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Research article
Climate Sciences

From hashtags to hostility: global dynamics of climate denialism on Twitter in the post-COVID era

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Abstract. The rise of climate denialism in the general population (+5% between 2019 and 2023) has been accompanied by a very significant increase in denialist activism on "X"/Twitter since the summer of 2022, and increased hostility towards climate scientists.

Through global tracking of Twitter exchanges about climate change between 2019 and 2023, as well as exchanges about COVID-19 pandemics, we analyzed this online trend and its interaction with other societal issues like politics and COVID-19 pandemics.

Beyond fact-checking, we show, through complex networks and semantic analyses, that there are structural differences between these denialist and pro-climate online communities, as well as between the circulation of false information and other climate change-related narratives.

All the evidence suggests that the behavior of deniers is designed to deceive, and that they are over-represented on social networks compared to what they actually represent offline. This is particularly true on "X"/Twitter since Musk's takeover.

We have also highlighted the globalized aspect of this new denialism, its alignment with the interests and visions of powers such as Russia and how it has benefited from the COVID-19 pandemic.

Keywords. Climate disinformation, Socio-semantic networks, Astroturfing, Opinion manipulation, Polarization, Computational social sciences.

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1. Introduction

Policies to combat climate change face a paradox[1]. A sharp reduction in greenhouse gas emissions is considered an absolute priority, with changes to our lifestyles and behaviour as one of the main levers (IPCC, 2022). This will only happen if public opinion is convinced that climate change is man-made and can be combated by a change in collective behavior (Huber et al., 2020).

But this seems to be less and less the case, although the consequences of climate change are becoming increasingly apparent. According to a worldwide longitudinal survey on 24k people from 30 countries and five continents (Witkowski et al., 2023), the proportion of population believing in anthropogenic climate change (ACC) has declined globally from 69% in 2019 to 63% in 2022, with 9% of the people surveyed believing that there is no climate change at all, and 28% believing that it has only a natural origin or having no opinion about it. Outliers

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[1] According to IPCC, we define *climate change* as anthropogenic shifts in the global climate system.

States are the United States of America and Russia, with only 52% of believers in ACC and France with the sharpest one year decline (−8% between 2021 and 2022), with 63% believing in ACC in 2022 (resp. 71% in 2021), 8% (resp. 9%) denying climate change and 29% (resp. 20%) denying its anthropogenic origin.

It's to be expected that the presence of an increasing and significant proportion of climate-denialists[2] in a country's population will lead to future climate measures being contested, possibly violently. Understanding this global anachronistic denialist trend is thus a major challenge for the efficient implementation of future climate policies.

Social networks such as Twitter/X could be both one of the factors contributing to the rise of climate skepticism and a privileged view point to observe and understand its evolution. For example (Rogstad, 2016; B. A. Conway et al., 2015) demonstrated the "symbiotic relationship" that exist between social networks such as Twitter/X and the media agenda, while (Wang and Guo, 2018) shows that Twitter could contribute to frame the debate on societal issues in advance of media coverage. On the other hand, computational science studies have illustrated the power of large scale Twitter analyses to depict opinion landscapes (Barberá, 2015) and their dynamics (Gaumont et al., 2018; Chomel et al., 2022; Chavalarias, 2022).

Twitter has been traditionally one of the main networks for disseminating climate information from medias, NGOs, grassroots activists, celebrities, and politicians (Fownes et al., 2018). But times have changed and it is today at the very heart of the climate denialist propaganda. Since 2022, climate crisis deniers have been increasingly targeting scientists on this platform (Fazackerley, 2023; Vidal Valero, 2023a), silencing climate scientists which results in both boosting climate disinformation[3] and slowing down climate science dissemination. A 2023 large scale *Nature* survey of scientists (Vidal Valero, 2023b) revealed that, while many said that they had noticed an uptick in the amount of fake accounts, trolls and hate speech, more than half reported that "they have reduced the time they spend on the platform in the past six months and just under 7% have stopped using it altogether." At the collective level, following low polarization of COP20 to COP25 debates on "X", (Falkenberg et al., 2022) reported an increase in polarization during COP26 which was mainly driven by growing right-wing activity. This context makes Twitter/X a particularly interesting vantage point from which to study the rise of the climate denialism.

Beyond fact-checking or the characterization of skeptics narratives, this article aims to better understand the structural and organizational specificity of denialist communities that enable them to sustain themselves over time, as well as the factors that contribute to the circulation of different denialist narratives at the global level. To this end, we analyze the 2022 upsurge of climate denialism at the global level through the Twitter lens with a special focus on two outliers of this dynamics, the United States and France.

2. Data and methodology

2.1. *The Climatoscope database*

Since 2015, we used the Twitter's track API to collect in real-time the tweets associated to a list of several dozens of English and French keywords related to climate change (see Supplementary Material A). More than 400 millions tweets related to climate change were collected until Twitter/X closed its APIs in spring 2023 (*Climatoscope* database). This data collection was not exhaustive but represents a sufficiently large and diverse sample of the climate change Twitter/X debates to understand the social dynamics driving them.

Similarly, we conducted a monitoring of the debates on COVID-19 (*Covidoscope* database 2.5 billion tweets over 2019–2023, 77 millions being vaccine

[2] In this article, we use "climate skepticism" and "climate denialism" interchangeably, the second expression having the advantage of not referring to skepticism, which is defended by some as a quality in science. See (Jacques, 2012) for more developments on this naming.

[3] Arguments range from "climate change is not real" to "CO_2 is not a greenhouse gas", to "there is no scientific consensus on climate change", "climate change is real but caused by natural climate variability" or "climate concerns are part of a left-wing political agenda to destroy capitalism" (see also Coan et al., 2021). It should be noted that all these arguments have made their way to the highest political circles and were officially relayed in 2025 by the US Department of Energy (Tollefson, 2025).

related) and on French politics (*Politoscope* database, 711 millions tweets over 2016–2023), two independently collected databases that allow for cross-reference between societal issues.

2.2. *Reconstruction of opinion landscape and social groups*

We adopted a socio-semantic analysis approach to identify online social groups associated to selected topics. Following Gaumont et al. (2018), we used the intensity of retweets[4] between two accounts as an indicator of belief and representation alignment. In short, the collection and analysis of millions of tweets and their retweets makes it possible to build the network of interactions between Twitter accounts. In these retweet networks, two accounts are linked if one retweets the other intensively. Such interactional approach to social phenomena is performed without having to know the content of the tweets.

By analyzing these interaction networks using graph theory tools, clusters or "communities" can be identified, i.e. groups of accounts which productions reflect shared representations and common beliefs on a given topic. We used the Louvain clustering algorithm (Blondel et al., 2008) to identify the communities which has proved suitable for this type of task (Gaumont et al., 2018). For example, the map of the entire climate change database for autumn 2022 is shown in Figure 1.

This interactionist categorization of Twitter/X accounts makes it possible to identify climate-denialist and pro-climate accounts, and paves the way for new analyses of the social structure, strategies and narratives of climate-denialist groups and their evolution.

Thanks to generic databases such as *Politoscope*, we can identify the different communities of opinion on more specific subjects by applying this method to a filtered database whose messages are filtered using certain keywords. Finally, these networks can be visualized to highlight the social structures of these groups and the relationships they maintain.

[4]The retweet is a message that is relayed from account to account without modification nor comment.

2.3. *Detection of inauthentic behavior*

Astroturfing—the attempt to win the support of the general public by artificially increasing the presence of an idea, person or product in a population—takes a new dimension online with the possibility to use automated accounts in opinion manipulation campaigns. The line between the proselytizing of an automated account or one operated by an actor paid to defend a cause and that of a grassroot supporter of that same cause is often blurred. However, it is possible thanks to machine learning techniques to assign a "score of inauthenticity" to an account based on its profile and online activity, which would somehow give a probability for it to be inauthentic.

Drawing on publicly available datasets[5] and including tens of thousands of accounts manually labeled as "probably automated" ("bots"), we trained an AI model to assign an inauthenticity score to a Twitter account based on the collected data and computed this score for over 13 million accounts.

We decided to define as "bot-like" the accounts having more than 50% of chances to be inauthentic according to this method. Identifying these accounts, however, is a race against the improvement of automated techniques, and it is difficult to really assess the accuracy of these methods without knowing exactly how advanced astroturfing techniques are (see Section 3.3.3).

Although we don't know the absolute level of performance of this approach, we can still get insights by comparing the level of inauthenticity between communities, or by analyzing its evolution for a given community. A community with a higher average inauthenticity score than others would point to possible *astroturfing* operations.

2.4. *Toxicity of the tweets*

Bouchaud et al. (2023) have shown that toxic *tweets*—such as insults, threats or obscenity, are amplified across the platform by Twitter's recommendation system, so that on average they are +48.7%

[5]Data aggregated by Indiana University, as part of the botometer project, containing thousands of bots involved in various online behaviors, such as hyperactive political bots or fake accounts purchased from multiple companies to increase a client's follower count.

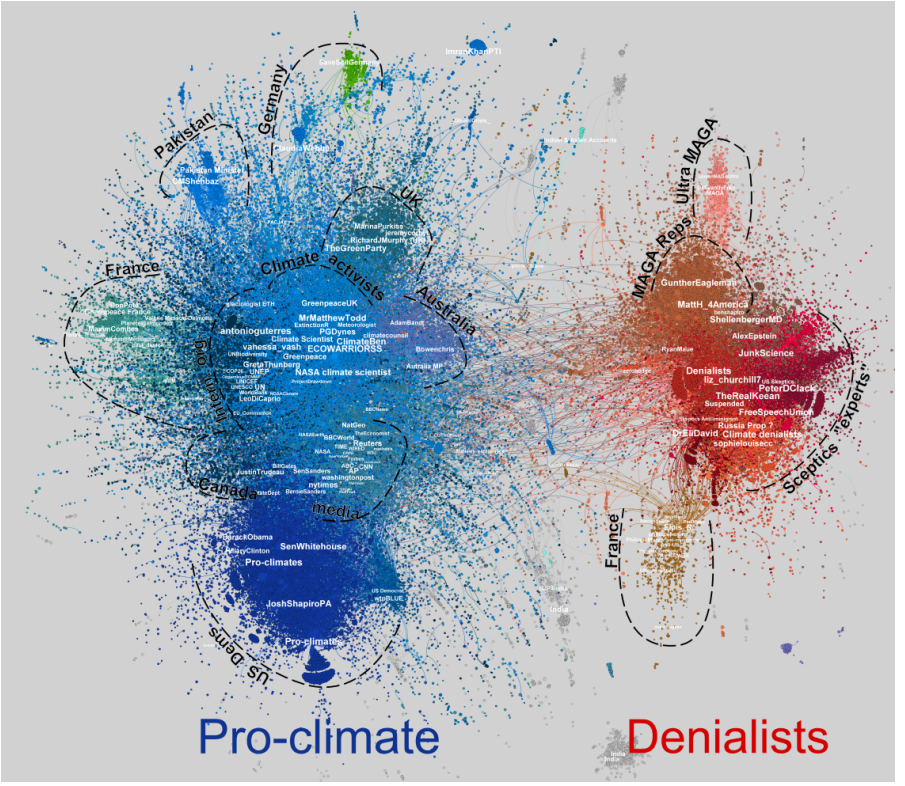


Figure 1. Climate Twittersphere in the fall of 2022. Mapping of 200k Twitter accounts retweeting climate change-related content, in English or French. Each color indicates a specific community, either geographic (country level) or ideologically oriented (pro-climate science activists or denialists). Links correspond to a retweet intensity equal to or greater than 7 over the period. On the left: pro-climate/IPCC communities, on the right: climate-denialists.

over-represented in users' news feeds. Moreover, Chavalarias, Bouchaud and Panahi (2024) showed that Twitter-like recommendation systems concentrate social power in the hands of the most toxic users. The toxicity of online discourse is thus an important dimension in understanding the over-representation of certain accounts and narratives.

We employed Detoxify (Hanu and Unitary team, 2020), an open-source natural language processing model trained on Google's Jigsaw toxic comments database, for the detection of toxic tweets. Significant attention was dedicated to mitigating unintentional biases in the training process, notably addressing racial biases, in accordance with the insights provided by Davidson et al. (2019). The suitability of utilizing this model in our study was affirmed through the manual annotation of randomly sampled tweets from the aggregated dataset.

3. Results

3.1. *The structure of the climate twittersphere*

Since 2015, the mapping of English and French speaking activists on climate change issues, regardless of time period, reveals a bi-polarized social structure at the global level, with two major regions clashing, one grouping Twitter communities that believe in anthropogenic climate change, the other region is made up of communities that dispute this fact—the narratives developed by these communities will be referred to as "denialists" (Figure 1).

Each of these regions has communities whose boundaries coincide with geographic, political, or ideological borders. The largest and most stable pro-climate science communities in this English/French speaking landscape are Canada,

the United Kingdom, Australia, France, Germany, Pakistan, major international media (AP, Reuters, BBC, etc.), international organizations (UN, COPX, UNICEF, NASA, etc.), climate activists (Greta Thunberg, Greenpeace, etc.) and, *last but not least*, the United States of America, divided into two sub-communities: the left wing of the Democratic Party-around Bernie Sanders and Alexandria Ocasio-Cortez-, and the "mainstream" Democratic party around Joe Biden, Kamala Harris and Barack Obama.

Overall, over the last few years (January 2021 to March 2023), the core[6] of pro-climate accounts that we identified on Twitter are composed of a little more than one million Twitter accounts that produced 51M tweets, 17.79% of them being original tweets, the rest being retweets (62.4%), retweets with/of comments (13.39%) or simply comments (6.37%).

As for the denialist communities, the geographical structuring is weaker, indicating greater coordination at the international level or greater geographical concentration. On the one hand, we find Donald Trump supporters and MAGA Republicans, accompanied by other leaders such as those of UKIP in England, and on the other hand, a group of influencers "experts" in climate science, who have their own audience and are densely connected to each other. It is in this latter denialist community that one finds accounts notoriously supported by the fossil fuel industries (Friedman, 2019), such as the Heart Land Institute or the Competitive Enterprise Institute. Last, a small French denialist community had appeared during the year 2022 (≈10k accounts).

Overall, over the last few years (January 2021–March 2023), the denialists communities identified on Twitter/X were composed of about 330,000 Twitter accounts that produced 20M tweets, 14.4% of them being original tweets, the rest being retweets (60.25%), retweets with/of comments (17.5%) or simply comments (7.8%).

[6]Core of online communities are defined as those communities detected on a graph whose links exceed a certain activity threshold. For this study, we considered communities detected on the interaction graph whose links represent a minimum of three to ten retweets, depending on the extent of the reference period. For Figure 1, communities were detected with links of strength 3 or more. Restricting the analysis to the core ensures a high degree of accuracy in the categorization of accounts attitudes.

3.2. *When Twitter descends into climate-denialism*

The relationships between communities change over time, but overall, the communities at the heart of the pro-climate science region, which link all the others, are climate activists and to a lesser extent mainstream media and news agencies. Over the period from Autumn 2019 to Spring 2022, the proportion of denialist accounts was roughly stable between 25% and 30%, which is consistent with sociological surveys (Witkowski et al., 2023).

These digital communities are evolving social structures, both in terms of their activity and their composition. Years of observation through the *Climatoscope* show that the intensity of the climate change debate is locally modulated by extreme seasonal events that may be linked to climate change (e.g. Australian bushfires, extreme heat waves or droughts), but it is also influenced by international events such as the COP, political events such as the 2020 US primaries—where the mainstream Democrats' agenda was challenged by the left wing of the party (Bernie Sanders)—, or events with strong societal impacts such as the COVID-19 pandemic. The latter caused a significant drop in activity in all communities for a few months (cf. Supplementary Figure B.1).

This relative stability between the pro-climate and denialist communities was, however, challenged in July 2022, with a clear resurgence of climate skepticism at the global level from July 20, 2022 as depicted on Figure 2 and Supplementary Figure B.2: the relative weight of denialists communities on Twitter/X largely increased to reach 50% in December 2022 (against 37% offline Witkowski et al. (ibid.)). How is this evolution possible in a period where climate change impacts have been more visible than ever?

The balance of power between digital communities is based on their ability to keep their members mobilized and to recruit new ones. Each of these phenomena has evolved in recent times on Twitter in ways defavorable to pro-climate communities.

First, while pro-climate communities historically enrolled more new members than denialist communities (i.e., accounts that were contributing to their online momentum for the first time), the trend has been reversing since April 2022 (cf. Supplementary Figure B.2). A first increase in relative denialist

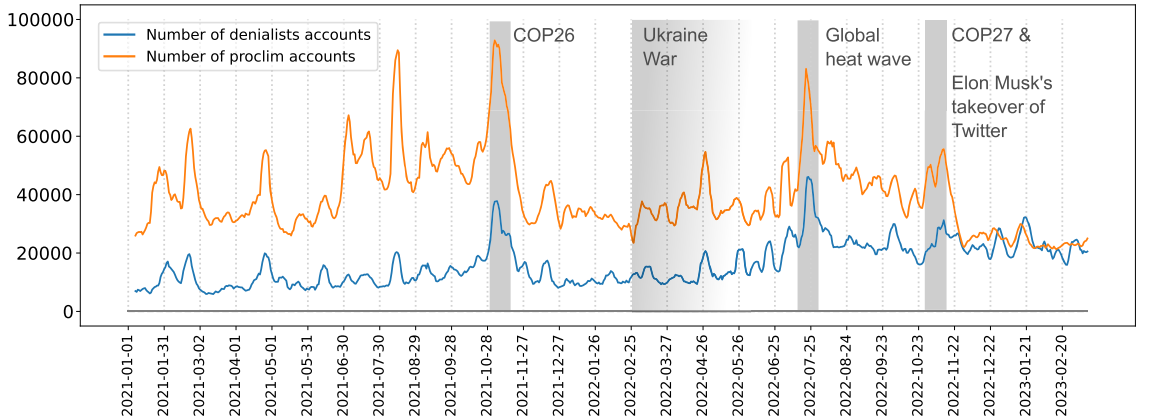


Figure 2. Worlwide evolution of number of estimated core pro-climate and climate denialists accounts on Twitter between 2021 and 2023. Data are averaged over a rolling week for better readability.

recruitment capacity occurred over the period April–July 2022 with a spike of activity in July 2022 for both pro-climate and denialist activists. For the former this correspond to reactions to that month's extreme heat waves, and for the latter to reactions following the release of a *Project Veritas*[7] video (cf. Section 3.3.4). This video—featuring a "CNN technical director" talking about "instilling the next fear (climate change) because COVID is no longer a fear factor to control Americans"—illustrates the rise of conspiracy theorists who are increasingly taking over the climate change debate and have become a significant part of climate deniers on Twitter/X. As documented in Section 3.3.6, they are not there by chance and a geopolitical explanation cannot be ruled out with potential links to propaganda operations by the Kremlin, whose hybrid war with Europe and NATO intensified following its invasion of Ukraine.

But the major alteration in relative recruitment capacities occurred the weeks following Elon Musk's takeover of Twitter in October 2022. On one hand, Musk's decreed an "amnesty" for accounts previously banned from the platform i.e. for abusive behavior, harassment or identity theft. This allowed super hate and misinformation spreaders to return to the network (Milmo and editor, D. M. G. t., 2022). On the other hand Musk changed Twitter's recommendation algorithm in a way that led to an increase of the *algorithmic negativity bias* (Chavalarias, 2022), i.e. the over-representation of toxic content in users' news feeds, which jumped from 32% to 48.7% (Bouchaud et al., 2023). Given the increased toxicity of climate denialists' tweets (cf. Section 3.3.1), this has mechanically reduced the exposure of pro-climate messages and increased that of climate skeptics, altering the ability of both communities to recruit new supporters.

As for the capacities of communities to keep their members mobilized, there has been a clear "Elon Musk effect" on pro-climate communities. Immediately after Musk's takeover, the number of pro-climate tweets halved and 33% of pro-climate activists stopped tweeting, along with 25.5% of their supporters, while those who stayed on Twitter reduced their number of daily messages by 33% (Figure 2).

In contrast, climate-denialists content producers experienced a weaker than usual seasonal decline in mobilization (−10%) and daily publication rate (−11.2%), while the activity of their relays even increased slightly (cf. Supplementary Table B.1). We can reasonably assume that this silencing of pro-climate accounts is partly explained by the perceived wave of "abuse and rude comments" against climate scientists since Musk's takeover (Fazackerley, 2023), fostered both by the increase in the number

[7] *Project Veritas* was an American far-right activist group which used deceptively edited videos and secret recordings in an effort to discredit mainstream media organizations and progressive groups. It was among others financed by the Donald J. Trump Foundation and had close links to the Trump administration.

of denialist accounts and the increased visibility of their posts due to a higher algorithmic negativity bias.

Two preliminary conclusions can be drawn from the observation of these global trends since 2022. First, Twitter/X has become an active place of conversion to climate skepticism, as long as these new accounts are not mostly fake accounts. Second, Twitter/X is losing its status as a globalized space for the expression of opinions on climate change, with a desertion of people supporting the IPCC synthesis. These two phenomena could reinforce each other, as the lack of contradiction makes it easier for deniers to convert new accounts on Twitter/X. Ultimately, this could also reinforce the offline pattern: Witkowski et al. (2023) has shown on a 30 countries survey that climate denialism has gained 3% globally in 2022, and up to 8% in France.

We will now investigate the structural differences between denialist and pro-climate communities.

3.3. *Characterization of denialists communities*

The communities of activists and the complex network they form are mathematically reconstructed independently of the content of the messages exchanged. The reason why denialist accounts are found in the same community is that they mainly retweet each other. The same is true for accounts supporting the IPCC conclusions. We can now draw on this categorization to determine how these communities differ in terms of their attitudes, skills, and the types of content they produce or relay.

3.3.1. *Acute toxicity*

The comparison of the toxicity of the tweets for different communities reveals a glaring difference between the denialist communities and the member of pro-climate communities. Performing a toxicity detection over 20k randomly sampled tweets either in the pro-climate or denialist communities, at the global scale, we reveal that the later produced on average 2.75 times more toxic tweets than the former with some geographic variations. For example, the proportion of messages identified as "toxic" circulating in the French denialist community is 3.5 times higher than that of the French IPCC community, and 1.5 times higher than that of pro-sufficiency community (cf. Supplementary Figure D.4).

A public report presenting preliminary results of this study was published online in (Chavalarias, Bouchaud, Chomel, et al., 2023). We collected 7718 original tweets published within twelve days in reaction to this publication, 1604 being produced by accounts categorized in Figure 1. These tweets have generated a total of 2.4M impressions, 1.3M retweets, 17.7k likes and discussions involving 3920 replies and 400 quotes. The over-toxicity of reactions of the denialist community reached +373.3% compared to the IPCC community (see Supplementary Figure E.1 and Supplementary Table E.1), with estimated weights of 60.88% for "insult", 23.71% for "obscene" and 5.71% for "identity attack" contents. This is a modest illustration of what climate scientists face when they try to combat online climate denialism.

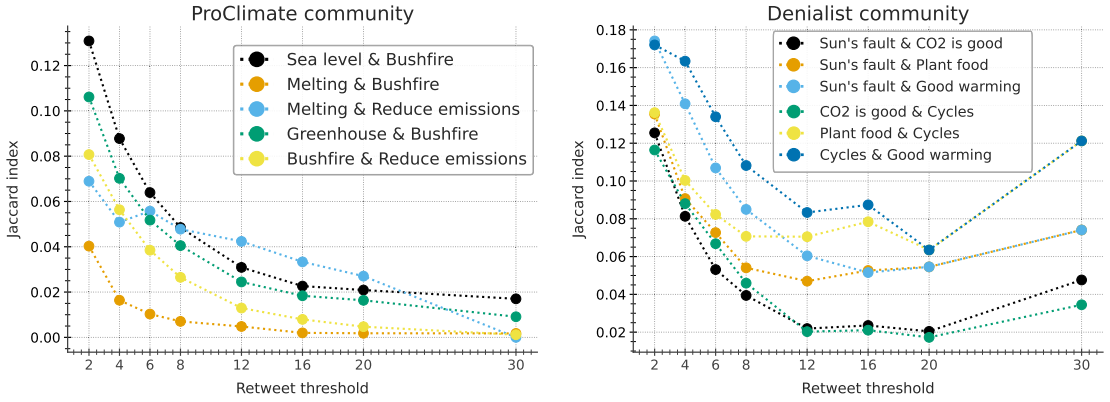
3.3.2. *Inauthentic forms of expertise and concentration of social power*

Since it is difficult to have extensive expertise in distinct domains, it is reasonable to expect that the number of people able to talk about two different topics with a certain level of expertise will decrease as the required level of expertise increases.

This intuition can be formalized with the multi-expertise index[8] developed in (Chomel, 2022), which indicates the extent to which multi-experts are present in a given community (see also Supplementary Material J).

By quantitative and qualitative analyses of tweets, we first identified the narratives most often used by members of the various Twitter communities over a six month period in 2019 in order to identify their favorite topics. For the denialist community, we focused our analysis on the following narratives: the influence of the sun, the natural variability of the climate and its cycles, the fact that CO_2 would be beneficial for plants and the planet, or the idea that global warming is simply a good thing. For the pro-climate science community, we have identified narratives such as the greenhouse effect, melting ice, rising sea levels, and bush fires.

[8]The measure of multi-expertise on two topics a and b is simply the normalized proportion of accounts using both arguments at least n times, n being the expertise threshold, among all users using at least one of them (Jaccard index) (Chomel, 2022).



(a) within the pro-climate community

(b) within the denialist community

Figure 3. Jaccard index based on retweet threshold, calculated on online discussions that took place on Twitter in 2021. A high jaccard index for a high threshold means that the exact same accounts are tweeting or retweeting about the two topics with high volume (see Supplementary Material J).

For each of the topic pairs and each of the communities, we computed the multi-expertise index, whose variations as a function of the required expertise threshold are presented in Figure 3. The pro-climate science community has an expected expertise profile (Figure 3a): most vocal accounts on one topic are not vocal on the others (or not to the same extent). This could be explained by the fact that only the "true" specialists of a given subject speak frequently on this subject, and speak much less on the other subjects. As for the other members of these communities, if they were to speak about several subjects, it would only be very occasionally for each of them (for example in reaction to extreme events related to climate change).

The denialist community exhibits a very different and somewhat anomalous expertise profile. While for low levels of expertise, the same initial decrease in the multi-expertise index is observed as a function of the required expertise threshold, there is a sharp increase in this index for high expertise thresholds (Figure 3b). Therefore, there are accounts that speak on all topics in large quantities. Either these topics are not really technical and, given the complexity of earth systems, do not contribute much to the debate, or these denialists speak on topics regardless of their actual knowledge of them. Either way, instead of having prescriptive power distributed across many specialists as in the pro-climate community, there is a small group of accounts within the denialist community that concentrates the presumed expertise and fabricates the majority of the narratives that circulate there.

3.3.3. *A higher density of accounts with inauthentic behavior*

The global proportion of bots on Twitter is estimated between 8% and 18% by 2022 (Fukuda et al., 2022) and it is quite easy to buy fake Twitter accounts, operated by humans or robots, which will act according to the wishes of their buyers (see for an example the 2023 "Team Jorge" case (Kirchgaessner and correspondent, S. K. U. i, 2023)).

For this reason, *astroturfing* is a very popular strategy for some actors (Chavalarias, 2016). With the arrival of conversational artificial intelligence such as ChatGPT, which reduces its costs while increasing its effectiveness (Hsu and Thompson, 2023; Goldstein et al., 2023), an intensification of this practice is to be expected.

We have estimated the proportion of "bot-like" accounts in climate change discussions to be about 3.5% in the global pro-climate community when it approaches 6% for the global denialist community (+71% in comparison with the pro-climate community). As pointed in Section 2.3, these figures are probably underestimated but relative proportions of "bot-like" accounts between communities and their evolution is informative.

The proportion is not uniform within the different sub-communities. For example, it is estimated at 10% in the Indian pro-climate community accounts but at only 1.8% in the British pro-climate community.

As for the evolution, two indicators point to an intensification of astroturfing practices since 2022. First, the yearly proportion of account creation with inauthentic behavior in climate exchanges has seen a sharp increase between 2020 and 2022 globally on Twitter (cf. Supplementary Figure B.3). As we collected the tweets in real time, this means either that there has been an increase in the creation of such accounts over the last few years, or that this type of account is used in turn on different subjects and that the oldest ones were more likely to be detected and deleted by Twitter as they were campaigning on subjects we didn't monitor.

Second, there has been a steady increase in the proportion of "bot-like" active accounts since the end of February 2022. For the North America and Australia communities the increase was of +400% by the end of 2022 compared to the end of 2021 (see Figure 4a). The same phenomena is observed for France (cf. Supplementary Table D.1).

Last, as demonstrated in Section 3.3.6 (Figure 8), the most influential accounts in the core denialist community behave almost exactly like the rest of the group on a wide range of topics at various times, which is a sign of coordination.

In short, climate skeptics use inauthentic accounts and bots to propagate their ideas far more than any other actors in the climate debate, and this practice is intensifying since February 2022.

3.3.4. *Opinion and platforms' algorithm manipulation through planned astroturfing operations*

By focusing on the level of activity on certain topics of discussion rather than interactions among accounts, the denialist community community reveals a very particular form of social organization that relies on the ability of a few to influence the flow of information, a form of organization already documented in other fields (Starbird, 2017).

We identified two different strategies: repeated operations over longer periods that use repetition bias to make a narrative plausible to those exposed to it; and massive operations over short periods to influence recommendation algorithms.

An example of the former is detailed in Supplementary Figure G.1. An example of the latter is provided by a detailed analysis of the climate denial wave of July 20, 2022. It gives insights into both the scale of these practices and the extent to which the proportion of fake accounts could be underestimated.

July 20, 2022 saw the emergence of a narrative that had been circulating only quietly until then, namely that CNN and the U.S. government were planning "to instill the next fear [Climate change] as COVID is no longer a fear factor in controlling Americans." This narrative was based on a video first published on YouTube[9] on April 13, 2021 by far-right group *Project Veritas*. It features a "CNN Tech director" who had supposedly been trapped on hidden camera. We identified most variants of this narrative and analyzed the corresponding tweets captured by the climatoscope[10] in order to analyze its propagation.

Although a first rumor surfaced in the U.S. as early as January 1, 2022[11], with an average of 6 tweets per day between January and July 2022, this narrative did not get much traction on Twitter until July 20, 2022 with only 1281 accounts in total participating to its diffusion so far. Suddenly, between July 20, and 21, the number of tweets skyrocketed to more than 22k per day involving 43.3k accounts before quickly fading out (see Supplementary Figure F.1-3).

Not only is this pattern of activity highly inorganic, but the study of the 43.3k accounts' profiles that took part in this narrative burst leads to other troubling elements. While there is less than a dozen accounts with same creation day on average, more than 1807 of them (4.17%) have been created in just one week between 2022-04-25 and 2022-04-30 (cf. Figure 4b). This means that most of these accounts are fake accounts created few months before the operation for the purpose of astroturfing. Creating a cohort of astroturfing accounts with such a statistical anomaly

[9] https://www.youtube.com/watch?v=Dv8Zy-JwXr4.

[10] Climatoscope query = climat* AND ("CNN tech director" OR "CNN technical director" OR "CNN director" OR "CNN employee" OR "CNN guy" OR "CNN producer" OR "directeur de CNN" OR "directeur technique de CNN" OR "project Veritas" OR "CNN leaks" OR (fear AND CNN)).

[11] See https://twitter.com/LetsgoBrandonDE/status/1477127280044482566.

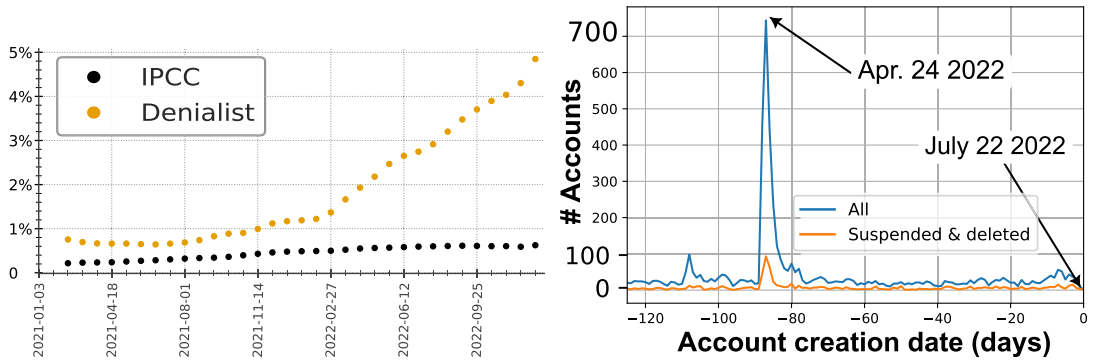


Figure 4. Astroturfing operations. (a-left) Evolution of the proportion of "bot-like" accounts for North America (USA and Canada) and Australia; (b-right) Anomaly in the creation dates of the accounts that participated to the #CNNExpose operation during the period July 20–21, 2022.

is a gross error, and we can reasonably assume that the proportion of fake accounts among the 43.3k accounts that took part in this operation is much higher than this 4.17%.

Indeed, among those 1807 accounts, only 126 are characterized as "likely-bot" by our bot detector and only 189 were suspended by the Twitter Moderation Research Consortium[12], which was supposed to remove content and accounts violating the platform's manipulation and spam policy, before "X" put an end to its moderation program. On the assumption that accounts have been suspended by Twitter because of their inauthenticity, this means that only about 10% of accounts used for astroturfing practices are identified either by Twitter or by state-of-the-art AI bot detectors. Since there are 2205 suspended accounts among the 43.3k, we can estimate the order of magnitude of the proportion of fake accounts that took part to this astroturfing operation to near 50% (21k accounts). This is more than enough to manipulate Twitter/X trends (Chavalarias, 2022) and get some Twitter/X users outside the denialist community to relay this story.

This case study illustrates both the astroturfing practices of these communities and the scale of their digital army: a low-key dissemination of a narrative, followed by a "one-two punch" operation to impose it on the recommendation algorithms and some of the users of a social network, insisting in the process that it has been hidden from the public for months.

Last, it should also be noted that both phases of dissemination take advantages of a globalized space. The second phase, more intense, feature messages in English, French, Italian and Dutch in the case studied. As for the first phase, although the very first tweets on January 1, 2022 came from an apparently U.S. citizen (see Supplementary Figure F.4), French accounts also contributed as soon as January 14, 2022 (see Supplementary Figure F.5) as well as to the bootstrap of the second phase on July 17, with for example the participation of the @Elpis_R account (Supplementary Figure F.6).

This last account occupied a particular position in the French informational landscape in 2022 and the detailed analysis of its messages reveals an other important aspect of the new climate disinformation and denialism trends.

3.3.5. *Opportunism and the connection of global extremes*

@Elpis_R is not just an insider in U.S. denialist narratives, it is also the main influencer who structured the new denialist community in France at the summer 2022. Both the *PageRank* or the *eigenvector centrality*, two metrics from graph theory used to measure influence in a network, rank this account first during summer 2022 in the French part of the landscape depicted by Figure 1 (see also Supplementary Figure C.1).

[12]https://transparency.twitter.com/en/reports/moderation-research.html.

This account is anonymous and has a male profile picture retrieved from an image bank (see Supplementary Figure H.2). For this reason, we will refer to this account with "he/his/him", although there is no guarantee that this account is owned by one and the same person. It was created in July 2012, but had only 27 followers in September 2021, which means that it was dormant between 2012 and 2021.

As of 2023-10-08, *Elpis_R* defines himself as "*Climate Science Research—Climate Realist—Alarmists Ignore The Geological Climate Record.*"[13].

By reconstructing the network of interactions of *Elpis_R* from the global data of the climatoscope (all second neighbors), it appears that this account serves as a bridge between the French information space and the community of English speaking climate deniers (cf. Figure 5). If this is not sufficient to attribute any geographical origin to it, it nevertheless points to a convergence of interests at an international level in climate misinformation, as it has already been documented on other subjects such as COVID-19 (see ibid.).

To defend its point of view, the account *Elpis_R* uses a rhetoric that can be analyzed with the "4D" approach, developed to investigate Kremlin propaganda (Nimmo, 2015), (see Figure H.3): *Dismiss* ("if you don't like what your critics say, deny the allegations on the ground, or denigrate the one who makes them"), *Distort* ("if you don't like the facts, distort them"), *Distract* ("if you're accused of something, turn the attention away by launching accusations elsewhere"), *Dismay* ("if you don't like what someone else is up to, try to scare them"). In particular, *Elpis_R* specifically attacks IPCC members as well as climate science scientists, with several daily posts, some of them very technical.

He complements these 4Ds with a fifth that is perhaps the most important in promoting climate inaction: *Doubt* (Oreskes and E. M. Conway, 2010).

Elpis_R is also one of those accounts that spread contradictory messages, such as "there is no global warming" along with "the climate has always changed and warming is not due to our emissions" (Supplementary Figure H.2). When someone pointed this out to him, the interaction came to a screeching halt, proving that this was not an attempt to convince on the basis of proven facts.

His climate activism is however quite recent. As shown in Figure 6, prior to the spring of 2022, this account had a long period of anti-vaccine activism, with the transition between these two periods taking place through a phase where he was the discreet relay of the pro-Kremlin propaganda that flooded the social networks at the beginning of the war in Ukraine. In fact, before defining himself as "Climate Science Research (Independent)", he defined himself between 2021-12-23 and 2022-06-10 as "Biostatistician, (data analyst)" and indicated at other times in his profile wanting to "Reinform against this Orwellian propaganda", or to be a "Free spirit, for a fair information and not biased by the systemic corruption which gangrene this world". Supplementary Material H.1 provides the full history of his profile description, a timeline that is only accessible to those who, like us, did record tweets and their associated profile descriptions on the fly.

One of his profile description even once referred to his profile on Gettr, a microblogging platform popular with the American far right and on vk.com, the Russian Facebook controlled by the Kremlin (Nast, 2022), that he has since deleted. A snapshot of Nov 8 2021 by the WayBackMachine[14] of his VK homepage shows that of the nine archived messages posted by *Elpis_R* on its wall between 3/07/2021 and 11/10/2021, eight were "vaccin alarmist" and one warned about the impending food shortage due to the pandemic. Nothing on climate change.

Elpis_R thus appears to be an opportunistic anonymous account, whose real motivations are obviously not those displayed in his profile. He has jumped from one divisive debate to the other but it is however his climate denialist period which allowed him to gain in visibility in France, making him pass in few months, from less than 1000 followers (July 2022) to more than 25.5k in 2023.

3.3.6. *Globalized, multi-topic disinformation*

The multi-topics opportunism of *Elpis_R* is not an isolated case nor specific to France. We have been

[13] Note that although all his posts are in French, his profile is in in English with elements of language borrowed from American denialists.

[14] https://web.archive.org/web/20211108200828/http://vk.com/real_elpis.

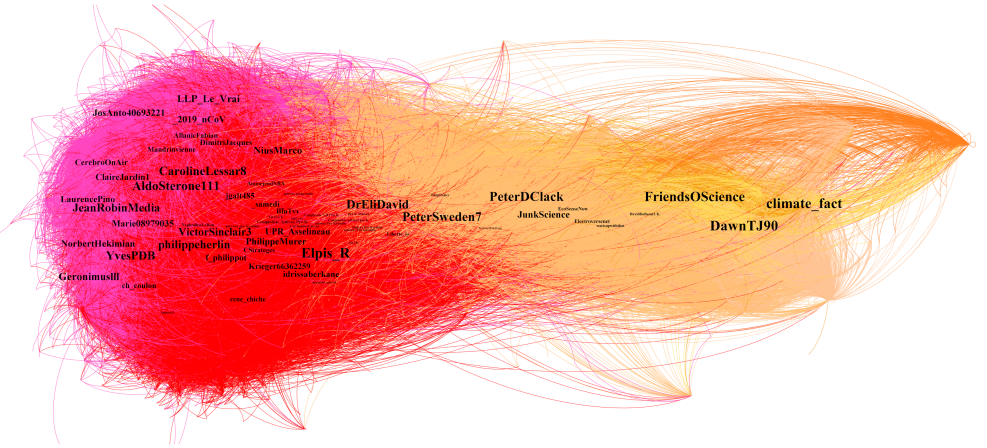


Figure 5. Core of the information flow network between U.S. and French denialists (dense network of second neighbors of @Elpis_R with at least three links to other members of this group). Pink and red communities are French speaking, orange communities are English speaking.

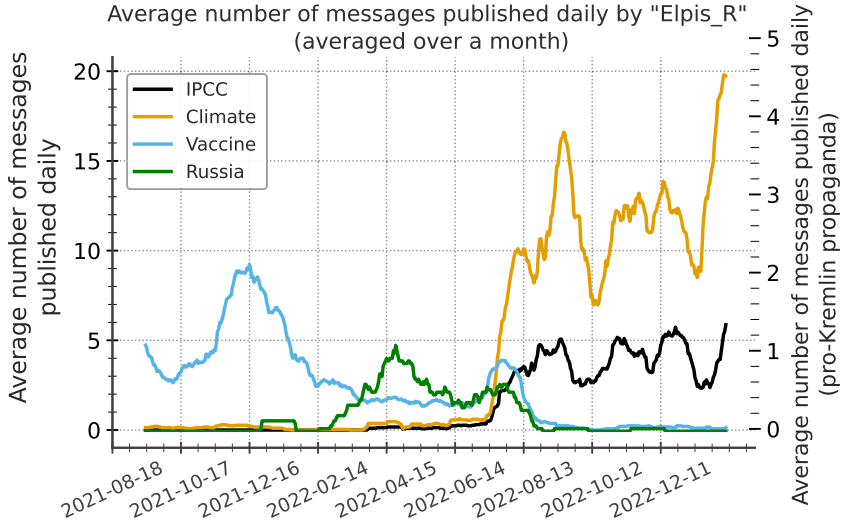


Figure 6. Daily number of messages from the account *Elpis_R* on some key topics. Warnings: the plot of messages relaying Kremlin propaganda has been drawn on another scale for questions of readability. All Elpis_R messages were retrieved using Twitter's public API before it was shut down. Key words used to define the topics (originally in French): *Climate*—"CO_2", "warming", "climate"; *IPCC*—IPCC, GIEC; *Covid*—"covid", "vaccination", "vaccine"; *Russia*—"Putin", "russia", "ukraine", "Zelensky".

independently monitoring the English and French speaking COVID-19 Twitter debate since 2020 and could map the full COVID-19 Twitter landscape in these two languages over the period January 2020 to June 2021 (core composed of 157k accounts for 40M tweets, see Supplementary Material I). The structure of the COVID-19 landscape (period 2020–2022) is different from the one of the climate: a core formed by the bi-pole of US pro-vaccine vs. "anti-sanitary dictatorship"/anti-vaccine accounts, with a replica of this dipole structure for each country. Although the confusionist covid-19 "antivax" communities form a less coherent global structure than for climate change, there is a significant flow of (dis)information

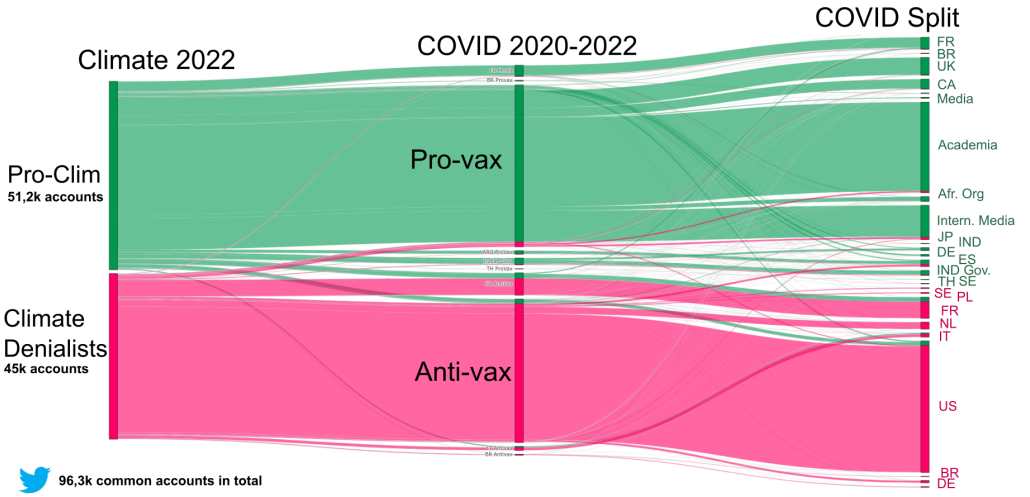


Figure 7. Core activists common to the COVID and climate debates. The split of the COVID-19 landscape into geographical communities is also given (right side) to highlight the multi-country alignment. The climate change data collection focused on messages in English and French, which explains why other languages are under-represented in this visualization.

between the main alt-right/anti covid-19 vaccine community in the USA toward other communities in other countries (cf. Supplementary Figure I.1).

Tweets about climate and Covid-19 have been collected independently within two separate digital observatories. Moreover, the focus period of this climate change study (2021–2023) only partially overlaps the "hot" period for the Covid-19 database (2020–June 2021). There are however accounts that appear in both databases. Cross-referencing the two debates, we found >96.3k worth of accounts that talked about both climate change and Covid-19 between 2020 and 2023. Figure 7 shows their ideological alignment. This analysis reveals a clear pattern: in every country involved in this analysis (here mainly USA, UK, France, Netherlands, Italy), all confusionist covid-19 "antivax" accounts who also took part in the climate debate where, except few exceptions, denialists and vice versa. This means that there is a global alignment between anti-Covid-19 vaccine attitudes and climate denialist attitudes. What's more, in France, since climate denialist communities only emerged after the pandemic was over, we can deduce that the pandemic created fertile ground for the development of very powerful anti-system communities with conspiracist and confusionist tendencies, which then converted to climate denialism under the influence of their leaders. Consequently, all we had to do to anticipate future disinformation actions was take the opposite of what the *Project Veritas* fake news announced at spring 2022: the Covid-19 disinformation campaigners were about to become climate change disinformation campaigners as the Covid-19 epidemic comes to an end.

This opportunistic pattern of mobilization is not an isolated case. Among French climate activists accounts identified in the Climatoscope a significant proportion of accounts representing 53.1k accounts are also active in politics and can be identified in the Politoscope: 96.5% of the core of French climate deniers (9.2k accounts), 77.4% of the core of IPCC aligned accounts (15.6k accounts), 77.8% of the core of techno-solutionist group (6.2k accounts), those core communities being mapped on Supplementary Figure C.1.

We can see that climate deniers over-invest in politics. To describe their contribution to the political arena, in addition to their involvement in anti-covid vaccine polemics, we have analyzed their participation to some other divisive issues studied with the Politoscope (Chavalarias, 2024) (see Supplementary Material Section K for their precise definition). The selected issues are "Islamo-leftism" (50.6k accounts), "Great replacement theory"

(35.9k accounts), "Israeli-Palestinian conflict" (39.8k accounts), "Jean-Michel Trogneux" (21.6k accounts), "Anti-wokism" (5.3k accounts) and "Kremlin propaganda" (62.4k accounts). The social groups identified in the politoscope database over 2020–2023 are the far-right communities (*Rassemblement national* and *Reconquête!*; 69k accounts in total), the *Patriotes*[15] (74.7k accounts) and all other political communities that we aggregated in a group labeled "All but far-right" (458.8k accounts). To give an order of magnitude, we identified 602k accounts in the Politoscope (mostly French accounts) between 2020 and 2023 that belong to clearly identified communities while we identified 138k accounts (most English and French speaking accounts) in the Climatoscope over the period 2021 to 2022, that were categorized either as pro-climate or as deniers. 53.1k accounts are common to these two database samples, making it possible to cross-reference political affiliation with attitudes to climate change.

We compare the involvement in politics of French deniers with a reference group formed by IPCC aligned communities from the Climatoscope database over the same period (20.2k accounts), i.e. the union of the mainstream media community, the IPCC community and the pro-sufficiency community. These three communities form a supercluster of French pro-climate accounts (cf. Supplementary Figure C.1) which have in common that they are not opposed to sufficiency, and that they recognize the reality of ACC. We also computed this involvement for the top 10% of the most influential deniers accounts in terms of pageRank to assess the profile of the group's leaders.

As it can be seen on Figure 8, the common characteristic of the core climate denialist community is that it invests opportunistically in divisive issues compared to the reference group of IPCC-aligned communities (20k accounts): 84.5% contributed to anti-vaccine propaganda (8.45 times more than the reference group), 59.4% to exchanges about the Israeli-Palestinian conflict (3.36 times more than the reference group), 47.1% to great replacement theory propaganda (25.9 times more than the reference group), 44.7% to the promotion of "islamo-leftism" concept (12.7 times more than the reference group), 17% to "anti-wokism" movement (36.7 times more than the reference group). 94% of core climate deniers are involved in far-right groups (see also Supplementary Figure D.5): 20.8% in the *Rassemblement national* or *Reconquête!* communities and 73.2% in the *Patriotes* (vs. 3.81% for the reference group). But what is most striking is their involvement as relays of Kremlin propaganda. More than 80% of them have relayed at least once some Kremlin narratives about NATO, the Ukraine war or President Zelensky, this estimation being a lower bound. In comparison, only 5.48% of the reference group had done so.

4. Discussion

We investigated at climate denial through the prism of Twitter/X. Although Twitter/X is not representative of the general population, it was home to some of the most influential figures in public life and, by working with long time series data, we can assess trends in climate change denial, investigate the structure of denialist groups and the evolution of their strategies.

Climate denialism has many facets, each of them often developed by a small number of actors whose true motivations are generally masked. The best-known and historically most active is supported by the fossil fuel industries, which have an economic interest in delaying action against climate change (Oreskes and E. M. Conway, 2010; Brady, 2021). Their involvement in online climate disinformation has been revealed on several occasions, including recently following the bankruptcy of an American coal company (Friedman, 2019).

Another strand of climate skepticism is politically motivated and is historically associated to conservative ideologies (Oreskes and E. M. Conway, 2010). Indeed, we observed that one of the world's largest climate-skeptic communities was made up of MAGA activists who were particularly active during election campaigns (cf. Figure 1 and Supplementary Figure B.1).

Ultimately, these two trends in climate denialism have a seasonal activity that peaks when the news deals with extreme climatic events in the case of the former, or election campaigns in the case of the latter.

[15] *Patriotes* is a fringe confusionist far-right political community, one of whose leaders is Marine Le Pen's former right-hand man, formed in reaction to the discovery of a vaccine against covid-19. It has no weight in the pool but has one of the largest Twitter community (cf. Chavalarias, 2022).

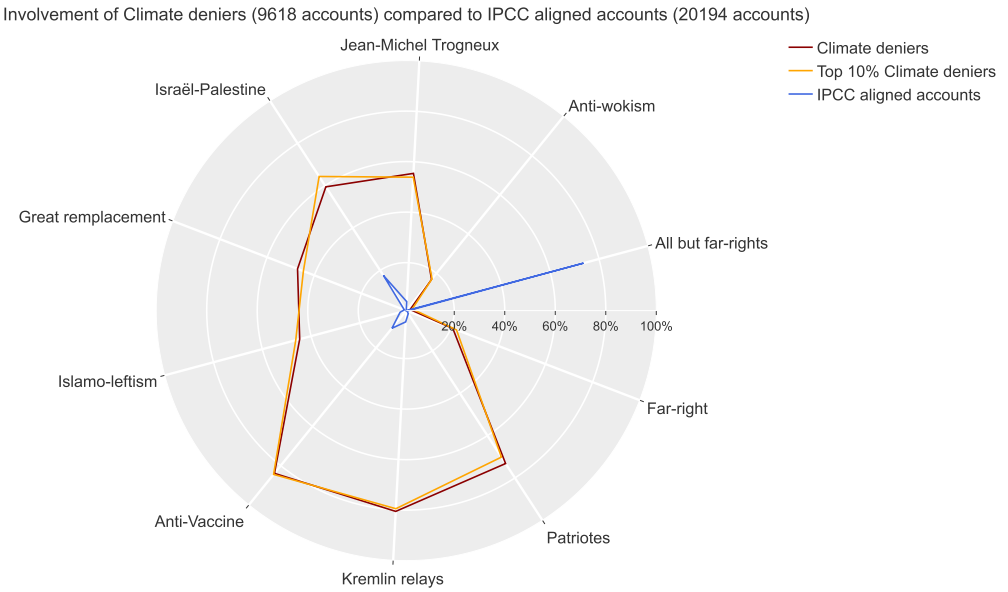


Figure 8. Involvement of the French climate denialist accounts in other divisive societal issues and extremes political groups (see Supplementary Material Section K for their description). Involvement in a topic is defined as the proportion of climate deniers who have also contributed to that topic on Twitter/X. Level of involvement for the 10% of the most influential accounts (yellow) as well as for all climate denialist accounts (red) can be compared to the one of pro-climate accounts that do not oppose to sufficiency (blue) which correspond to the mega-cluster of Supplementary Figure C.1. made up of the IPCC community, the media community and the community of pro-sufficiency advocates. The fact that the top 10 most influential accounts behave almost exactly like the rest of the group on such a wide range of subjects and at such varied times indicates a very high degree of coordination among climate deniers, which is a sign of inauthenticity.

But a new globalized trend that doesn't follow these patterns has recently been added to the landscape. Involving activists from the American alt-right, the French far-right and Kremlin's propagandists among others it contributes to a globalized circulation of narratives and is made up of opportunistic accounts accustomed to social conflict.

Climate denialists stand out for the type of disinformation they produce: a high degree of toxicity in their messages, fake expertise, a high degree of coordination across topics, an abnormal proportion of "probably bots" or inauthentic accounts—mobilized for astroturfing operations and manipulation of the platform's algorithms—and a tendency to relay conspiracy theories and Kremlin propaganda.

Although the conspirationist and confusionist approach to climate change has been active for years (Uscinski et al., 2017), we should not understate the particular context in which this trend is now unfolding. First, we are in a post-pandemic world that has witness an unprecedented growth in online anti-system and conspirationist theories. These theories have been favored by two years of fears and uncertainties engendered by the pandemic and the scale of the restrictive and often liberticide measures that had to be put in place by governments to contain it. This situation has provided fertile ground for the development of very powerful digital communities (Chavalarias, 2022), which are now being re-mobilized on the climate denialism front by leaders seeking to maintain an audience.

We also live in a world where authoritarian states such as Russia have long been waging a permanent hybrid war on social networks with the strategy of amplifying divisions within democracies in order to weaken them (Schoen and Smith, 2016; Colon, 2023; Linvill et al., 2019; Howard et al., 2019). This cyber-war has been amplified by the Ukraine war with a

surge of online Kremlin's propaganda on social network (OECD, 2022; Geissler et al., 2023; Chavalarias, 2024) and the emergence of fossil fuels as the bone of contention in economic sanctions against Russia.

Last, restricting the focus to Twitter, the situation is exacerbated by Elon Musk's choices (Chavalarias, 2025), which have made this network a major forum for climate denial and proselytizing.

The issue of climate change is an area where governments are being urged by a part of the of the population to take strong actions, involving major changes in the lifestyles of all citizens. Many of them will only accept these measures if the results are worth it. Instilling doubt and misinformation about the reality of climate change in some communities, while heightening awareness of the climate emergency in others, is therefore a very effective way to destabilize governments by placing them at the center of conflicting demands from their citizens. Whatever the policy adopted, social revolt is guaranteed and violence can steam from all sides.

In Januray 2025, Poland's military counterintelligence service revealed that "Russia is intensifying its disinformation activities on the climate crisis. Increased activity in this regard has been observed since the outbreak of the war in Ukraine. It affects the entire European Union, with a special focus on Poland" (Grostern, 2025). Although it is impossible, with the data available to us, to prove the exact origin of the climate disinformation, they do suggest that former Russian disinformation channels and actors are now being used to spread disinformation about climate change and attack climate scientists globally.

Putin is known for its climate denialism (V.-P. Tynkkynen and N. Tynkkynen, 2018; Ashe and Poberezhskaya, 2022) and his support to far-right occidental groups (Futàk-Campbell, 2020). It would have been a major strategic mistake not to take advantage of this opportunity in his roadmap to undermine Western democracies.

Sowing division through online interference is inexpensive and risk-free for would-be agitators because, unlike in dictatorships, it is not illegal to engage in this kind of activity within democratic regimes. Having at their disposal powerful digital communities inherited by the pandemics and eager to rebel against the "system" in place is an unhoped-for opportunity.

Donald Trump's second term in office has given these anti-establishment actors an unexpected ally: the US administration, whose officially climate-denialist policy directly attacks climate science and climatologists (Voosen, 2025), and whose Department of Energy includes in its reports the climate-sceptic theories that until now had been circulating in the depths of the Internet (Tollefson, 2025), some being referenced in this paper.

We consequently must expect that the low-risk, high-gain amplification of climate-denialism and conflicts linked to the fight against global warming to be further exploited in the future.

5. Conclusions

The rise of denialism in the general population has been paralleled by a very significant increase in climate denial activism on Twitter/X since the summer of 2022.

Beyond fact-checking, we've shown that there are structural differences between these deniers and pro-climate online communities, as well as between the circulation of misinformation and other climate change-related narratives.

All the evidence points to the idea that the behavior of denialists is deceptive adn coordinated, and that they are over-represented on Twitter/X compared to what they actually represent offline, especially since Musk's takeover. This probably also applies to other social networks.

We have also highlighted the globalized aspect of this new climate denialism, as well as how it has benefited from the pandemic and the alignment of its protagonists with the interests and visions of powers such as Russia and, since Donald Trump's second term in office, the United States.

So it's no coincidence that we're witnessing a resurgence of climate skepticism at a time when it's becoming indisputable that global warming is man-made. Not only must the fossil fuel industries redouble their efforts to slow down the implementation of measures that are becoming increasingly urgent, but climate change issues are becoming an active field of subversion for actors for whom the deterioration of living conditions on Earth is nothing compared to the prospects of strengthening their power.

Division is an effective strategy for conquering power, theorized millennia ago by Sun Tzu in *The Art*

of War (Tzu, 1963), which during the Cold War was the bedside guide of KGB officers. It's hard to say how effective this strategy will be in weaponizing climate change, but one thing must be said: it loses much of its effectiveness when revealed to the public.

This is why it is imperative that independent players, including the scientific community, are able to analyze and publicize the large-scale manipulation of the digital information space. Given the tendency of very large online platforms such as Twitter/X to close off access to their data, this is another anachronistic trend that needs to be addressed. The fight against climate misinformation will only succeed in this broader context. For now, we need to be aware that online, the climate change "debate" may not be a debate at all.

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Declaration of interests

The authors do not work for, advise, own shares in, or receive funds from any organization that could benefit from this article, and have declared no affiliations other than their research organizations.

Supplementary materials

Supporting information for this article is available in open access in the Harvard Dataverse repository, at https://doi.org/10.7910/DVN/QIC8SB.

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