Article

Climate Change Misinformation in the United States: An Actor–Network Analysis

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Abstract: Climate change misinformation refers to inaccurate, incomplete, or misleading climate change-related information created and spread in the public domain. Despite substantial consensus among the scientific community on the reality of anthropogenic climate change, public opinion still remains divided. Combating the climate crisis requires immediate and meaningful actions; however, various actors generate and propagate climate change misinformation, with vested interests in sowing doubts in the public sphere about the reality and urgency of climate impacts. The United States of America, where public opinion holds a strong sway in many social and political spheres, acts as a pertinent case in point, where the prevalence of climate denial fueled by persistent climate change misinformation contributes to this divided public perspective. For this reason, it is imperative to enhance the understanding of the subtle ways climate change misinformation exists and functions. This article employs actor–network theory and the concept of black-boxing to explore a case of climate change misinformation in the United States, with the aim of comprehending the workings of climate change misinformation within its network.

Keywords: climate change; climate change misinformation; actor–network theory; black-boxing; the United States

1. Introduction

Anthropogenic climate change poses pervasive threats to natural ecosystems and societies (Thuiller 2007; Malhi et al. 2020). The scientific community widely agrees that the centuries-long anthropogenic externalities produced by the extensive burning of fossil fuels, deforestation, and environmental degradation primarily caused an increase in global average temperatures to unprecedented and uncontrollable levels (Clark and York 2005). As a result, the ensuing disasters carry a devastating magnitude. From altered local weather patterns that affect small-scale farmers and their agricultural output, to global-scale rising sea levels, catastrophic hurricanes, and flooding, all have direct links to the changing climate (IPCC 2021).

While scientists have discovered and disseminated evidence-based knowledge of the patterns, mechanisms, and consequences of climate change, there remains a notable gap in understanding how individuals perceive and interpret climate change information received from various outlets. This understanding has a crucial importance, because the nuances of climate information dissemination play a key role in enhancing public climate literacy and fostering awareness of sustainable and responsible practices among citizens (U.S. Global Change Research Program 2009). Furthermore, they play a pivotal role in galvanizing public support for future climate change adaptation and mitigation plans and policies (Dabla-Norris et al. 2023).

In the United States of America (U.S.), the annual average temperature between 1901 and 2016 increased by 1.0 °C (Wuebbles et al. 2017a). Scientists predict an alarming, accelerated rise in temperature of ~1.4 °C from 2021 to 2050 for the U.S. (Wuebbles et al.

2017b). Along with the long-term warming trend, weather anomalies also play a large part in climate change, such as intense but less frequent cold waves and the increased frequency of heat waves observed in the country in recent decades. The consequences of these observed climatic changes are sometimes devastating to local communities. For example, the heightened frequency of recorded hurricanes since the 1980s have been extremely costly and detrimental to coastal communities in the country (U.S. Global Research Program 2014). Similarly, according to the sixth assessment report of the Intergovernmental Panel on Climate Change (IPCC), North America contributes approximately about a quarter of global greenhouse gas emissions (Hicke et al. 2022). These emissions have been steadily on the rise since 1990, and in 2019 alone, North America contributed 5.9 $MtCO_2$ (million tons of carbon dioxide) of greenhouse gas emissions worldwide (Friedlingstein et al. 2020). In 2019, the U.S. emitted 16 tCO_2 (metric tons of CO_2 per person) annually, followed closely by Canada with 15 metric tons per person, while Mexico had a lower rate of 3.4 metric tons of CO_2 emissions per person (Friedlingstein et al. 2020). The rises in average and extreme temperatures have led to a reduced snowpack, rising sea levels, and occurrences of marine heatwaves attributed predominantly to human activities in the region (Hicke et al. 2022). This has been quoted with high confidence, indicating a strong scientific consensus on the role of human influence in causing these climatic changes and affecting the environment (Hicke et al. 2022).

The mounting scientific evidence gathered each passing year establishes the impacts of the changing climate on natural ecosystems and consequently on peoples' lives, as well as providing us a glimpse into the impending future. From the first IPCC report in 1990 to the latest report in 2023, each report has underscored climate change as a global challenge and emphasized the need for global cooperation to deal with it. These reports aimed at providing a scientific basis for governments to formulate climate-related policies. While the 1990 IPCC report was certain that human activities significantly increased the levels of greenhouse gases in the atmosphere (IPCC 1992), the second IPCC report in 1995 presented important scientific findings and data regarding human-induced climate change, foreseeing continued alterations to the global climate (IPCC 1995). Similarly, the third IPCC report in 2001 delved into addressing a broad range of key policy-relevant questions (IPCC 2001). Among the many observed changes in climate and their effects, the fourth IPCC report in 2007 highlighted significant changes in many physical and biological systems, and these changes occurred as a response to global warming (IPCC 2007). The fifth report, finalized in 2013-2014, provided an overview of the state of knowledge concerning climate science and noted that the anthropogenic emissions of greenhouse gases were the highest in history (IPCC 2014). Finally, the sixth report of 2023, based on the three Working Groups (the Physical Science Basis, Impacts, Adaptation, and Vulnerability, and the Mitigation of Climate Change), emphasized the latest scientific insights into the climate system and climate change, including its impacts on various sectors at the regional and global scales, along with an assessment of mitigation strategies, policy instruments, and their societal implications (IPCC 2023).

Despite these historic facts, and scientific evidence presented by subsequent IPCC reports, climate change unfortunately ends up becoming more of a political debate (Bernauer 2013). In the case of North America, where climate change impacts have become more frequent and intense, some vested interest groups have generated misinformation to undermine climate science and the urgency of climate change risks, particularly in the U.S. (IPCC 2023). The IPCC's sixth assessment report also demonstrates a high confidence in the assertion that strong party affiliations and partisan views in the U.S. exacerbate polarization, thereby impeding climate mitigation and adaptation efforts (IPCC 2023). Moreover, the skepticism toward the scientific consensus on climate change has often arisen from the resistance of US conservatives to agreeing to policy approaches that challenge their ideologies (Bolsen and Druckman 2018). In the U.S., the 2021 Yale Climate Opinion Maps reported that 72% of respondents, from a dataset of $n > 28,000$ representing the entire nation, believe in global warming, whereas 14% consider it to be a lie (Marlon et al.

2021). Another 2016 study, conducted by the Pew Research Center on the politics of climate change, reveals that only 36% of Americans are greatly concerned about climate issues, whereas 38% are somewhat concerned and accept human responsibility for heating up the planet (Funk and Kennedy 2016). Among the 36% who were greatly concerned with climate change, 72% were Democrats, whereas 24% were Republicans. This may suggest that Democrats and Republicans remained divided in their ideologies about the scientific consensus on climate change, and they hold varying levels of confidence in the scientific research and data. Republicans tend to be more doubtful of climate science information and the research findings on climate matters. The Republican side strongly opposes climate change mitigation policies, making climate change a contentious issue in U.S. politics (Funk and Kennedy 2016). An individual's interest in and affiliation with a specific group function as strong factors in determining their identity and shaping their beliefs, values, attitudes, and behaviors for issues such as climate change (Brown 2000). The studies above also show that, while there is a notable proportion of the population that accepts the reality of climate change, there still exists a concerning minority that denies or questions its existence.

The population who deny the existence of global warming suggest a notable level of skepticism influenced by various sources of information shaping individuals' perceptions. Climate change deals with an amalgamation of issues related to the natural and social systems and variables, including the intentions and outcomes of actors, functioning together (Islam and Kieu 2021). Consequently, despite the enormity of the issue, effectively communicating the magnitude of climate change impacts to the public can pose a significant challenge. Climate change misinformation (hereinafter, CCM) compounds this challenge by causing misperceptions, ambiguity, and even miseducation, leading to uncertainty and hindering mitigating actions. CCM can arise from a variety of sources and for various reasons, some of which may not be readily apparent. It can be driven by ideological motivations, political and economic agendas, and even a limited understanding of climate science (Lewandowsky et al. 2017). Regardless of the sources, CCM can erode trust in scientific evidence, sow confusion, and impede informed decision-making, hindering societies' ability to address the impacts of climate change. Hence, investigating CCM holds particular importance in the case of the U.S.

The current scientific data show that carbon dioxide constituted 79% of the total greenhouse gas emissions in the U.S. resulting from human activities (Environmental Protection Agency 2024). Another study shows that the U.S. has cumulatively produced the most carbon dioxide and remains one of the major contributors to greenhouse gas emissions historically and globally (Gabbatiss 2021). As the leading emitter of carbon dioxide, the U.S. bears a substantial responsibility in addressing climate change. Therefore, understanding and countering misinformation is essential for guiding effective policy responses and public action to mitigate these emissions and transition towards a more sustainable future. Similarly, differing political ideologies in the public also likely influence the manner and extent that Americans value their environment and act according to their belief on climate information, as well as supporting or opposing investments in pro-climate actions (Gromet et al. 2013). Given the U.S.'s influential role in shaping global climate policy, combating misinformation domestically can have far-reaching implications. Furthermore, addressing CCM within the U.S. is essential for fostering resilience and adaptation strategies to mitigate the impacts of climate change within the nation.

Strong political identities and individual adherence to political identities as Democrats or Republicans significantly influence how the public receive and interpret certain information (Iyengar and Krupenkin 2018). Furthermore, divergent political views influence the diverse mediums through which the public consumes climate information. This dynamic underscores the profound influence of politics in shaping perspectives, behaviors, and perceptions related to climate change and CCM. Political affiliations can lead individuals to trust and believe information disseminated by their respective sources, even if it includes misinformation about climate change (Cook et al. 2017). These media, acting as influential actors in a network, play significant roles in shaping public opinion on the issue of climate

change, thereby influencing individual actions (Carvalho 2010). Consequently, a proper understanding of CCM necessitates an approach that can untangle the intricate links that provide a nuanced understanding of this mechanism.

2. Approach and Structure

This study examines the potential of Bruno Latour's actor–network theory's (ANT) black-boxing concept to enhance the understanding of actors, networks, and assemblages. We opted for an exploratory approach with no predefined hypothesis. The exploratory nature of this article facilitated in examining the multifaceted CCM issue within the framework of ANT and the black-boxing concept and providing a broader understanding of various actors and their connections involved in CCM's production, dissemination, and influence on the society. This article primarily draws insights from scholarly literature available in search engines the Web of Science and Google Scholar. We inserted these key words and phrases: 'climate change', 'climate change misinformation', 'climate change polarization', 'actor–network theory', 'black box', 'climate change misinformation history in the U.S.' and 'climate change misinformation and social media' to select the literature. We also referred to google search for online websites that discussed some cases of CCM in the U.S.

The following sections present the definition, context, and historical development of CCM. Then we present a brief overview of CCM studies in the existing literature. This is followed by a discussion on the concepts of ANT and black-boxing. We analyzed a case of CCM using the black-boxing concept, followed by a discussion of counteracting measures to address the CCM issue from the literature. This article seeks to shed light on the interactions and dynamics within the CCM black box and explores the possibility of using the concept in explaining the CCM phenomenon.

3. Climate Change Misinformation Context and Issues

Climate change information refers to data, facts, forecasts, or analysis related to the Earth's climate system based on rigorous scientific research, observational data, and the modeling of past, present and future climate conditions. This can include information about temperature trends, precipitation patterns, atmospheric composition, weather phenomena, climate change projections, and more, and these are provided by scientists and reports from reputable organizations such as the IPCC, National Aeronautics and Space Administration, National Oceanic and Atmospheric Administration, World Meteorological Organization, and Environmental Protection Agency.

The term 'misinformation' broadly refers to inaccurate, misleading, or false information produced and disseminated either deliberately or unknowingly (Guess and Lyons 2020; Schmid-Petri and Bürger 2022). According to the Merriam-Webster Dictionary, misinformation is "incorrect or misleading information"[1]. A closely linked term to misinformation is disinformation, which is defined as "false information deliberately and often covertly spread (as by the planting of rumors) in order to influence public opinion or obscure the truth".[2] Disinformation is described as being intentionally fabricated and spread with a clear intent to cause harm or deceive others (van der Linden et al. 2017; Lazer et al. 2017).

Regardless of the intent, CCM's main objective is to sow doubt about the scientific consensus on climate change. It may sometimes be used interchangeably with 'disinformation', because both these terms have overlapping meanings, sometimes hard to distinguish, and both entail inaccurate or misleading information. Various researchers have distinguished the difference between the two terms, characterizing disinformation as more deliberate and intentional (Tucker et al. 2018). Within the broader umbrella of information, both misinformation and disinformation can be viewed as subsets (Treen et al. 2020). Following Treen et al.'s (2020) treatment of disinformation as a part of misinformation, this article adopts a similar stance, considering disinformation to fall within misinformation, and the misinformation analysis discussed here encompasses disinformation as well.

Scholars relate the notions of skepticism, contrarianism, denial, and disbelief with misinformation about climate change, and argue that people who deny climate change are often skeptical about the information climate science generates, rather than the scientific methodology involved in generating the results (Treen et al. 2020). In line with this argument, CCM can manifest in ways that cast doubts on climate information through the people that seek to discredit climate science (Elsasser and Dunlap 2013). The false assertions in CCM often lack substantiated scientific evidence, yet their basis may stem from exploiting pre-existing doubts and skepticism surrounding climate information. In addition, climate deniers also downplay the severity of climate impacts, which further fuels public distrust regarding this issue. Moreover, by contradicting the scientific consensus on climate change and its impacts, CCM largely aims at or results in preventing climate action (Maertens et al. 2020). Particularly in the realm of online information dissemination, assessing the intentions behind the sharing of CCM may be challenging (Treen et al. 2020). Misinformation tends to spread rapidly through online channels, and information that was created with an original intent to deceive may be shared by those without any deceitful intentions, or genuine information may also be shared deceptively by others (Treen et al. 2020).

3.1. CCM in the U.S.

The fossil fuel industry's opposition to environmental regulation in the U.S. sheds light on the complex origins and motivations behind CCM and denial (Franta 2021). Hall (2015) reports that ExxonMobil (previously called Humble Oil) recognized the climate risks associated with the combustion of fossil fuels as early as 1977 (Hall 2015). At the time, scientists at ExxonMobil understood the link between the use of fossil fuels and increasing carbon dioxide in the atmosphere. Oil industries for decades tried to convince the public about the lack of evidence regarding the direct connection between burning fossil fuels and global warming (Rannard 2023). One can conclude from the strategies of fossil fuel industries that they had knowledge about climate models but chose to misinform the public about it (Supran et al. 2023). Similarly, the Stanford Research Institute in 1968 presented a report to the American Petroleum Institute (API), indicating that carbon dioxide emissions from fossil fuels at the time were outpacing the Earth's natural carbon dioxide removal mechanisms that maintain atmospheric balance (Robinson and Robbins 1968). However, this acknowledgment of climate risks had no effect on the fossil fuel industries, as they understood that promoting climate denial would benefit their business model and profit margins. Hence, they persisted in contradicting climate science. Since then, fossil fuel magnates such as ExxonMobil and Koch Industries have channeled millions of dollars into conservative think tanks and organizations to propagate climate denial (Banerjee 2017). Their early misinformation strategies involved emphasizing the uncertainty surrounding climate science. This approach aimed to create ambiguity and downplayed the seriousness of climate change to the public, safeguarding their long-term industrial interests (Hall 2015).

Furthermore, the following examples demonstrate the behavior and impacts of several contemporary actors, such as fossil fuel giants and conservative think tanks, and organizations' use of mainstream media, news outlets, and the internet to propagate climate denial. Historically, fossil fuel companies have actively promoted climate denial in mainstream news media since the 1990s. A 2008 study revealed that 70% of U.S. television news segments aimed to present a "balanced coverage" when discussing human contributions to climate change (Boykoff 2008). However, this often perpetuated CCM, as the news carried skeptical climate perspectives. A documentary titled 'Frozen Planet' that was broadcast by the Discovery Channel in 2012 barely touched on the human factors associated with causing and exacerbating global warming (Linfield 2011). In 2013, USA Today published an op-ed, claiming that the IPCC exaggerated climate change risks and that no warming had occurred in the past 15 years (Bast 2013). In 2023, Mike Huckabee's 'Kid's Guide to the Truth About Climate Change', a guidebook marketed to children and parents as an alternative to mainstream climate education, downplays the anthropogenic factors of

climate change and disregards crucial scientific advances in the field, while manipulating the factual information in a misleading way (Gopal 2023).

Media outlets are vital in disseminating CCM, with its spread through online platforms resembling the rapid transmission of a virus, proliferating among social masses akin to a global pandemic (Amoruso et al. 2020). Just as viruses spread rapidly, CCM proliferates because individuals tend to share and reshare information, irrespective of accuracy or beliefs (Karlova and Fisher 2012), leading to its widespread acceptance without scrutiny. Consequently, the frequency with which climate denial posts are viewed and shared on platforms like Facebook or YouTube is crucial, potentially cementing them as perceived "truth" (van der Linden 2022). Additionally, it insinuates that anthropogenic global warming and climate change is a matter of opinion, undermining scientific objectivity.

The above examples show a diverse range of actors, all of whom contribute to propagating climate denial. They are but a few among many instances in the major public media that cherry-pick or present data in a misleading framing (Farmer and Cook 2013), and falsely present the findings and analysis of scientific data to suit a certain narrative intended to distort public understanding of climate change, as well as perceptions of consensus in the scientific community (Lewandowsky et al. 2013). These instances from the past demonstrate the significant implications of media coverage and its role in advancing misleading narratives about climate science. Likewise, these and many similar cases imply that individual actors, interest groups, and institutions all have a critical role in spreading information regarding climate change through different information channels. The impact of CCM in the U.S. extends beyond the public sphere, posing challenges for the effective communication of climate science by scientists and widening disparities in climate change ideologies (Cook 2019; Lewandowsky 2021). CCM is often deliberately produced to hinder climate actions by reducing public support and increasing political inaction (Readfearn 2016; Turrentine 2022).

3.2. Notable Findings from Past CCM Studies

CCM studies are gaining traction at present. In the U.S., over two decades, networks spreading CCM have become intertwined with philanthropy, with funding ties often associated with corporate donors (Farrell 2019). Treen et al. (2020) conducted a comprehensive study of the origins, spread, and impact landscape of CCM, recognizing a CCM network. Bloomfield and Tillery (2019) focused on the dissemination of climate change denial on popular Facebook pages such as Watts Up with That and the Global Warming Policy Forum. This study revealed that these pages use rhetorical strategies and social media platforms to create an illusion of credibility, marginalizing credible scientific climate change information and shedding light on the manipulation of such information and its distribution in digital environments.

Zhou and Shen (2022) investigated confirmation bias as a factor contributing to the persistence of CCM. Their study revealed that individuals tend to perceive and process information in a biased manner, especially when it aligns with their preexisting beliefs, intensifying polarization, particularly among climate change deniers (Zhou and Shen 2022). Rode et al.'s (2021) meta-analysis of interventions aimed at influencing climate change attitudes in the U.S. demonstrated that it is easier to sway people towards climate change skepticism than to foster belief in it. They also revealed that certain efforts aimed at encouraging positive attitudes toward climate change have not been very successful. People's existing beliefs and attitudes about climate change are more influential than the strategies used to try to change those beliefs and attitudes.

Moreover, according to a study by Elsasser and Dunlap (2013), people may be more open to having their opinions influenced when it comes to their understanding or perspective on climate change itself, rather than their support for policies, actions or measures to address it. Interestingly, a 2024 study by Stoetzer and Zimmermann found, in a survey of 4000 U.S. adults, that the results did not provide evidence that people's pre-existing beliefs or motivations influence their views on climate change and their behavior in relation to environmental

issues (Stoetzer and Zimmermann 2024). McCright et al. (2013) further demonstrated that political orientation significantly influences the perceived scientific consensus, beliefs about global warming, and support for governmental efforts to curb emissions in the atmosphere. Misconceptions regarding the scientific consensus have been found to significantly diminish public support for an effective climate policy (Ding et al. 2011).

Communicating climate science faces multifaceted challenges, including cognitive difficulties in understanding the effects of misinformation. The existing literature on how to counter CCM converges on several conclusions, including strategies for effective climate communication, emphasizing the scientific consensus, utilizing culturally aligned messages and messengers, and employing preemptive inoculation techniques to mitigate the spread of misinformation (Lewandowsky 2021).

4. Understanding CCM Using Social Theory and Concepts

4.1. Actor–Network Theory and Black-Boxing

Actor–network theory (ANT) came into existence in the 1980s, when Bruno Latour asserted the need for studying the dynamics of the action and interactions between science and technology (Latour 1987). Latour was a French sociologist and anthropologist known for his innovative work in the field of science and technology[3]. According to Latour, the science and technology relation dynamics can be conceptually and methodologically understood by using ANT (Cordella and Shaikh 2003). Later, Bruno Latour, Michel Callon, and John Law further conceptualized ANT to describe the complex dynamics of interactions between human and non-human agents influencing social processes (Latour 2005). ANT is defined as a theoretical framework that encompasses associations among heterogenous elements, both human and non-human (Dolwick 2009). According to Latour, Callon, and Law, the term 'social' is conceptualized as an association represented by webs, or actors–networks composed of diverse elements (Dolwick 2009), and ANT places more emphasis on how such associations emerge and evolve (Latour 2005). In ANT, an actor is the source of an action, regardless of its status as human or non-human, and the concept examines how each actor influences social processes within a network (Cresswell et al. 2010). Although ANT initially entailed micro-level research into science and technology studies (Cressman 2009), social scientists have increasingly used this theory in wide-ranging research (Fenwick and Edwards 2010). In ANT, actors represent entities that exert agency and have the capability to influence. Actors are not only humans but also ideas, organizations, and technologies that have fundamental roles in creating a social phenomenon (Latour 2005; Yao and Liu 2022). Likewise, when multiple heterogeneous actors interact together to form a network ecosystem, it becomes an assemblage (Deleuze and Parnet 2007).

By highlighting the role and agency of non-human actors, this theory deviates from human-centric approaches in understanding a social system (Latour 2005). These non-human actors are more than just inert objects and instead are the practices and outcomes of a social system (Law 1992). Similarly, at the core of ANT lies translation, which essentially creates a linkage between heterogenous actors (Neisser 2014). Translation functions by establishing a network that facilitates connections, fosters convergence between actors, and creates a conducive environment for these actors to actively contribute to the production of knowledge and information, with an aim to create a space for networks to form and for actors to act in the network. According to ANT, society is one giant network with human and non-human actors as interconnected nodes, all of which have direct and nuanced impacts on the behavior of their space (Crawford 2020). ANT has been considered one of the prominent frameworks for providing a critical analysis of networks within the assemblages of social space (Whittle and Spicer 2008).

As ANT emphasizes the agency and role of non-human actors in social networks, it undermines the conventional sociological perspectives that concentrate mainly on human involvement and agency in constructing a social phenomenon (Wessells 2007). This implies that non-human actors themselves have the ability to act upon and affect social processes, rather than acting only as directed by humans. Take social media platforms as an example.

Social media platforms may not be deemed merely as technologies and tools in mediating information, but rather they constitute their own individual assemblage of networks. Therefore, social media platforms, such as Facebook and the like, can each be seen as an actor. Its assemblage consists of its founders, developers, algorithms, servers, users, platform functionalities, and the digital space occupied on smartphones. Facebook as an actor shows that human agency is not the only factor shaping its operation. Rather, it is the interaction between humans, hardware, software, and ideas involved in the web of a network influencing outcomes and experiences. The employment of ANT broadens the analysis of non-human actors and their roles, providing a deeper understanding of social phenomena (Pennycook et al. 2020).

According to Latour, ANT assumes that nothing social exists 'out of the box' without first being constructed or performing as an actor (Latour 2005). Hence, it is the role of a social scientist to examine how, in our case CCM, exists as an actor within the social framework. ANT provides a foundational perspective for identifying and analyzing the complex interconnections of actors and networks that contribute to the formation of climate change-related knowledge and dominant discourses. This approach will better allow us to see how CCM disseminates and proliferates within society and help contemporary societies adjust to and counteract CCM.

In the realm of science studies, the concept of black-boxing is rooted in the idea of a black box, which is a metaphorical representation of a system or a process whose internal workings are not visible or understood (Latour 1999). The notion of the black box was first introduced by Bruno Latour within the framework of ANT, suggesting that science, technology, and society are interconnected and cannot be separated (Latour 1994). They come together as black boxes which are closed and simplified units. Callon and Latour (1981) suggest that "a black box contains that which no longer needs to be reconsidered, those things whose contents have become a matter of indifference". This quotation explains that, when something is black-boxed, its internal mechanisms, interactions, or contents are either accepted without further examination or are normalized, or they eventually become invisible and obscure over time (Latour 1999). A black box is an assemblage of actants bearing a functional character or specific purpose (Rodriguez 2009). It is a complex network made up of different actors like humans, machines, and processes, all working together as if they were a single entity (Nawararthne and Storni 2023). Latour and Callon use the term black box to refer to a set of stabilized relationships (Krarup and Blok 2011). In the context of ANT, an actor's influence increases when it is able to add more relations into the black box and simplify them, resulting in that actor's sustained influence and the stabilization of relationships within the black box network (Callon and Latour 1981). ANT can be utilized to re-examine black boxes and explore their ontology, which includes actors and actors–networks that contribute to their formation (Latour 2005).

4.2. CCM in Actor–Network Studies

ANT has been applied to analyze systems across various disciplines: natural sciences (Newton 2002), social sciences (Fine 2005), medical sciences (Cresswell et al. 2010), information systems research (Stanforth 2006; Silvis and Alexander 2014), accounting literature (O'Connell et al. 2014), and humanities (Piper-Wright 2020). In climate change studies, actor–network topics have become increasingly discussed, particularly in relation to the network of actors and institutions and media platforms that have a role in distributing CCM.

Bloomfield and Tillery (2019) made use of ANT, argumentation, and a topical analysis to understand how online discussions relating to scientific information are shared and interpreted within networks, particularly among climate change deniers. They examined the use of hyperlinks and other capabilities as active participants in the network of climate change information that contribute to skepticism about climate change. Colston and Ivey (2015) employed ANT to research the dynamics between different actors involved in educational policymaking, and to analyze the spaces where policies are defined and negotiated and how they shape climate change education in Oklahoma. Kukkonen et al. (2021) analyzed

the media debates regarding Arctic climate change in Finland and Canada from 2011 to 2015, using a discourse network approach. In advancing theoretical knowledge on the role of mass media in environmental policymaking, they reveal that governments and universities in both countries are central actors frequently discussed in media debates. But the media visibility of actors does not always correspond to their actual political power in environmental decision-making. This suggests that attention should be paid to the justifications these actors use in environmental debates in the media. Björklund (2022) combined a social network analysis with cultural industry studies and disinformation research to analyze the Nongovernmental International Panel on Climate Change (NIPCC) and its production of climate disinformation texts. The author demonstrated the NIPCC's network structure behind climate disinformation text production and dissemination, revealing its funding connections to economic and political elites and suggesting that there is a corrupt process and chain of disinformation text creation and distribution.

Almiron et al. (2023) utilized a social network analysis to map the network structure of the most influential climate change contrarian think tanks in Europe, uncovering their links to the U.S. contrarian network as identified by Farrell (2016). This analysis indicated that the network is predominately neoliberal, male-dominated, and resistant to self-reflection, spreading contrarian narratives about climate action in Europe, and it emphasized the adoption of intersectional approaches in understanding climate change contrarianism in any context. Hassan et al. (2023) used a sociotechnical model of media effects to examine how climate change disinformation is spread across different media platforms. The study attempted to explore the identities of agents who spread disinformation across media platforms, and it indicated that politicians, organizations, and anonymous groups frequently disseminate fabricated climate change content. These results align with the sociopolitical model of media effects (Marwick 2018), which suggests that various factors, such as actors and media platforms, collectively contribute to the spread of disinformation.

Yang (2024a) interrogated the most influential climate change deniers, and the factors that make some deniers more influential than others, over a decade. This led to the identification of a core group of deniers maintaining a significant influence by spreading false information about the social and economic effects of environmental policies. Conservative media outlets were the most prominent deniers, known for their attacks against their opponents and questioning climate science. Yang (2024b) also investigated the role of influential climate change deniers in shaping the evolution and stability of networks regarding climate disinformation discourse over a period of 10 years. This network had remained remarkably stable, forming smaller groups and often retaining climate disinformation topics discussed within the network. These findings underscored the need to analyze these networks as long-term and strategic entities, their operationalization, and their cumulative effects over time Yang (2024b).

While this emerging literature does not explicitly apply ANT to dissect and understand the CCM network, it presents a diverse range of studies examining the actors and networks involved in CCM dissemination. These few among numerous other contemporary studies somewhat share a common thread, in analyzing the roles of various actors within their networks and the consequential effects the actors have on the persisting misinformation regarding climate science. In recent times, climate misinformation research endeavors have emerged to provide valuable insights into the complex web of actors and networks.

4.3. CCM as a Black box

In ANT, the idea of a black box refers to the process by which a network of diverse human and non-human actors come together and stabilize their connections to function as a single unified actor, thereby masking the intricate details of its structure, relations, and functionalities (Latour 1999). In the context of CCM, the idea of black-boxing within ANT implies that misinformation can be seen as an assemblage of networks and actors within a black box. In its closed state, CCM as a black box serves a specific function within the broader sociopolitical landscape. Its primary purpose is to sow doubt and confusion about

the reality and severity of climate change, thereby undermining efforts to address the issue effectively. This leads us to investigate the specific ways in which humans and non-humans are aligned and black-boxed (or concealed) in misinformation networks that ultimately facilitate the production of deceptive climate science information. When the black box of CCM is closed, it represents a phenomenon where the narrative of climate change denial is perpetuated and reinforced through the collective efforts of various actors functioning together within a network. This phenomenon establishes CCM within society. As a result, public attention tends to shift away from the intricate details of how the information was produced and how it functions, but rather, the misinformation, as a black box, becomes simplified and obscured (Stalph 2019).

Using Latour's concept of black-boxing can help illuminate different aspects of CCM. For instance, we can take a widely popular and often repeated phrase 'climate change is a hoax' as an example for how a phrase acts as a black box for CCM. The skepticism towards climate science had been noticed as early as 1996, when there were corruption accusations within the IPCC, as reported in the Wall Street Journal (Lahsen 1999; Oreskes and Conway 2011). In 2003, a portion of a speech on the Senate floor by the Oklahoma Senator, James Inhofe, questioned whether anthropogenic global warming might be considered as 'the greatest hoax' and deception ever imposed on the American people (Boykoff and Boykoff 2007). In 2012, Senator Inhofe authored a book titled "The Greatest Hoax: How the Global Warming Conspiracy Threatens Your Future" (Inhofe 2012), further perpetuating the idea of global warming as a hoax. Similarly, the then President of the U.S., Donald Trump's, 1 January 2014 tweet "This very expensive Global Warming bullshit has got to stop. Our planet is freezing, record low temps, and our GW scientists are stuck in ice" implied that the Earth was experiencing low temperatures rather than warming, further fueling the notion of global warming as a hoax and dismissing climate science. A website article from 2017 reported that Trump expressed skepticism about climate change in 115 of his tweets from 2011 to 2015. (Matthews 2017). These examples show that the hoax narrative regarding climate change has been amplified by certain influential political figures (Sarathchandra and Haltinner 2021). Moreover, the narrative that climate change is a hoax has grown due to well-funded and often active disinformation campaigns, supported by corporations such as Koch Brothers and other fossil fuel industries (Sarathchandra and Haltinner 2021). To say that there is no scientific consensus on climate change is a key factor in creating uncertainty about the climate crisis in the public mind (Poortinga et al. 2011).

Using a case study of one of the most widespread narratives called 'climate change is a hoax', we analyzed CCM based on the black-boxing concept. We label this narrative as false information that emerged from skepticism regarding the scientific consensus on human-induced climate change. We attempt to understand why certain individuals or groups consistently deny climate science and where this denial stems from, while uncovering the black box of this narrative. While the black box of CCM in the U.S. contains numerous examples, for the scope of this analysis, we focused on examining a single assemblage within a broader context. Hence, we focused on deconstructing the example of James Inhofe's 'greatest hoax' narrative through the black-boxing concept, as shown in Figure 1.

(a) As a prominent political figure, Senator Inhofe possesses significant power and influence over public opinion and policy decisions regarding climate change. Inhofe has utilized his platform to propagate the narrative of climate change as a hoax, in the process solidifying his position as a leading voice of climate change denial. He authored "*The Greatest Hoax: How the Global Warming Conspiracy Threatens Your Future*" in 2012, and he has delivered speeches and engaged in public discourse that undermines the credibility of climate science and dismisses the overwhelming evidence supporting anthropogenic climate change. In 2015, he also infamously brought a snowball onto the Senate floor as a prop for his argument that global warming was not real (The Guardian 2015). By disseminating the hoax narrative, he undermines climate science and influences environment- and climate-related policies which threaten the fossil fuel industries. Inhofe is a central actor in the misinformation network, as he fulfills

his objective within the misinformation network to advance his political agenda. He also leverages his position as a senator to amplify his hoax narrative.

(b) Inhofe's book serves as a pivotal actor in spreading CCM. Its objective is to present a persuasive argument that climate change is a hoax, thereby shaping public opinion and influencing policy decisions. Through the dissemination of this book, the hoax narrative of climate change gets reinforced.

(c) Specifically in the case of Senator Inhofe's book, the publishing house WorldNetDaily (WND)—an American far-right news website—played a role in the black box network by disseminating the book to a wider audience. WND is known for publishing content voiced by or originating from right-wing politicians and pundits (Nelson 2012). By leveraging its platform and audience reach, WND amplifies the narrative of climate change denial presented in Inhofe's book, contributing to the reinforcement of skepticism surrounding climate science. WND serves as a critical actor in the dissemination of CCM, functioning within a network of interconnected actors. Whether through opinion pieces, news coverage, or social media posts, WND amplifies the climate denial agenda for its audience. Media outlets act as intermediaries within the network, amplifying Inhofe's narrative to a wider audience. The objective is to attract viewership by catering to the biases and interests of their audience and to perpetuate the hoax narrative and contribute to the dissemination of misinformation on climate change.

(d) Between the publisher and the public, various channels contribute to the dissemination and amplification of Senator Inhofe's climate change denial narrative. In the case of the publisher, news outlets (including newspapers, television channels, or online websites) are vital in conveying information to the public, amplifying the message of Inhofe's book through coverage and reporting, simplifying its content, and making it challenging for the public to critically examine climate change denialism.

(e) The dissemination of a false narrative is also often influenced by several interconnected characteristics in a social network (Treen et al. 2020). For example, users on social media platforms are connected to other users through a network of friends, followers, or groups. This is where the role of social media is crucial, because once the misinformation is posted online, it reaches a global audience within a short period of time (Boussalis and Coan 2018). When one user shares false information or a claim about climate change, then it instantly reaches the user's connections in his or her network. Various studies suggests that Facebook and Twitter are often used to propagate misinformation about climate science to the public (Al-Rawi et al. 2021). In this case, these social media platforms serve as avenues for promoting the book and engaging with supporters, further amplifying the narrative. Supporters of Inhofe's climate denial narrative may also use specific features on Facebook, such as pages and groups, to promote his book or share excerpts from his book, thereby engaging with like-minded individuals within their network. Moreover, user engagement metrics on Facebook, such as likes, shares, comments, and posts related to Inhofe's book and its contents, may also provide insights into public interest and interaction with the CCM narrative. Other social media platform products like YouTube videos, capable of going viral, may provide another avenue for spreading Inhofe's message widely and swiftly, reinforcing the simplicity of the narrative and impeding public inquiry.

(f) Google searches, a common source of online information, may also direct individuals to resources related to Inhofe's book, perpetuating the simplified narrative and obstructing critical examination.

(g) Book vendors and online sellers, such as Amazon, facilitate the accessibility of Inhofe's book to a broader audience, contributing to the amplification of the narrative and reinforcing the black-boxing of CCM. Moreover, reviews and recommendations by like-minded individuals and groups on these platforms may further influence the public's decision to engage with the book and its contents, contributing to promoting more discussion around this narrative.

(h)   The public absorbs and internalizes the message that climate change is a hoax through repeated exposure to misinformation. They serve as both recipients and interpreters of misinformation propagated by Inhofe and other actors within the network. Their objective is to make sense of the information they encounter and form opinions on climate change based on the narratives presented to them. By consuming and internalizing the hoax narrative, individuals may develop skepticism towards climate science and resist calls for action on climate change (Treen et al. 2020). The general public serves as the audience for Inhofe's book and other forms of media that perpetuate CCM.

(i)   According to a 2019 report, Senator Inhofe received USD 1,530,500 from the fossil fuel industry during his career to disprove climate change (Geary 2019). Furthermore, between 1989 and 2020, Senator Inhofe received significant funding from various entities with vested interests in the oil and gas industries, namely, Koch Industries and American Consolidated Natural Resources, to contribute to Inhofe's climate denial campaigns (McKie 2023). Similarly, Senator Inhofe had strong connections with organizations known for opposing climate change action, such as the Heartland Institute, an American conservative and libertarian think tank well-known for climate change skepticism (Boykoff 2023). The financial support and platform from corporations, think tanks, and other entities sharing a common goal has a role in amplifying climate denial voices. In this way, this kind of support has been leveraged in the creation of a network of like-minded individuals and entities to reinforce the narrative that climate change is a hoax. They further bolster skepticism towards climate science and maintain their dominance in society.

(j)   Although, the scientific community strives to communicate the consensus on anthropogenic climate change and the need for urgent action, their efforts are often discredited by actors like Inhofe, who deny that climate change is caused by humans (Petersen et al. 2019). The dissemination of hoax narratives undermines public trust in scientific information and leads to doubts about the reality of climate change. The emergence and reproduction of false or fabricated information or news regarding climate change, which infiltrates the scientific community, may result in a whirlwind of concerns and discussions surrounding such information (Alonso García et al. 2020).
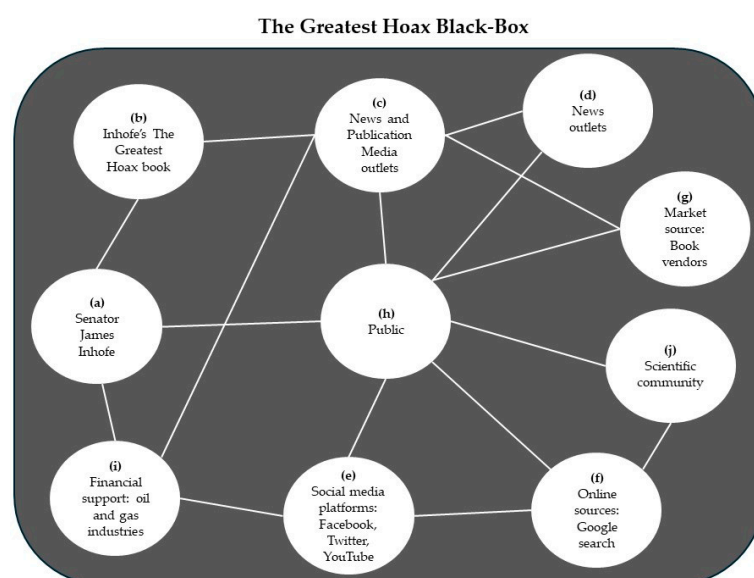

Figure 1. A simplified illustration of different actors and their potential associations within the greatest hoax narrative, perceived as a CCM black box.

5. Counteracting Measures against Climate Change Misinformation

One of the most important measures to deal with the politicization of climate science and CCM is emphasizing the significance of scientific consensus (Bolsen and Druckman

2015). A fundamental aspect of proper climate change communication is exploring how to inform the public about the scientific consensus and how such communication can affect people's perceptions and attitudes about the reality of climate change (Bayes et al. 2023). Scientific consensus represents a collective agreement among climate science experts on the climate data and findings generated through extensive research, analysis, and peer review. But, in the case of the U.S., research indicates that the U.S. public tends to downplay the degree of scientific consensus regarding anthropogenic climate change (Druckman 2017), the reasons likely being the spread of misinformation and the politicization of the climate change issue in the country (Druckman 2017).

The existing body of literature concerning CCM includes methods to effectively communicate climate science and combat the global reach of misinformation (e.g., Lawrence and Estow 2017; Farrell et al. 2019; Chen et al. 2023). Through a comprehensive literature review, four broad categories of strategies to tackle CCM have emerged. The first type is "public inoculation" (Schmid-Petri and Bürger 2022), which involves deliberately exposing people with minimal misinformation or disinformation messages and help them recognize and understand misleading content. This approach aims to immunize the public against the consequences of CCM (van der Linden et al. 2017). Public inoculation can improve people's capacity to identify and reject false information, thus enhancing their resilience against climate denial. The second strategy focuses on "spreading education and awareness regarding climate impacts". This strategy is often used in conjunction with inoculation to foster critical thinking abilities regarding the various climate-related information available online and offline. Treen et al. (2020) emphasized the importance of 'agnotology' in countering climate misinformation. Agnotology studies the deliberate creation of doubts concerning the reality and severity of climate change. Agnotology research can be crucial in understanding how misinformation networks have been historically framed and how to assist in countering climate denial efforts. Various studies have indicated the need for incorporating technological innovations in addressing CCM. This third strategy deals with "introducing detection mechanisms" for identifying and labeling bogus climate change claims in various media channels and social networking platforms (Shao et al. 2018). A study by Pennycook and Rand (2019) reveals that crowdsourcing trust ratings from the public regarding climate topics can be a useful tool in combating disinformation and news items with considerable political bias. The final category involves "enacting legal strategies and introducing policies" to regulate the generation and diffusion of misinformation across different media channels (Chen et al. 2023). Legal frameworks provide direction in holding institutions, people, and climate misinformation networks accountable for propagating climate denialism.

In addition, effective policies can be set in place to encourage the circulation of accurate climate information. While governments play a vital role in controlling false information, social media platforms and online webpages, where misinformation tends to thrive, should also initiate and implement regulation procedures. By employing these multiple strategies, stakeholders can work together to address climate change misinformation, ensuring the public receives accurate information and empowering them to make informed decisions regarding climate change and its impacts.

6. Discussion and Conclusions

In this article, we discussed how CCM can be explored through the lens of ANT and the black box. By considering both human and non-human actors, ANT and the black box concept offer valuable insights into how CCM is produced and flows within its network. Our analysis dissected the roles of different actors and their actions, which contribute to perpetuating skepticism towards climate science. While the ANT framework helps in understanding the alliances and relations different actors form within a CCM network, the black box concept sheds light on the complexity of these relations and interactions, which may become obscured over time. An important discussion in opening the black box of CCM is that, once this black box is opened, its inner network and functions become apparent. This

black box no longer remains a black box; however, this unveiling process helps in revealing actor networks and their interactions in the production of CCM, and the mechanism through which CCM sustains its presence in society. We argue that this exercise, by illuminating the intricacies of the CCM network, may provide a perspective for understanding how CCM channels operate in society. We also argue that, once CCM is out in the public domain, the nuances of its inner workings may become less of a concern. This may be due to the constant exposure to an overwhelming amount of information, and people do not always have the opportunity to critically evaluate every piece of information they encounter. However, understanding how CCM functions from its inception to dissemination may foster more discourse on the topic and inform the development of strategies aimed at addressing CCM impacts more effectively.

In the ANT study of CCM, all actors, whether humans or non-humans, are given equal consideration in the analysis of the network they form. These actors are not examined for their inherent qualities but for their actions and interactions within a CCM network (Cresswell et al. 2010). This study examined an example of a CCM network in the U.S., delving into its multifaceted nature and the interconnected factors influencing the CCM network. We reflect upon the potential use of ANT and black-boxing by illustrating a case of CCM from the U.S. The central idea of using ANT and black-boxing here is to analyze how different actors get enrolled in the CCM network, identify what associations between these actors exist, and how the whole CCM network becomes stabilized and black-boxed in the process.

Various scholarly studies have identified close ties between CCM and the fossil fuel industries and conservative ideas and principles, which serve as primary drivers of CCM narratives in this country. The issue of CCM's creation and dissemination is further compounded by the vast network of media outlets and supportive allies who promote CCM to fulfill their corporate interests and profit motives. The widespread dissemination of CCM highlights the urgency and importance of addressing and countering climate misinformation, to foster informed public understanding of and action on climate change. As long as CCM persists, it continues to shape perceptions and acts as a confirmation bias for climate change deniers, reinforcing their existing beliefs and impeding efforts to advance the understanding of climate change as a proven reality. This article integrates insights from Latour's ANT and black-boxing concept to explore CCM as a black box. This exercise shows that CCM is a complex issue from within, despite it seeming straightforward. In this article, we argued that ANT has a significant potential to enrich our understanding of CCM. We used an example of an infamous climate change narrative to uncover its internal workings using the concept of black-boxing. Opening the black box elucidates the way that the complex system and processes become simplified, accepted, and invisible over time. And we believe that this exercise will be a springboard for a deeper analysis of the CCM issue.

CCM proves to be a multifaceted problem, with various actors and sub-actors playing roles in its information flow, reiteration in the media, and amplification in the public sphere. Science, politics, economics, and human psychology perspectives are all entangled in this complex issue. Hence, there is a pressing need for an integrated approach to address the problem effectively. Addressing the CCM problem necessitates a comprehensive approach involving scientists, policymakers, media professionals, journalists, and the public. In light of this study, it is evident that tackling CCM requires a concerted effort from multiple stakeholders, all working towards promoting accurate climate information and combating misinformation. By collectively addressing this CCM issue, we hope to foster a more informed and united approach to climate action, enhancing the potential for meaningful progress in climate change adaptation and mitigation.

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Notes

[1] Extracted definition from: https://www.merriam-webster.com/dictionary/misinformation (accessed on 22 April 2024).
[2] Extracted definition from: https://www.merriam-webster.com/dictionary/disinformation (accessed on 22 April 2024).
[3] https://www.britannica.com/biography/Bruno-Latour (accessed on 22 April 2024).

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