming is not happening” (1.3). Although every claim we deconstructed could be represented by a single argument structure, it is likely that there are further argument structures that are not captured by our current analysis. Evidence for this comes in Zanartu et al. (2025) which built a dataset of climate misinformation examples spanning both CARDS categories and FLICC fallacies, finding a broader distribution of fallacies across each CARDS category than that found in these results. This points to the need to expand the taxonomy to include more variations of contrarian claims, which would in turn necessitate further training of any machine learning model used to detect claims.

The fact that contrarian claims contain multiple fallacies has psychological and communication consequences. For arguments with multiple fallacies, assessing which reasoning fallacy played the greatest role in making the argument misleading is beyond the scope of this study. With regard to corrective strategies, would explanation of more than one fallacy be more or less effective than explaining a single fallacy? If a correction was to include just a single fallacy explanation (e.g., due to space or attention constraints), how would one choose one fallacy among several to maximize the effectiveness of a correction? Future research into logic-based corrections should consider these questions when experimentally testing interventions.

While our research yields theoretical insights that stand on their own, this work was designed to be implemented within broader frameworks, such as the 4D framework (Cook, 2024). Our work seamlessly integrates within this framework, by closely interfacing with the detection research in Coan et al. (2021) and building on the deconstruction methodology developed in Cook et al. (2018). In addition, our output lends itself to debunking interventions that include logic-based explanations (Kim et al., 2020).

Explaining the logical fallacies in misinformation shows a number of unique benefits over alternative approaches such as fact-based corrections. For example, logic-based corrections can be effective across topics (Cook et al., 2017) while fact-based corrections are limited to a specific topic. Similarly, logic-based corrections are effective regardless of whether they are shown before or after misinformation, while fact-based corrections can be canceled out if misinformation is shown afterwards (Vraga et al., 2020; Christner et al., 2024). Consequently, our results can act as an encyclopedic resource for communicators developing logic-based corrections against climate misinformation.

Another limitation of fact-checking is that they are most appropriately applied to empirical questions and if applied inappropriately (e.g., to policy questions that involve values and societal priorities), can risk undermining public support for science (Freiling et al., 2023). Logic-checking can address some claims that fall outside the scope of fact-checking by identifying misleading arguments that contain reasoning fallacies. This work offers another tool for scientists, educators, and communicators seeking to build public resilience against misleading arguments. The approach of teaching science by explicitly addressing how misinformation distorts scientific facts, known as agnotology-based learning (Bedford & Cook, 2013) or misconception-based learning (McCuin et al., 2014), has been shown to be one of the most effective ways of teaching science, achieving greater and longer-lasting learning gains as well as increased critical thinking skills (Kuhn & Crowell, 2011). More specifically, deconstruction of misinformation has been used in the classroom to educate students about the reasoning fallacies used in climate misinformation (Cook et al., 2023). Our research may be leveraged by educators employing misconception-based lessons to teach climate change material.

While logic-checking can address some of the shortcomings of fact-checking, it should be acknowledged that these two approaches, even combined, are insufficient to critically address some discourses, such as framing that filter our perceptions of the world by making some information more salient than other information. Consequently, an additional complementary approach worthy of consideration is “frame-checking”, a critical practice that encourages individuals to move beyond surface facts and instead interrogate the underlying rhetorical frame of claims (Cloud, 2018). Frame-checking examines how an issue is being presented by different parties, and identifies what information, perspective, or context is left out of the framing. This approach asks who is doing the framing, and who benefits from having information portrayed in this way, with the intention of uncovering how rhetoric shapes our reality in ways that often serve the interests of the powerful. However, there appears to be no direct experimental study that has tested the effectiveness of frame-checking as an intervention in response to misinformation. While frame-checking is a broader and more holistic framework than logic-checking, nevertheless, logic-based inoculation and logic-checking can play an integral part of this approach.

Similarly, Ceccarelli (2011) argues that scientists should counter attempts to cast doubt on a scientific consensus through rhetorical strategies such as explaining the history of scientific debate that resulted in a consensus of experts. This approach frames scientific consensus not as suppression of debate, but the result of a rigorous, past debate that has been resolved by the scientific community. Another misleading technique used by those who manufacture controversy is the exploitation of "balancing norms" (the journalistic norm of presenting "both sides"), used to portray a resolved scientific consensus as an ongoing debate. Although Ceccarelli focuses on broader rhetorical devices (such as the ethos of the dissenters or the manipulation of media norms), the deceptive arguments she refers to often rely on logical fallacies, such as appeal to false authority and false equivalence. One of the available strategies for those who respond to a manufactured scientific controversy is to "equip readers and their students to refute deceptive arguments"–an approach much in line with logic-based inoculation. While Cloud's frame-checking and Ceccarelli's rhetorical strategies are broader and more holistic than logic-based inoculation, both approaches can still benefit from the methodologies and resources published in this article.

Alternatively, Barzilai and Chinn (2020) propose four educational approaches , each applying a different lens to post-truth problem. In the first lens (Not Knowing How to Know), where people lack the necessary knowledge and skills to evaluate complex scientific claims, providing factual information and fallacy explanations provides people with the critical thinking tools to navigate the information landscape. The second lens (Fallible Ways of Knowing) acknowledges that people have inherent cognitive vulnerabilities such as biases and heuristics, making them susceptible to misinformation. In this case, inoculation theory offers a framework for building public resilience to misinformation by forewarning them of the threat of being misled, thus increasing their epistemic vigilance. The third lens (Not Caring About Truth) and fourth lens (Disagreeing About How to Know) require responses beyond the scope of this paper, such as adapting science to make sense in people's lives and helping students and teachers navigate multiple epistemologies. Again, as with frame-checking, logic-checking is an integral part of the broader framework proposed by Barzilai and Chinn (2020).

This study sought to deconstruct a comprehensive taxonomy of climate contrarian claims, identifying reasoning fallacies and misleading claims. In the process, we expanded the critical thinking deconstruction methodology developed by Cook et al. (2018). Our work is the most comprehensive effort to date that deconstructs contrarian claims about climate change incorporating both climate science and solutions misinformation. It provides a foundation for future work on deconstruction and a generalizable methodology that could be applied to a variety of applications and other topics afflicted by misinformation.

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Competing interests

The authors have no competing interests to declare.

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New study uses critical thinking to deconstruct a comprehensive taxonomy of climate contrarian claims, finding the most common fallacies are slothful induction, cherry picking, and oversimplification.