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PAPER

Unravelling climate misinformation: fact-checking of climate disinformation in spanish-speaking podcasts

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Abstract

Climate change remains a critical global challenge, yet denialism endures across various sectors despite growing scientific consensus. Climate misinformation poses a major obstacle, with radio podcasts—an influential medium—contributing to its spread. This study, conducted in collaboration with C3/IU-RESCAT/URV, VERIFICAT, Kinzen, and Chequeado, represents the first analysis of climate mis- and disinformation narratives in Spanish-speaking podcasts. Over eight months, podcasts were monitored, focusing on content from June to November 2022, coinciding with COP27. The dataset comprised 629 podcast excerpts, totalling over 241 h. The study aimed to identify, categorise, and assess the prevalence of climate misinformation narratives. The podcast selection phase proved to be the most critical stage of the workflow. The most frequent climate misinformation narratives were: 'Climate science is unreliable (conspiracy)', 'Climate change does not exist', and 'Solutions do not work'. These were predominantly present in programmes categorised under Politics, Economy & Opinion, and Mystery & Other Realities. Notably, the 'Greenwashing' narrative appeared exclusively in Politics, Economy & Opinion content. During COP27, the daily rate of climate mis- and disinformation claims (7.5 per day) was significantly higher than during the regular period (2.9 per day). Podcasts showed heightened scepticism towards the effectiveness of climate solutions, while conspiracy-driven doubts about climate science and outright denial decreased. These findings are consistent with previous analyses of social media, highlighting the pervasive nature of climate misinformation across platforms. The study reinforces the importance of confronting such narratives to counter climate denial effectively.

1. Introduction and framework

In the digital information age, alongside the growing accessibility of diverse information sources, we are also witnessing a rise in both misinformation and disinformation. In addition, there is no consensus on the development of a potential legislative framework to address these challenges (Rodríguez-Fernández 2019). The key distinction between misinformation and disinformation lies in intent: misinformation refers to false or misleading information shared unintentionally, whereas disinformation is deliberately created and disseminated to deceive, cause harm, or manipulate public opinion (Flores Vivar 2019, Treen *et al* 2020). Previous studies have examined the spread of mis-/disinformation on various digital platforms—for example, the faster dissemination of false news compared to true news on Twitter (Vosoughi *et al* 2018), the circulation of

misinformation via instant messaging apps like Telegram (Almansa-Martínez *et al* 2022) and the presence of disinformation in podcasts hosted on platforms such as Spotify (Caramancion 2022).

Regarding climate change, it has become a crucial issue that is highly relevant to today's society. However, climate misinformation, which is also increasing, can distort public perception and undermine efforts to address the current global challenge. Global warming of the Earth and the climate system is unequivocal, and the human influence is clear (IPCC 2021). Under the current situation of global change, with the climatic component upfront, the rapid provoked modifications in the Earth system have already caused negative effects at different levels and, can trigger social-climatic tipping points that irreversibly destabilize the Earth system and the human societies (Lenton *et al* 2019, Graham *et al* 2023).

Recently, it has been quantified that seven of the eight global-scale safe and just Earth System Boundaries have already been crossed (Röckstrom *et al* 2023). In the case of the Climate, the study points out that global warming beyond 1.0 °C above pre-industrial levels, which has already been exceeded (IPCC 2021), carries a moderate probability of triggering tipping elements (e.g., the collapse of the Greenland ice sheet; Armstrong *et al* 2022). In contrast, above 1.5 °C or 2.0 °C warming, the likelihood of triggering tipping points increases to high or very high, respectively, with a high confidence level. It should be noted that climate change enhances the severity of other environmental problems (Röckstrom *et al* 2023).

The Earth's climate has undergone natural variations throughout its history. The climate system is inherently complex, governed by multiple forcings that interact with one another and can give rise to both positive and negative feedback mechanisms. The relative influence of these forcings on climate modulation varies depending on the temporal scale under consideration: plate tectonics operate over millions of years; orbital parameters exert influence on millennial scales; and ocean circulation plays a key role on sub-millennial timescales.

However, the current warming scenario is unprecedented in terms of the rate at which carbon dioxide is being released into the atmosphere. Although there have been periods in the past when atmospheric CO_2 concentrations exceeded present-day levels (Zachos *et al* 2001), such concentrations were reached through gradual processes over extended timescales—unlike the abrupt rise observed in recent decades, which is directly attributable to anthropogenic activity. The near-global coherence of the rapid warming observed over the past 150 years has no parallel in any cold or warm period of the past two millennia (Neukom *et al* 2019). In addition, and while today's warming is affecting the planet on a global scale, its impacts are not uniformly distributed. Certain regions are particularly vulnerable—for instance, mountain ranges, which are especially susceptible to climatic shifts (Sigro *et al* 2024, and references therein).

An interdisciplinary approach is needed in order to effectively navigate out of the climate crisis, integrating diverse understandings about how transitions evolve in intertwined social-environmental systems (Graham *et al* 2023). In addition, truthful information and environmental awareness can be key aspects in changing the direction of the current transition moment.

Unfortunately, the extensive propagation of online misinformation has substantially fostered public scepticism about the reality of climate change (Smith and Leiserowitz 2012, Hornsey and Lewandowsky 2022, Chen 2024, Pearson *et al* 2024). On occasions, part of the scepticism arises from the opinion that climate change is not due to anthropogenic causes (Oreskes 2018). In Europe, for instance, a surprisingly significant proportion of the citizenship holds ambiguous views regarding human responsibility in climate change. This group is particularly vulnerable to disinformation and is substantial enough to impede progress in addressing climate change (Vardaxoglou 2022, Mata *et al* 2024). It should be noted that, on occasions, climate change denialism has influenced the decisions made by some governments and administrations, worsening civil protection management, for example, in response to extreme weather events such as floods (Abellán-López 2021 and references therein). Unfortunately, this was the case in the tragedy that took place in the Valencian Community (Spain) at the end of October 2024, where the poor management of an Isolated Depression at High Levels caused severe flooding, resulting in more than two hundred fatalities and extensive material damage. While it is true that the magnitude of the climatic event was extreme, the impacts of the catastrophe would have been less severe if, in the preceding years, the management of civil protection agencies in climate change-related scenarios had taken into account the forecasts of the scientific community.

Despite all the previously exposed, the number of studies focused on climate change misinformation is still sparse. Some of them have focused on the denial arguments or on the narrative's climate conspiracy (Washington and Cook 2011, Cairns 2016, Abellán-López 2021). Other works have analysed the climate misinformation online and also on Twitter (Treen *et al* 2020, Biamby *et al* 2022). Supran and Oreskes (2021) developed a frame analysis of fossil fuel industry propaganda and climate change communication. Examples of more regional studies include Pasquaré and Oppizzi (2012), which explores the construction of the Italian print media regarding climate change and geological hazards, and Meddeb *et al* (2022), which examines French fake news on climate change by using language models. In this context, radio podcasts have grown in popularity as

platforms for the exchange of ideas and opinions on climate change. However, the proliferation of misinformation within these podcasts has become a matter of serious concern (Caramancion 2022).

In the present study, a team of researchers, in collaboration with the fact-checking organisation Verificat, have undertaken an innovative investigation aimed at addressing this issue. To the best of the authors' knowledge, only the recent study by Pathiyan Cherumanal *et al* (2024) has explored climate-related disinformation in podcasts. That study approached the issue by employing auditory signals to alert listeners to potential inaccuracies within podcast excerpts, yet it did not analyse the underlying narratives. Consequently, the content of climate mis- and disinformation in audio-based formats—such as podcasts and spoken conversational searches—remains largely unexplored, with most existing research focusing on screen-based interfaces.

The objective of the present study has been to detect and classify identified climate misinformation by utilizing computer-assisted filtering of potential denialistic claims. This has been achieved by employing pre-selected indicators, such as 'chemtrail' or 'geoengineering' (Cairns 2016). Subsequently, the veracity of these claims has been verified by expert climatologists and contrasting with peer-reviewed literature or official information. The collaboration with Verificado, a company specializing in fact-checking and quality journalism, has provided a comprehensive approach to addressing this complex challenge. The research methodology involved monitoring a wide range of climate change podcasts using advanced natural language processing and machine learning to detect and categorize misinformation. Spanish speaking podcasts analysed were broadcasted in Spain but also some countries from South America. The study was conducted during 8 months (from June, 2022, to February, 2023). It encompassed the period of the 27th Conference of the Parties to the United Nations Framework Convention on Climate Change (COP 27), which took place from 6 to 18 November, 2022 in the city of Sharm el-Sheij (Egypt).

In summary, this study holds significant implications for both the academic field and the domains of journalism and science communication. On the one hand, it contributes to enhancing the characterisation of overarching patterns in climate misinformation, an area in which, as previously noted, empirical research remains scarce. In particular, this constitutes the first known study to analyse climate change denial narratives in podcasts—a medium with substantial reach and influence across diverse audiences. Furthermore, the decision to focus on Spanish-language podcasts is particularly relevant, given that Spanish is the second or third most widely spoken language in the world by number of native speakers. On the other hand, this research is methodologically challenging and contributes meaningfully to the broader research context. Monitoring and analysing oral media present considerably greater difficulties compared to written formats, particularly given the wide variation in podcast structure and content delivery. Therefore, by identifying and addressing climate misinformation in podcast formats, this study promotes improved media literacy and helps to reinforce public trust in credible sources of information.

2. Method

In this study, a multidisciplinary team of researchers, in collaboration with the fact-checking organization Verificat, has undertaken an innovative investigation aimed at addressing the issue of the spread of climate misinformation. As it has been mentioned, previous research exploring climate disinformation within the context of podcasts is scarce (Pathiyan Cherumanal *et al* 2024) and to the best of the authors' knowledge, no one has examined their narratives. Our research process involved monitoring a broad sample of climate change–related podcasts and applying advanced natural language processing and machine learning techniques to identify segments containing misinformation. We have checked the creation of climate misinformation in Spanish-speaking podcasts for 8 months (ClimaCast Project, from June 21, 2022, to February 21, 2023) and we have analysed and classified the content of this misinformation obtained during more than 5 months (from June 21, to November 30, 2022).

2.1. Workflow: from the selection of podcasts and the definition of a 'claim' to Narrative analyses

The development of the project has been carried out based on the workflow shown in figure 1. Firstly, with regard to the *Podcast selection phase,* the process was guided by Verificat's expertise and in-depth understanding of the Spanish-speaking climate misinformation landscape. A list of keywords associated with conspiratorial climate narratives was compiled from various sources, including Instagram groups, YouTube channels, Ivoox, Listen Notes, Spotify, and trending topics on Twitter (now X). These Spanish-language keywords were central to identifying relevant podcasts for monitoring. The selection was based on two primary criteria:

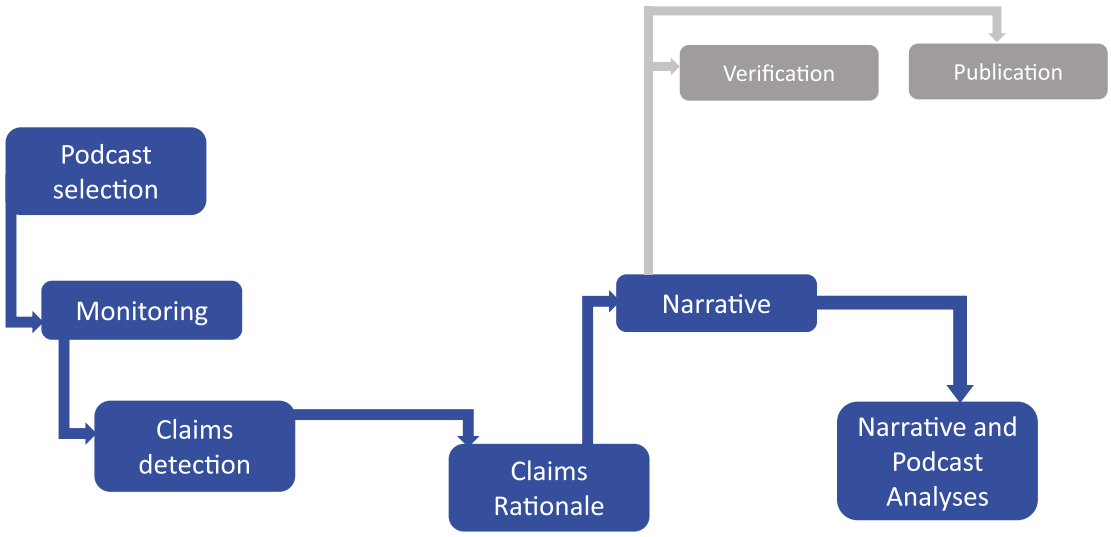

Figure 1. Workflow of the ClimaCast Project: from podcast selection and claim definition to narrative analysis (highlighted in blue). The complementary phases of verification and the publication of selected counterclaims to climate contrarian narratives are also included (shown in grey).

i) Podcasts hosted or produced by individuals who actively disseminate climate misinformation or conspiracy-related content on social media—specifically, those who regularly post material featuring the identified keywords.

ii) Podcasts whose titles clearly suggested climate-related conspiratorial perspectives, indicated by the presence of anti-climate or denialist terminology.

A further technical requirement was introduced: only podcasts that could be embedded via Really Simple Syndication (RSS) feeds were included. This restriction was due to the capabilities of the monitoring platform employed, which accepted only this format. Based on these criteria, 32 podcasts were selected for active monitoring, resulting in a dataset comprising approximately 5,000 h of audio content. The listening time varied across podcasts due to differences in episode duration, overall programme length, publication frequency, format, and the extent to which misinformation was present.

In total, over 500 distinct keywords related to climate misinformation were employed to identify the podcasts to be analysed, following the criteria outlined above. These keywords formed the basis of the system used to detect potential misinformation candidates, which were subsequently reviewed and verified by the verification team (comprising researchers and editors). The aim was to refine the system's ability to accurately identify misinformation claims.Examples of keywords include terms such as for example: 'climate change', 'warm temperatures', 'climate emergency', 'carbon dioxide', 'climate change is a lie', 'chemtrail', etc The keywords included inverted phrases (e.g., 'the ice is melting' and 'melting is the ice'), gender and plural variations, as well as synonyms for verbs and other concepts (such as CO_2 and carbon dioxide). The terms were deliberately designed to be concise, using the fewest possible elements to maximise the system's effectiveness in detecting relevant content.During the *Monitoring phase*, the podcasts were transcribed through an artificial intelligence tool and were fed into the dashboard previously developed by Kizen. If problematic content was detected, the system highlighted the keyword for greater detection by analysts. In the *Claims detection phase*, the analyst checked if: i) the keyword referred to some climate and/or meteorological aspect; ii) the sense and context of the keyword involved denial or trivialization of climate change and its effects. Then, the analyst team literally wrote the claim on the shared spreadsheet.

During the *Claims rationale phase*, the analyst explained the reasons for considering the podcast's statement as a claim. In this project, a claim is defined as the issuance of a message that explicitly or implicitly denies or trivializes the existence of climate change or its effects. This broad definition also includes the trivialization of climate science and its results, the actions that can be taken both to mitigate the effects of climate change and to adapt locations and activities to its impacts, as well as the targeting of scientists, experts, and individuals who strive to raise climate awareness. Each claim is also accompanied by metadata referencing the podcast, the type of podcast, the broadcast date, the listening date, the approximate minute where the claim is found, and the type of podcast.

Table 1. The six narratives used to classify the climate contrarian claims and some examples of corresponding claims. The first five narratives correspond to those proposed by Cook (2016, 2019) and Coan *et al* (2021) as a taxonomy of claims and the sixth one has emerged as a necessity arising from the claims analysis conducted in this study.

Narrative	Description	Example of claim
Climate change does not exist	The definition of climate change is an invention	*'When you enter Asturias, and in the morning it's 12 degrees, and right now 15, you start thinking about this nonsense of global warming and climate change'*
Climate change exists, but it is not anthropogenic	The causes of climate change are not due to human activity	*'The climate has been changing since we have known it. Climate change means absolutely nothing.'*
Climate change is not bad	Climate change is not negative for the Earth's ecosystems and societies	*'CO_2 is beneficial for vegetation, making the soil more fertile, improving the properties of food, and leading to trees producing more wood. The Mérida study from '93 also demonstrates that higher temperatures make the soil even more fertile. But they won't tell you this.'*
Climate science is unreliable (conspiracy)	Everyone is conspiring to establish a new world order	*'They lie us; the polar bears are increaing in number; polar bears are not less. They lie to us in all: the polar bears and the sea level.'*
Solutions do not work	Scientific and technical solutions do not work because there are others (usually China) that do not follow the rules [e.g.: carbon emissions].	*'The minister's thinking is irresponsible because it seeks to promote a cataclysmic ideology to the country and drive us toward poverty and economic decline as the only way to save the planet.'*
Greenwashing	Companies engage in greenwashing to appear more environmentally friendly than they truly are in order to attract environmentally conscious consumers or improve their public image	*'In China, the mini nuclear plants they are developing have already achieved the technology needed to recycle nuclear waste, thereby completing the cycle of green nuclear energy. This addresses the only problem with nuclear energy, which is its waste.'*

After the *Claims rationale phase*, the analyst classified the claims in the pre-defined main narratives (*Narrative phase;* figure 1). The narratives defined in this project have been developed, on the one hand, largely based on the work of Cook (2016, 2019) and Coan *et al* (2021), and on the other, as our analysis of claims progressed. Coan *et al* (2021) represents, to our knowledge, the most recent and extensive analysis of climate-contrarian claims conducted to date and proposes five main narratives (table 1). Most of the claims analysed in this research fit within these five narratives taxonomy; however, a small fraction required defining a sixth narrative, which we have termed 'Greenwashing'. The use of this term has increased significantly in the last two decades (Pinilla-Jurado and Alzate-Montoya 2023) and its effect has not been studied much (Gil-Cordero *et al* 2021).

In order to mitigate climate misinformation, some of the claims were selected to be fact-checked by the scientific reporters from Verificat and, after publication, they were republished in Europa Press, a news agency based in Spain but with scope in all Spanish-language countries *(Verification and Publication complementary phases;* figure 1). The criteria were: social impact, interest for the citizen, actuality and noticeability, and relevance within the climate debate.

The first claim defined in the project was: 'The methodology for climate modification has already been regulated.' This claim falls under the narrative portraying climate science as unreliable, suggesting that certain groups (allegedly conspiring for a new world order) possess a method for altering the climate. Lastly, in the *Narrative and Podcast Analyses phase* (figure 1), a statistical analysis of the collected narratives was conducted, taking into account metadata referencing the podcast as well as other attributes accompanying each podcast claim, such as the country where the podcast was broadcast. It should be noted that in some cases, there is not a single narrative in each claim, but that the claim can have a predominant narrative, and a secondary one (which was noted for more accurate analysis in the future).

2.2. Methodologic design

The design of the methodology employed is the result of a decision-making process that addresses the challenges and constraints that emerged at various stages of the workflow. Consequently, some methodological observations are presented in the results and further developed in the discussion.

For instance, some radio programs do not always have RSSavailable, a format that adheres to the XML standard for sharing content on the web. Therefore, we included only the podcasts and radio programs with

accessible RSS. This modified the podcasts monitored and the sample design. The RSS feed availability supposes a limitation and a potential source of sample bias.

Another challenge is the limited availability of audience data, which complicates sample selection. This constraint hinders the ability to conduct scientifically accurate estimations of the programs' influence on society and, consequently, the impact of climate disinformation on the audience. Because of that, a sample was selected based on other metrics, like the communities that they had in their social media accounts or the reproductions in some of the radio platforms such as iVoox.

Other aspect is that the lifespan of podcasts and radio programs is relatively brief. Consequently, many programs selected for monitoring at the outset of the project tend to become unavailable, altering both the sample composition and the analysis results. This required ongoing monitoring of the program list to ensure that content remained up to date, adding unanticipated time to the project's monitoring phase.

With regard to claim detection, transcription accuracy was at times inconsistent, thereby limiting the ability to reliably identify climate-related misinformation keywords within the transcripts. To address this, collaborative efforts were maintained throughout the project with the dashboard developers, offering real-time feedback to technology providers in order to improve transcription quality.Another question is that the company cancelled Kinzen's Dashboard due to business reasons and then, since December, 2022 to February, 2023, the Dashboard used was designed by Chequeado. On the one hand, this fact created new conditions regarding the collaborative work with the dashboard developers to enhance transcription quality in real-time by providing feedback to the new technology providers. Due to this modification of the methodologic conditions, the quantitative distribution of the narratives in the podcasts was only performed on the data derived from the Kinzen Dashboard (hereinafter, Dashboard A). On the other hand, changing the 'dashboard' variable provided us with the opportunity to verify trends in the results across both scenarios. As a result, the outcomes from the Chequeado Dashboard (hereinafter, Dashboard B) were utilized to evaluate factors influencing the detection of claims in our workflow and were duly considered in quantifying podcasts identified with claims compared to those without claims.

2.3. Analyses timeframe and COP27 event

The ClimaCast Project period extends from June 21, 2022, to February 21, 2023. However, as it has been already mentioned, the analyses and classification of the claims was performed only for the period June 21, to November 30, 2022, during which Dashboard A was utilized. COP27 occurred from November 6 to 18, 2022. Accordingly, the podcast analyses and the claims obtained have been conducted for the entire period (June 21, to November 30, 2022), with a distinction made between the COP27-period and the regular-period. Thus, results are shown for three different periods, considering the issue dates of the radio-programmes: the total-period (June 21, to November 30, 2022), COP27-period (November 6 to 23, 2022) and the regular-period (June 21, to November 5, 2022 & November 24 to 30, 2022; table 2). It should be noted that the analysis of the podcasts during the COP27-period encompasses not only the dates of the event itself but also the five days following its conclusion on November 18, 2022.

Starting from the beginning of the COP27-period, a new approach was introduced for the team in the claim detection phase: recording those podcasts suggested by the Dashboard developed by Kinzen that ultimately did not contain claims. This approach enabled the calculation of frequency percentages of climate-related podcasts in relation to the total number of podcasts identified by the dashboard as potentially containing climate misinformation.

3. Results

During the entire analysis period of the podcasts and their narratives using Dashboard A, spanning from 21 June to 30 November 2022 (the total period), a total of 629 podcast fragments were examined based on the broadcast dates of the programmes (table 2). This period encompassed over 10,166 min of listening time (>241 h). Of these, 198 fragments corresponded to the timeframe surrounding the COP27 event, accounting for over 4,294 min of listening (>72 h). The remaining 431 fragments pertained to the regular period, comprising more than 10,140 min of listening time (>169 h).

3.1. Claims detection

During the COP27 period (November 6 to November 23, 2022), a total of 198 podcast fragments were analysed. The proportion of claims relative to all analysed podcast fragments was 49%, rising to 52% when considering only the exact days of the COP27 event (table 2). A claim was detected approximately every 44 min of the total listening time of all podcast fragments and, every 14 min considering only the listening time of the claims themselves.After the COP27-period and during the last week of analyses of the regular-period (November 24 to

Table 2. Summary of the analysis's timeframes, the total number of podcasts analysed and the claims obtained during all the ClimaCast Project. The Narrative and Podcast analyses were performed for the period during which Dashboard A was utilized. COP27 occurred from November 6 to 18, 2022. The analysis periods consider the podcasts' issue dates.

Number of fragments of podcasts	Period of analyses (date of issue)	Description	Listening time (hours)	Dashboard	Climate contrarian claims
818	21/06/2022–21/02/2023	Total detected fragments of podcasts during the ClimaCast Project	>330	A & B	575
629	21/06/2022–30/11/2022	Fragments of podcasts analysed during the total-period	>241	A	517
431	21/06/2022–5/11/2022 & 24/11/2022–30/11/2022	Fragments of podcasts analysed during the regular-period	>169		420
198	06/11/2022–23/11/2022	Fragments of podcasts analysed during the COP27-period	>72		97

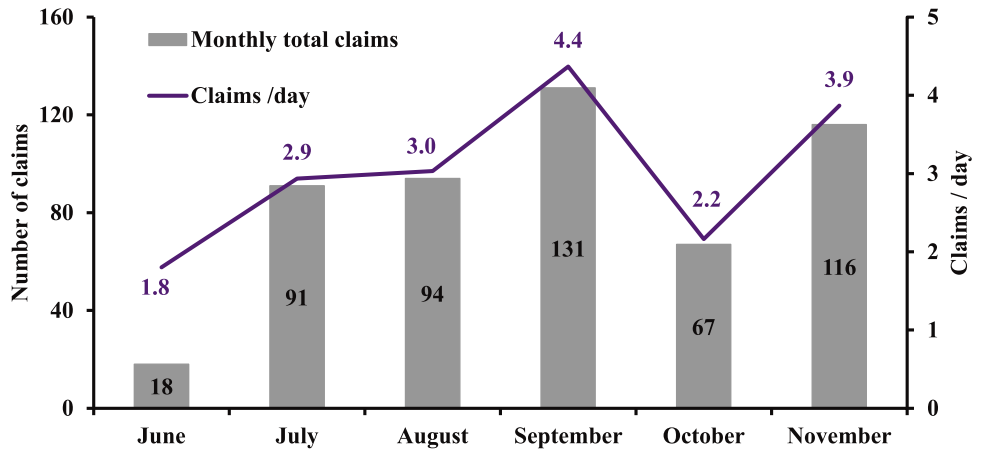

Figure 2. Monthly quantitative distribution of the identified claims from June 2022 to November 2022. The grey bars indicate the total number of claims detected each month, with black figures denoting the exact counts. The purple line represents the average number of claims identified per day within each month, with corresponding values shown. Notice that June was not analysed entirely due to the date of beginning of the project (June 21, 2022).

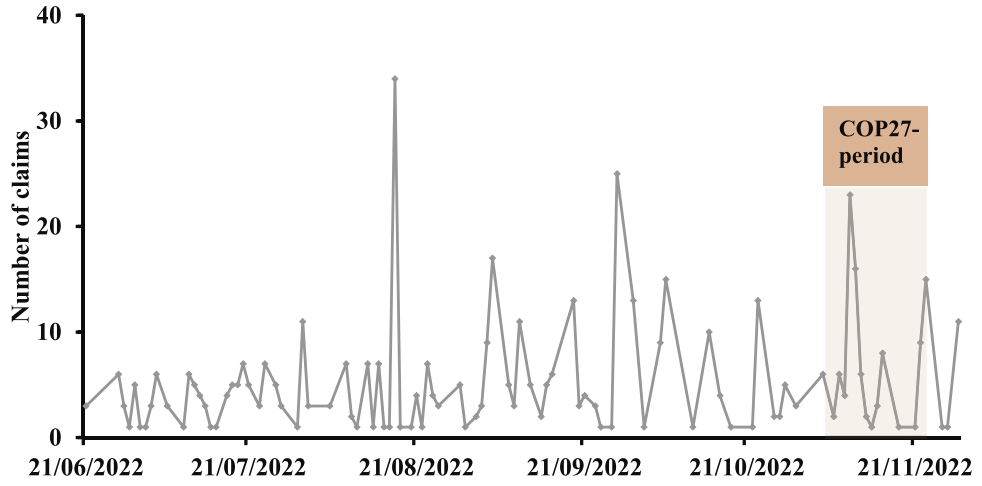

Figure 3. Claims detected per day during the studied total-period (June 21, 2022, to November 30, 2022).

30, 2022), when the process of distinguishing podcasts with and without misinformation (claims) was also carried out using Dashboard A, a total of 24 podcast fragments were analysed and the proportion of claims was 54%. Based on the total listening time of all fragments, a claim was detected approximately every 42 min. When considering only the listening time of the claims themselves, a claim was found roughly every 16 min.

3.2. Temporal and quantitative distribution of the claims

Over the five-month study period, a total of 517 claims were identified (~3 claims per day; figure 2). When considering only the 98 specific dates on which podcasts containing claims were published, the daily average rises to approximately ~ 5 claims per day. September 2022 recorded the highest number (131) and October the lowest (67). November, which included the COP27 conference (6–18 November), accounted for 116 claims, making it the second most active month.

The daily rate of detected claims is notably higher during the COP-27 period (7.5 claims/day) compared to the regular period (2.9 claims/day). These findings suggest temporal fluctuations in the dissemination of climate-related misinformation, potentially influenced by key events such as COP27 (figure 3). It should be noted the most notable peak of claims/ day occurring around August 2022, where daily claims exceeded 30. It corresponds to a particular programme and is commented in section 3.4.

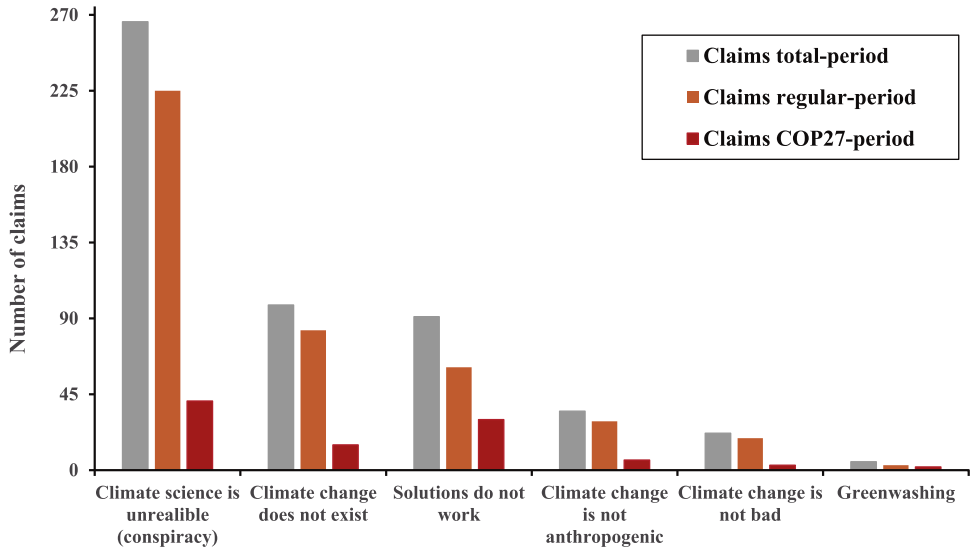

Figure 4. Number of claims for each of the six narratives during the total-period (grey; from June 21, 2022, to November 30, 2022), during the regular-period (orange), and during COP27-period (red; from November 6 to 23, 2022).

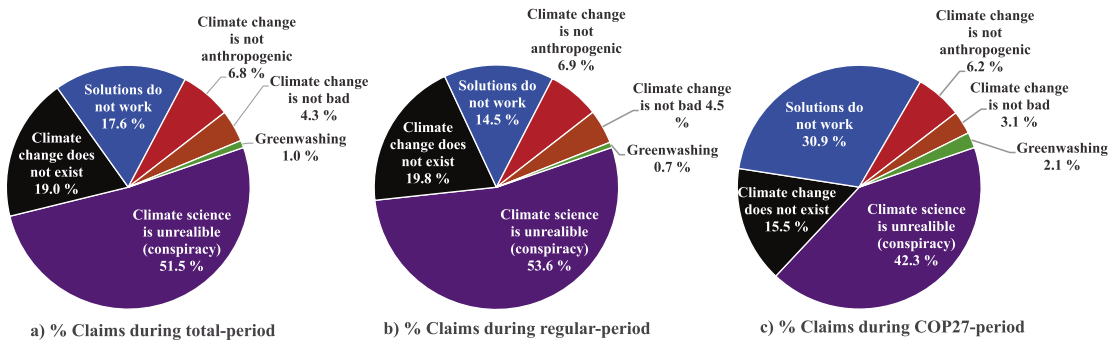

Figure 5. Distribution of narratives and their respective proportions of the total number of identified claims during: (a) the total period (21 June to 30 November 2022), (b) the regular period, and (c) the COP27 period (November 6 to 23, 2022). The six narrative categories, based on Coan *et al* (2021) and the present study, are represented using distinct colours.

3.3. Quantitative distribution of the narratives

The classification of the 517 identified claims across the six narrative categories is presented in figures 4 and 5. Over half of the claims (266; 51.5%) fall under the narrative 'Climate science is unreliable (conspiracy)', making it the most prevalent in both the COP27 and regular periods. The second most frequent narrative is 'Climate change does not exist', accounting for 98 claims (19.0%), followed closely by 'Solutions do not work' with 91 claims (17.6%), which notably ranks second during the COP27 period. The narratives 'Climate change exists but is not anthropogenic' and 'Climate change is not bad' are less prominent, representing 6.8% (35 claims) and 4.3% (22 claims) of the total, respectively. 'Greenwashing' appears least frequently, comprising just 1.0% of claims. These figures suggest a concentration of climate misinformation around narratives that question the legitimacy of climate science and the effectiveness of proposed solutions.

During the regular-period, the scepticism around climate science (narrative 'Climate science is unreliable -conspiracy') is significantly higher than during COP27-period (figures 5(b)–(c)). Denial of climate change's existence is also more prominent in the regular-period than during the COP27-period. However, during COP27, there was nearly double the regular-period level of scepticism about the effectiveness of climate solutions. The belief that climate change is not caused by human activity is similar during both periods but slightly lower during COP27. During COP27, there was also a small decrease in the narrative that climate change is not bad respect the regular-period. Claims about Greenwashing were more prevalent during COP27.

3.4. Types of radio programmes and narratives taxonomy

Between June and November 2022 (total period), Dashboard A identified potential climate misinformation in 26 podcast programmes. Of these, 22 originated in Spain, three in Colombia, and one in Argentina. According to

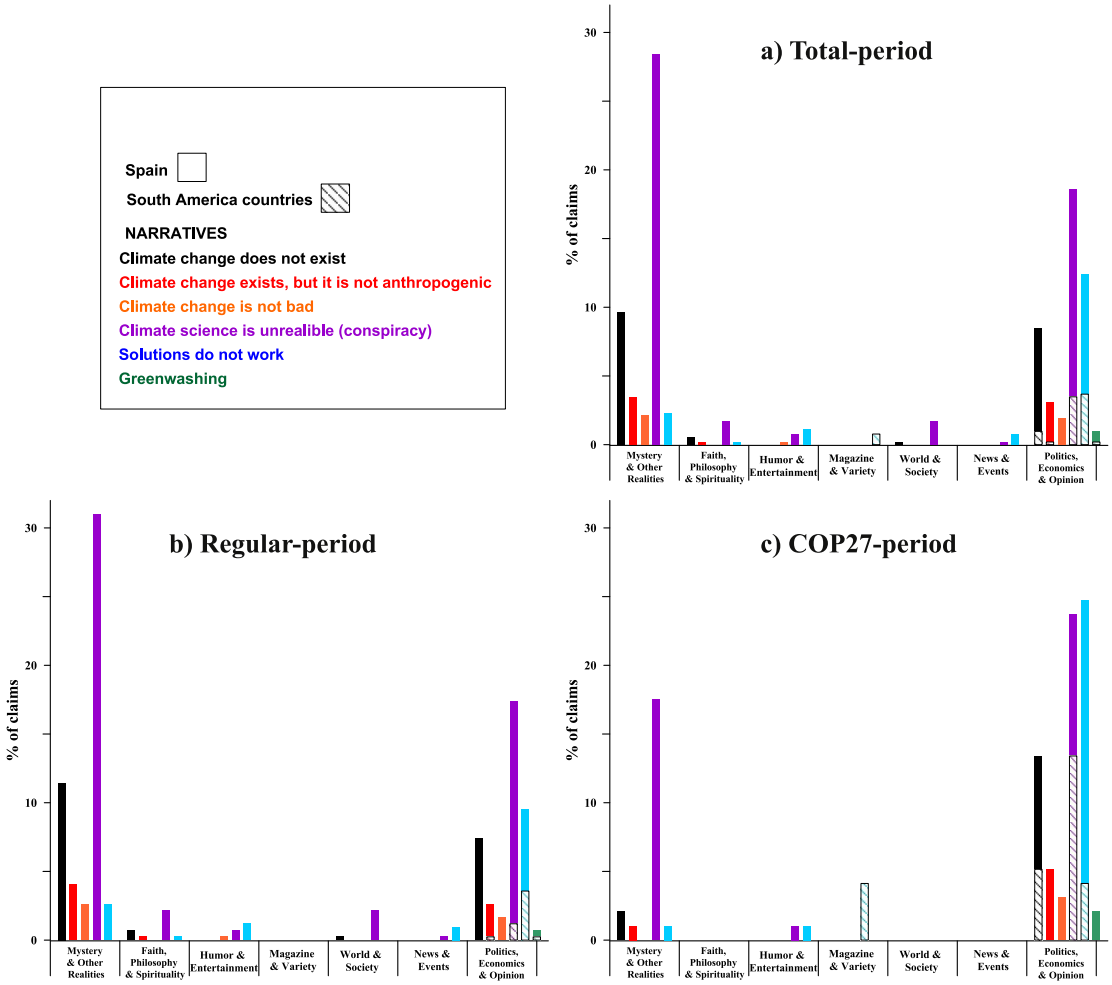

Figure 6. Percentage distribution of claims according their narratives and across the different type of programmes for the studied periods with the Dashboard A. (a) Total-period from June 21, 2022, to November 30, 2022), includes (b) Regular-period and (c) COP27-period from 6 to 23 of November, 2022. The different colours correspond to the six defined narratives. The striped pattern indicates claims from South American programs, while the solid pattern represents those from Spain. The horizontal axis shows the seven types of programmes where claims have been detected.

the self-assigned classifications of these programmes, seven content categories were represented (figure 6 and table 3). Some programmes employ multiple category labels for their episodes. For example, one Spanish programme assigned 83% of its episodes to Politics, Economics & Opinion, while the remainder were distributed across categories such as Magazines & Variety (6.3%) or other with less percentage. Among the 22 Spanish programmes containing claims, seven displayed similar multi-category labelling patterns. For four of these, over 80% of recent episodes fell within a single dominant category; for two others, the figure was above 54%. In such cases, the most consistently applied category was selected for the purposes of this analysis. One remaining programme presented a more dispersed distribution of content: Faith, Philosophy & Spirituality (30.4%), News & Events (21.7%), Health, Home & Consumer Topics (12.2%), World & Society (10.4%), Art & Literature (7.8%), Politics, Economics & Opinion (7%), Science & Nature (5.2%), etc In this instance, the most frequently used category—Faith, Philosophy & Spirituality—was selected, as it aligned with the classification of the specific episodes in which the claims were detected.

Of the 517 claims identified during the total period using Dashboard A (figure 6(a)), 469 were associated with programmes broadcast in Spain, while 48 originated from South American programmes (41 from Colombia and 7 from Argentina). Claims from Spanish podcasts were predominantly associated with the narratives 'Climate science is unreliable' (48.0%), 'Climate change does not exist' (18.0%), and 'Solutions do not work' (13.2%). Less frequently, claims aligned with 'Climate change exists, but it is not anthropogenic' (6.6%) and 'Climate change is not bad' (4.3%), while 'Greenwashing' was marginal, accounting for just 0.8% of the total.

In terms of programme type, the highest proportion of claims from Spain were concentrated in Mystery & Other Realities (46.0%) and Politics, Economics & Opinion (36.9%). Within these categories, 'Climate science is unreliable' accounted for 28.4% and 15.1% of claims, respectively; 'Climate change does not exist' represented 9.7% and 7.5%; and 'Solutions do not work' was particularly present in Politics, Economics & Opinion (8.7%).

Table 3. Percentage distribution of claims by narrative and programme type across each analysis period, as identified using Dashboard A. The total period covers 21 June to 30 November 2022, including both the regular-period and the COP27-period (6 to 23 November 2022). For each narrative category, figures on the left refer to programmes broadcast in Spain, while those on the right relate to those aired in South America.

Type of programme	Narratives												
	Climate change does not exist		Climate change exists, but it is not anthropogenic		Climate change is not bad		Climate science is unrealible (conspiracy)		Solutions do not work		Greenwashing		
Mystery & Other realities	9.7	—	3.5	—	2.1	—	28.4	—	2.3	—	—	—	Total-period
Faith, Philosophy & Spirituality	0.6	—	0.19	—	—	—	1.7	—	0.2	—	—	—	
Humor & Entertainment	—	—	—	—	0.19	—	0.8	—	1.2	—	—	—	
Magazine & Variety	—	—	—	—	—	—	—	—	—	—	—	—	
World & Society	0.2	—	—	—	—	—	1.7	—	—	0.8	—	—	
News & Events	—	—	—	—	—	—	0.2	—	0.8	—	—	—	
Politics, Economics & Opinion	7.5	1	2.9	0.19	1.9	—	15.1	3.5	8.7	3.7	0.8	0.19	
Mystery & Other realities	11.4	—	4.0	—	2.6	—	31.0	—	2.6	—	—	—	Regular-period
Faith, Philosophy & Spirituality	0.7	—	0.2	—	—	—	2.1	—	0.2	—	—	—	
Humor & Entertainment	—	—	—	—	0.2	—	0.7	—	1.2	—	—	—	
Magazine & Variety	—	—	—	—	—	—	—	—	—	—	—	—	
World & Society	0.2	—	—	—	—	—	2.1	—	—	—	—	—	
News & Events	—	—	—	—	—	—	0.2	—	1.0	—	—	—	
Politics, Economics & Opinion	7.4	—	2.4	0.2	1.7	—	16.2	1.2	6.0	3.6	0.5	0.2	
Mystery & Other realities	2.1	—	1.0	—	—	—	17.5	—	1.0	—	—	—	COP27-period
Faith, Philosophy & Spirituality	—	—	—	—	—	—	—	—	—	—	—	—	
Humor & Entertainment	—	—	—	—	—	—	1.0	—	1.0	—	—	—	
Magazine & Variety	—	—	—	—	—	—	—	—	—	4.1	—	—	
World & Society	—	—	—	—	—	—	—	—	—	—	—	—	
News & Events	—	—	—	—	—	—	—	—	—	—	—	—	
Politics, Economics & Opinion	8.2	5.2	5.2	—	3.1	—	10.3	13.4	20.6	4.1	2.1	—	

Table 4. Number of podcasts and their corresponding number of claims per day of issue.

Number of claims per day of issue	Number of podcasts (total-period)	Number of podcasts (COP27-period)
1	66	15
2–3	45	10
4	14	14
5–9	16	3
10–11	4	4
12–17	7	2
32	1	—

The narrative 'Climate change exists, but it is not anthropogenic' was also notably represented in Mystery & Other Realities (3.5%) and Politics, Economics & Opinion (2.9%). Other categories contributed fewer claims overall, including Faith, Philosophy & Spirituality (2.7%), Humour & Entertainment (2.1%), and World & Society (1.9%).

Regarding the 48 claims corresponding to programs aired in South America, primarily align with Narratives 'Solutions do not work' (4.4%) and 'Climate science is unreliable' (3.5%). Narrative 'Climate change does not exist' is the third most frequent (1%). With respect to the types of programs featuring climate misinformation broadcast in South America, two categories have been identified: Magazine & Variety and Politics, Economics & Opinion. In both types of programs, the narrative 'Solutions do not work' stands out (0.8% and 3.7%, respectively).

Differences and common patterns in the program typologies and the taxonomy of narratives have been detected during the regular-period and the COP27-period (figure 6(b) and (c); table 3). During the regular-period all types of programmes have been detected except the category Magazine & Variety.

In both periods, the highest proportion of claims appeared in programmes categorised as Politics, Economics & Opinion and Mystery & Other Realities. During the COP27 period, Politics, Economics & Opinion accounted for 72.2% of misinformation claims—the highest—while in the regular period, it ranked second (39.7%). Conversely, Mystery & Other Realities accounted for 21.6% during COP27 and 51.7% in the regular period. Narrative distribution also varied between periods. In Politics, Economics & Opinion during COP27, the most frequent narrative was 'Solutions do not work' (24.7%), followed by 'Climate science is unreliable' (23.7%). This order reversed in the regular period: 'Climate science is unreliable' (17.4%) and 'Solutions do not work' (9.5%).

In Mystery & Other Realities, the same narratives appeared in both periods, but with lower frequencies during COP27: 'Climate science is unreliable' (17.5% versus 31%) and 'Climate change does not exist' (2.1% versus 11.4%). Regarding differences in both periods of analyses between broadcasted countries, during the regular-period only was detected a 5.2% of programmes with claims from South America while during the COP27, this amount increased notably to 26.8%. Among the South American programmes detected, highlights the category Politics, Economics & Opinion regarding the regular-period and also the category Magazine and Variety, which was not present in the regular-period as mentioned before (figures 6(b) and (c); table 3).

3.4.1. Range of claims per programme and per day of issue

The number of claims detected in a single program per day of issue during the total-period varies between 1 and 32 claims. The most frequent trend (43.1%) corresponds to programs with a single claim per day of issue (66 podcasts; table 4). The second most frequent trend involves podcasts with 2–3 claims (29.4%). The percentage of programs with more than 10 claims per day of issue reaches 7.8%.

It should be noted that one of these programs stands out from the prevailing trends, as it issued up to 32 claims in a single day. It corresponds to the most notable peak of claims/ day occurring around August 2022 (figure 3). This program, broadcast in Spain, categorizes itself as Mystery and Other Realities and frequently featured climate misinformation. In fact, we found episodes explicitly dedicated to denialist themes. The claims identified in this program are so frequent that they account for 46% of the total-period (figure 6(a)); 9 of its podcasts contain 10 or more claims. Regarding the most frequent types of narratives found in this program, the two most predominant exhibit higher percentages than the trends observed across all programs during the total-period: 'Climate science is unreliable' (61.3%) and 'Climate change does not exist' (21.0%) (figure 5(a)).

The following three programs from the total-period with the highest percentage of claims relative to the total self-identify under the label Politics, Economics & Opinion. Two of these are broadcast from Spain, accounting for 8.3% and 7.4% of the total claims, respectively, with the number of claims per broadcast ranging between 1 and 6. Approximately one-quarter of the claims in each program consist of a single claim per broadcast.

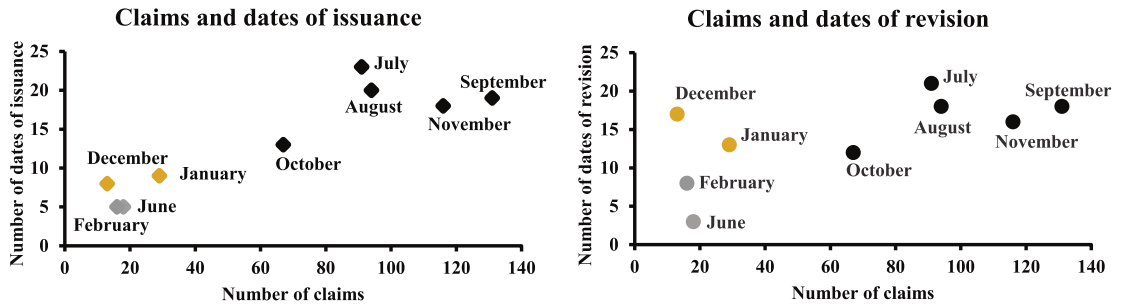

Figure 7. Monthly number of identified claims based on the podcast release dates (left panel) and the dates reviewed by our team (right panel). Black dots indicate months fully analysed using Dashboard A; the grey dot denotes a month only partially analysed due to the project's start date.

Regarding the most frequent narratives, in the first program, 62.8% of the claims fall under the narrative 'Climate science is unreliable.'

During the COP27-period, the distribution of claims per program and broadcast is similar to that of the regular-period (table 4). Although the maximum of 32 claims corresponds to the regular period, this program also ranks as the second-highest in claims per broadcast during the COP27-period. The 15 claims detected in that podcast pertain to an episode arguing that climate is being manipulated using chemtrails. The program with the highest number of claims during the COP27-period (16 claims) corresponds to the third program with the highest number of claims in the total-period, broadcast in South America (Colombia). The 16 claims in that episode were related to a podcast discrediting climate change discourse, stating that it 'deviates from scientific foundations and is rooted in politics.' It should be noted that among all the claims detected during the COP27-period, only one explicitly mentioned COP27, associating it with hypocritical attitudes. Many of the podcasts referenced the event indirectly, using alternative expressions.

3.5. Dashboard methodological observations

3.5.1. Number of claims detected, dates of issuance and dates of revision

During the Dashboard B period (from December 2022 to February 2023), the number of claims detected was lower than during the Dashboard A period; (figure 1 Supplementary material). February was only partially analysed due to the project's conclusion on 21 February 2023. Nevertheless, December and January recorded the lowest daily claim rates. Over the 83 days analysed with Dashboard B, 58 claims were detected, (only 0.7 claims / day). In the post-COP27 period (from November 24, 2022 to February 21, 2023; including both Dashboards A and B), during which the process of distinguishing between podcasts without and with misinformation (claims) was also developed, 72 claims were detected out of a total of 142 fragments of podcasts. In this way, the percentage of fragments of podcasts with claim was 34%, which is lower than those obtained during the COP27-period and the regular-period, respectively (49%–54%). Considering the listening time of the claims, approximately every 34 min a claim was issued, frequency which is lower than those obtained during the COP27-period and the regular-period (14 and 16 min, respectively). Taking into account the 90 days of this post-COP27 period with both Dashboards, 0.8 claims / day were detected which is also lower than those obtained for the COP27-period and the regular-period (7.5 and 2.9 claims / day, respectively).

In order to investigate possible controlling factors on claims detection and derived differences, in figure 7 are shown monthly claim counts in relation to podcast issuance dates and review days obtained by Dashboards A and B.

The Pearson coefficient between the number of detected claims and the number of analysed issuance dates indicates a strong and significant positive correlation ($r = 0.9011$, p *value* < 0.05; figure 7, left). When focusing exclusively on the data obtained using the Dashboard A (from June to November 2022), the correlation is slightly lower but still strong ($r = 0.8283$, p *value* < 0.05). Regarding the reviewed issuance dates per month, the correlation is not statistically significant but is positive ($r = 0.6461$, p *value* > 0.05; figure 7 right). Considering only the Dashboard A, data correlates significant and positively ($r = 0.8480$, p *value* < 0.05).

3.5.2. Dashboard A & B: distribution of the narratives and types of radio programme

The distribution of the narratives obtained with Dashboards A and B does not show significant differences and only differs slightly in the percentages obtained for each narrative (figures 5(a)–(b) and figure 2 Supplementary material). The narrative 'Climate science is unreliable (conspiracy)' shows the highest difference range (1.5%), being lower including Dashboard B.

The number of programs where the algorithm of Dashboard B from December to February 2023 (total-period) detected information or terms potentially associated with climate misinformation was 13, of which 10 were coincident with those detected by Dashboard A. The total of programmes detected show the same labels as those corresponding to Dashboard A, with the exception of the Magazine and Variety programmes, which are not present. It should be noted that this type of programmes was only detected during the COP27-perio During both Dashboard periods, programmes with the highest percentage of claims are labelled as Politics, Economics & Opinion and as Mystery & Other realities.

4. Discussion

4.1. Influencing factors on claims detection

The results presented in sections 3.1, 3.2, and 3.5 indicate that the claim detection rate during the Dashboard B period is lower than during the Dashboard A period. The range of claims detected per month with Dashboard A fluctuates between 131 (September 2022) and 67 (October), whereas with Dashboard B, the range fluctuates only between 29 (January) and 13 (December; figures 1 and 2 in the Supplementary Material). Considering the total analysis period for each Dashboard, the number of claims per day was 3 with Dashboard A and 0.7 with Dashboard B. These differences between the two dashboards are not related to the inclusion of the COP27-period in Dashboard A, because when comparing the regular-period of Dashboard A with the total-period of Dashboard B, the claims per day figures still show a significant difference: 2.9 versus 0.7 claims/day, respectively.

Regarding the distribution of the narratives, the comparison of the data obtained with Dashboards A and B does not reveal significant differences (figures 5 and 2 in the Supplementary Material). The types of programmes are also the same. One difference found pertains to the 'Magazine and Variety' type programmes, which are not present in Dashboard B; however, it should be noted that these are not neither present in the regular-period of Dashboard A and were only detected in the COP27-period. Additionally, with both Dashboards, the programmes with the highest percentage of claims are labelled as Politics, Economics & Opinion, and as Mystery & Other Realities. One difference between the two dashboards is that Dashboard B detected three new programmes, two of which were broadcast in the United States and one in Argentina, accounting for 25.9% of the total claims detected with this Dashboard.

Thus, during the corresponding analysis periods with both Dashboards, similarities and differences have been found in the results obtained. The distribution of narratives as well as the types of programmes detected do not show significant differences. In contrast, the claim detection rates between the two dashboards are markedly different. Taking into account the entire workflow of the ClimaCast Project, the observed differences appear to be primarily associated with the Podcast Selection phase (figure 1) and to be related mainly to the number of fragments of podcasts detected rather than the type of programme or narrative. Additionally, considering that the percentage of claims detected relative to the total number of fragments of podcasts flagged by the algorithm was 54% with Dashboard A and 34% when considering the entire post-COP27 period with both Dashboards A and B, these differences may primarily be attributed to varying detection efficiencies of each algorithm due to differences in the previous times of preparation.

Factors that could influence this phase of podcast detection may be related to the effort and dedication of the team. In order to investigate this, we have examined monthly claim counts in relation to podcast issuance dates and review days obtained from Dashboards A and B (figure 7). Regarding the issuance dates, the number of detected claims and the number of analysed dates show a strong and significant positive correlation ($r = 0.9011$, p value < 0.05). Focusing solely on the data obtained using Dashboard A (from June to November 2022), the correlation remains strong ($r = 0.8283$, p value < 0.05; figure 6, left). Thus, a higher number of detected claims seems to correspond with a greater number of analysed issuance dates, which was expected. Nevertheless, the months with the highest number of detected claims do not align with the highest number of analysed issuance dates (e.g., September and November; figure 7, left). This is due to the fact that on the issuance date, many podcasts contained not just a single claim but several, as discussed in section 3.4. Additionally, the month of December, which was the first month of analysis using Dashboard B, shows the lowest number of detected claims, yet it does not correspond to the lowest number of detected issuance dates. This is likely due to the lack of time dedicated to monitoring forums for words and phrases prior to the Podcast selection phase with Dashboard B. Thus, these data regarding the detected claims and issuance dates do not seem to be related to the team's dedication.

In relation to the reviewed issuance dates per month and the number of claims detected, the correlation is not statistically significant, but it is positive ($r = 0.6461$, p value > 0.05; figure 7, right). This fact seems to indicate that a greater amount of time dedicated by the team to reviewing the podcasts flagged by the algorithm does not correspond with a higher number of detected claims. It is important to highlight that the algorithm stored the podcasts suspected of containing claims from the days that were not reviewed, making them available

when the team was working. Considering only Dashboard A, the data shows a significant and positive correlation ($r = 0.8480$, p value < 0.05). Nonetheless, we find that the months with the highest number of detected claims do not align with the highest number of review days (September and November). The fact that the correlation is significant with Dashboard A but not when considering both Dashboards could again be related to the different levels of previous preparation and efficiency of the algorithms. During the months of analysis with Dashboard B, a high number of review days is observed, yet the number of detected claims is not similarly high (December and January).

Thus, the Podcast selection phase has been identified as the most critical part of the designed Workflow process. This phase was previously prepared with Dashboard A, fostering teamwork and, in a sense, training the algorithm. Forums where people post climate disinformation were monitored to detect podcasts and recurring words or phrases in this area, which were used to define keywords for identifying relevant podcasts. For reasons unrelated to the study, the time dedicated to this phase with the second Dashboard was significantly shorter, meaning that its efficiency and sensitivity were not as well trained as with Dashboard A.

During the algorithm's training phase, the team developed a range of methods for detecting misinformation that extended beyond the mere inclusion of specific keywords or phrases. The data underscore the importance of this phase and the need for regular updates to detection tools (Meddeb *et al* 2022). At present, the algorithm's artificial intelligence is not yet capable of automatically identifying claims. The podcast format varies considerably in both complexity and style—from multi-speaker discussions to single-speaker monologues (Pathiyan Cherumanal *et al* 2024)—which often disrupts the analytical unit required for effective detection and verification. A promising avenue for future research could be the development of AI systems capable of interpreting speech beyond lexical content, including, for example, the tone or intent of the speaker. Overall, despite the differences in the number of claims detected with both dashboards, the similarities found in the results obtained from both Dashboards regarding the distribution of narratives, the types of programs, and the highest frequencies of claims within the same types of programs highlight the significance and robustness of the data obtained with the Dashboard A.

4.2. About misinformation and disinformation

According to the Oxford English Dictionary (OED), the meaning of 'misinformation' is 'False or inaccurate information, especially that which is spread unintentionally'. The earliest known use of the noun misinformation is in the late 1500 s. OED's earliest evidence for misinformation is from 1587. Regarding to 'disinformation', is defined as 'deliberate dissemination of false or misleading information, typically intended to deceive or mislead, often for political or strategic purposes'. The earliest known use of the noun disinformation is in the 1950s. OED's earliest evidence for disinformation is from 1955, in the Times (London).

Thus, 'disinformation' appears to be a more recent noun than 'misinformation' and primarily differs from it in that it involves the deliberate creation and dissemination of erroneous information with the intent to cause harm or manipulate public opinion (Flores Vivar 2019, Treen *et al* 2020).

If 'misinformation' is considered the result of an unintentional error, it could be argued that some of the narratives identified in this study can be classified as 'disinformation.' This is the case for the narratives 'Climate science is unreliable (conspiracy)' and 'Greenwashing.' The former clearly aims to discredit the scientific community. With regard to the 'Greenwashing' narrative, which has the lowest frequency of occurrence in the analysed podcasts in all the studied periods (1.0% in the total period), the OED defines it as 'the creation or propagation of an unfounded or misleading environmentalist image.' More broadly, greenwashing refers to the practice whereby companies or organizations promote products, policies, or practices as environmentally friendly or sustainable when, in reality, they are not. This term was used by first time in the 1980s (Gil-Cordero *et al* 201). This often involves misleading claims or exaggerations intended to create the false impression that a company is more environmentally conscious than it actually is. In our view, we propose considering this as 'disinformation,' as there is a clear intent to deliberately mislead the public.

The aforementioned narratives, 'Climate science is unreliable (conspiracy)' and 'Greenwashing,' account for more than half of the claims identified in the podcasts during the total-period. Thus, it can be asserted that the majority of the messages detected in this study constitute disinformation rather than misinformation.

In the case of the remaining narratives, the classification as disinformation or misinformation is less obvious. For instance, the narrative 'Solutions do not work' has frequently been identified in Politics, Economics, and Opinion programs (figure 5), where policies implemented by administrations to mitigate anthropogenic CO_2 emissions—such as the modernization of the most polluting vehicles—are superficially analysed. In these cases, it has been observed that, to some extent, the term misinformation could be applicable in certain instances, though not always.

Another example relates to the 'Climate change does not exist' narrative, raising the question of whether the message disseminated by climate change deniers—who are fully convinced that climate change does not exist—

can always be classified as 'misinformation' or 'disinformation.' Denialist discourse spreads erroneous information; however, most of the speakers in the podcasts analysed in this study also appear to adopt a stance of wanting to 'enlighten' the audience. According to them, both governments and the scientific community are deliberately deceiving the public.

The debate also extends to discourses classified under the narrative 'Climate change is not that bad.' If this claim is made by someone from a country where global warming enhances agricultural production, it would not constitute disinformation in any case. However, it could potentially be classified as misinformation. It is possible that, although rising temperatures may benefit agricultural output in certain regions, they are simultaneously altering and/or harming other parts or functions of ecosystems and negatively impacting other species. This information may be unknown to the speaker, but it is not improbable.

Abellán-López (2021) conceptually distinguishes between deniers, contrarians, and climate sceptics. Deniers refers to those who reject the scientific evidence of climate change, which, in the present study, can be associated with the narrative 'Climate change does not exist.' The term contrarians typically refers to individuals who aggressively challenge both scientific evidence and reputable climate researchers, often with significant financial backing from fossil fuel industry corporations and conservative-leaning experts (O'Neil and Boykoff 2010, Abellán-López 2021). This term can be linked to the narratives 'Climate science is unreliable (conspiracy)' and 'Solutions do not work.'

Regarding the term climate sceptics, some social groups self-identify with this label not by denying climate change but by questioning the severity of the issue (Abellán-López 2021). Lavik (2016) argues that the key distinction between a denier and a sceptic lies in their intent: a sceptic engages in good faith, whereas a denier does not. In other words, a climate change denier automatically rejects arguments regardless of the empirical evidence supporting them. Similarly, Shermer (2010) contends that those who label themselves as climate sceptics are, in reality, deniers, as refusing to accept overwhelming evidence is not scepticism but denialism (Washington and Cook 2011, Abellán-López 2021).

In summary, the majority of the material identified in the analysed podcasts can be classified as disinformation rather than misinformation, although this distinction is not always obvious. Anyway, both of them can affect public perception of climate change and tend to downplay potential individual actions to counteract global warming (Pasquaré and Oppizzi 2012).

4.3. Climate change disinformation arguments on Spanish-speaking podcasts

As seen in section 3.4, the various narratives identified in this study within Spanish-speaking podcasts exhibit distinct distributions across the different types of programs. McIntyre (2021) points out that each type of climate change denial has its own audience. Thus, the discussion of the narratives detected in podcasts is presented by distinguishing between contrarian and denialist arguments and other types of arguments.

4.3.1. Attacking the integrity of climate science and scientists: contrarians

During the entire study period (June 21 to November 30, 2022), the most frequently observed climate misinformation narrative in podcasts was 'Climate science is unreliable (conspiracy),' accounting for more than 50% of the claims identified (figure 5(a)). The next two most predominant narratives were 'Climate change does not exist' and 'Solutions do not work' (19.0% and 17.6%, respectively). Thus, a significant portion of the observed climate misinformation aligns with questioning the reliability of climate science, with substantial portions also denying either the existence of climate change or the effectiveness of climate solutions. The observed dominance in our study of narratives challenging the science ('Climate science is unreliable' and 'Solutions do not work'; figure 5(a)) aligns with the general findings of Coan *et al* (2021), which indicated that claims disseminated by English-speaking conservative think-tank websites and contrarian blogs have primarily focused on attacking the integrity of climate science and scientists. This denial of science is ultimately a rejection of the scientific consensus on global warming and the role of humans as the driving force behind climate change (Abellán-López 2021).

Regarding the narrative 'Climate science is unreliable,' the percentages obtained from the analysed podcasts are comparable to those reported by Coan *et al* (2021) for contrarian blogs. However, our percentages are higher than those related to conservative think-tank websites. In the case of the narrative 'Solutions do not work,' the results are the opposite: the percentages observed in podcasts are higher than those in blogs but lower than those found on the websites analysed by Coan *et al* (2021).

In the present study, the programs in which this type of arguments ('Climate science is unreliable' and 'Solutions do not work' narratives) have been most frequently detected correspond to the categories Mystery & Other Realities and Politics, Economics & Opinion (figure 6(a)). The narrative 'Climate science is unreliable' is also used by programmes labelled as World & Society, Faith, Philosophy & Spirituality, Humour & Entertainment and even in News & Events label, being the narrative detected in more type of programmes.

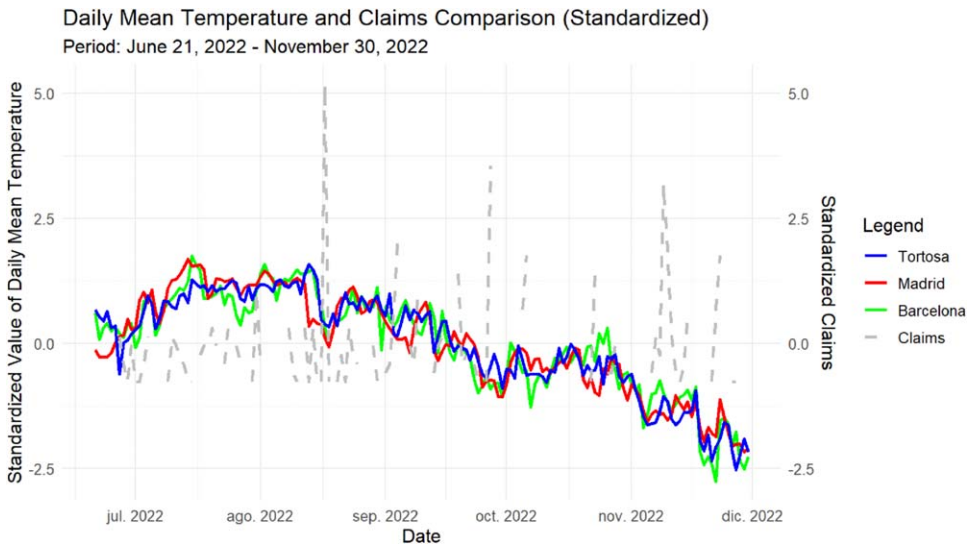

Figure 8. Daily mean temperature anomalies to the 1920-October 31, 2024 reference period and claims data per day during the total-period from June 21, 2022, to November 30, 2022. The data for temperature were obtained for three cities: Tortosa, Madrid, and Barcelona. Temperatures and claims/day datasets were filtered to match the same time period, from June 21, 2022, to November 30, 2022. The standardization process was performed separately for each city, ensuring that the variables had a mean of zero and a standard deviation of one.

Among these programs, representations from both the left and right of the political spectrum can be found. However, as noted by Cairns (2016) regarding 'chemtrail' conspiracy narratives, positioning these narratives along the political spectrum is challenging.

4.3.2. Climate change denialism

Taking into account the narrative 'Climate change does not exist', the obtained percentages are very similar to those reported by Coan *et al* (2021). In the podcasts analysed in the present study, it has been observed that the narrative 'Climate change does not exist' frequently employs the following climate change denialism argument: 'In the past, there have already been periods in Earth's history with higher CO_2 levels and temperatures than those of today; therefore, there is no reason to be concerned about the current situation.' It should be noted here that, although paleoclimate reconstructions point out some past moments when temperatures and CO_2 levels were higher than the present ones, the abruptness of the current change has no precedents. For instance, during the Paleocene-Eocene Thermal Maximum, which was a global warming event occurred more than 55 million of years ago, CO_2 levels were higher than the current ones (Zachos *et al* 2001). However, the rate of CO_2 release to the atmosphere of present human activities is 10 times faster than the rate of greenhouse gas emissions given during the Paleocene-Eocene Thermal Maximum (Gingerich 2019). The before-mentioned climate change denialism argument is aligned to one of the key arguments pointed out by Washington and Cook (2011; 'Climate's changed in the past'). Another frequently observed argument, primarily related to the 'Climate change does not exist' narrative, was associated with opinions regarding the meteorological conditions on the day the statements were made. Common arguments included: 'When you enter Asturias, and in the morning it's 12 degrees, and right now it's 15, you start to think about this farce of global warming and climate change' or 'The world with the scam of global warming… Now a heat wave in July—well, what a surprise, it's July and it's summer, of course it's hot.' These statements were issued on July 8 and 12, 2022, respectively. It should be noted that, during the year 2022 in Spain, the annual average temperature exceeded 15 °C for the first time, surpassing the warmest years recorded until then (2017 and 2020), according to data from the Spanish State Meteorological Agency (AEMET). To explore these trends, the present study has compared the number of claims recorded per day throughout the entire period with temperature data (figure 8).

The meteorological data used in figure 8 were obtained from the European Climate Assessment & Dataset (ECA&D), focusing on daily temperature records from three Spanish meteorological stations: Madrid Retiro, Tortosa Ebro Observatory, and Barcelona Fabra Observatory. Figure 8 compares daily mean temperatures for three cities (Tortosa, Madrid and Barcelona) with standardized claims over the period from June 21, 2022, to November 30, 2022. The temperature data is represented by coloured lines (blue for Tortosa, ref for Madrid, and green for Barcelona), while the claims data is shown as dashed grey line. The analysis involves standardizing the data to allow for an effective comparison, as both variables - temperature and claims- have different scales. Key observations are (1) temperature trends across the three cities exhibit similar seasonal patterns, with peaks in

summer (July- August) and a gradual decline towards winter (November), (2) Madrid generally shows higher temperature peaks compared to Tortosa and Barcelona, particularly during heatwave periods, (3) the standardized claims (grey dashed line) exhibit fluctuations that, in some instances, align with temperature peaks, suggesting a potential correlation between extreme temperatures and an increase in claims; (4) Notable, there are pronounced spikes in claims during certain periods, particularly around late September and early October, which could be linked to specific weather events or external factors beyond temperature variation alone.

Furthermore, the Pearson's product-moment correlation was conducted to assess the relationship between daily mean temperature and the number of claims. The results indicate a weak but statistically significant negative correlation ($r = -0.1613$, p value <0.05). The confidence interval (95% CI: -0.2707 to -0.0478) does not include zero, reinforcing the significance of the observed correlation. The t-statistic ($t = -2.7933$, $df = 292$) further supports the presence of a relationship between the variables, though the effect size is small. The statistically significant negative correlation points suggests that as daily mean temperature increases, the number of claims tends to decrease slightly. Anyway, given the weak correlation, these findings should be interpreted with caution.

Regarding the types of programs in which the negationist argument has been detected in the highest proportion, they fall into two categories: Mystery & Other Realities and Politics, Economics & Opinion (figure 6(a)). One of these programs, categorized under Mystery & Other Realities, corresponds to the highest peak of claims per day in August 2022 (figure 8). This program, broadcast in Spain, stood out with 32 claims in a single day. As mentioned in section 3.4, we identified episodes explicitly dedicated to denialist themes. The statements identified in this program are so prevalent that they account for 46% of the entire period (figure 6(a)). The radio host can be classified as a fake expert (Washington and Cook 2011). The most predominant narratives were 'Climate science is unreliable' (61.3%) and 'Climate change does not exist' (21.0%) (figure 5(a)). Additionally, some of the arguments used align with the findings of Washington and Cook (2011), such as: 'It's the sun' and 'There is no consensus.'

4.3.3. Other arguments

As observed, the arguments from the predominant narratives obtained align with efforts to discredit climate science and the scientific community but also reflect elements of climate denialism. The distribution of the remaining common narratives ('Climate change exists but is not anthropogenic' and 'Climate change is not bad'; 6.8% and 4.3%, respectively) closely resembles those observed on conservative think-tank websites reported by Coan *et al* (2021) but is lower than those found in contrarian blogs.

With regard to the 'Climate change exists but is not anthropogenic' narrative, the highest frequencies have been observed in programs categorized as Mystery & Other Realities and Politics, Economics & Opinion (figure 6(a)). Although the frequency of this narrative accounts for only 6.8% of all detected claims, previous studies indicate that the belief that climate change is not caused by anthropogenic activity is fairly widespread among the European population.

According to a survey of 11,600 adults across 11 European countries conducted using PUBLIC Voice (Vardaxoglou 2022), 32% believe that climate change is not anthropogenic. Mata *et al* (2024), utilizing data from the European Social Survey 10 collected in 2022 across 25 European countries, with a total of 18,060 interviews, found that 45% of Europeans perceive anthropogenic factors as having a significant impact, considering human activity to be either the sole or primary cause of climate change. Furthermore, this study concluded that the typical European citizen who attributes climate change to anthropogenic causes is more likely to be female, have higher levels of education, place greater trust in scientists, be younger, spend more time reading the news, and exhibit a heightened awareness of misinformation in online and mobile communications.

With respect to the types of programs where the narrative 'Climate change is not bad' has been detected most frequently, they also fall into two categories: Mystery & Other Realities and Politics, Economics & Opinion (figure 6(a)). Regarding the Greenwashing narrative, it has been detected exclusively in programs labelled as Politics, Economy & Opinion. (figure 6(a)).

4.4. COP27-period

During the COP27-period (November 6 to November 23, 2022), the percentage of claims detected regarding the 198 fragments of podcasts analysed was 49%, and focusing only on the exact days of the COP27 celebration, this percentage is higher (52%). Considering the listening time of the claims, approximately every 14 min a claim was found. Regarding the regular-period, during which the process of distinguishing between podcasts without and with misinformation (claims) was also developed with the Dashboard A (November 24 to 30, 2022), the percentage was 54% and, approximately every 16 min a claim was detected. Thus, the obtained percentages of the claims detected regarding the total of fragments analysed show similar range during both periods. November, during which the COP27 was held, is the second month with the highest number of claims (116),

being the first month September with 131 claims (figure 2). However, the number of claims detected per day during the COP27 period is indeed higher than that detected during the regular period (7.5 and 2.9 claims/day, respectively; figure 2). Therefore, an increase in climate change misinformation was indeed detected during the COP27 period. Trends to more climate disinformation have been observed at the beginning as well as at the end of the COP-27 period (figure 3). This observation is in agreement with those pointed out by CAAD (2023) on Facebook and Twitter.

The three most frequent narratives appear in both periods, though in different order and with varying percentages (figures 4 and 5(b)–(c)). 'Climate science is unreliable (conspiracy)' is the most common in both periods (42.3% during COP27; 53.6% in the regular period). 'Solutions do not work' ranks second during COP27 (30.9%) and third in the regular period (14.5%). 'Climate change does not exist' ranks third during COP27 (15.5%) but was second in the regular period (19.8%). The 15.5% prevalence of climate change denial during COP27 is concerning, particularly in light of CAAD (2022) data indicating that between 6% and 23% of the populations in Brazil, England, the USA, India, Australia, and Germany either reject or are uncertain about the existence of climate change. The distribution of the three most predominant narratives during COP27-period on Spanish-speaking podcasts is similar to those obtained by CAAD (2023) during the same event, analysed on Facebook, Twitter and Instagram, where also the five narratives suggested by Coan *et al* (2021) are analysed. The main differences with the podcasts are associated with the narratives 'Climate change is not anthropogenic' and 'Climate change is not bad,' which occupy the fourth and fifth positions in the CAAD study (2023) and the fifth and fourth positions in the podcasts (figure 5(c)).

Therefore, the COP27-period on podcasts saw heightened scepticism about the effectiveness of climate solutions, nearly doubling from the regular-period. However, conspiracy-driven scepticism about the reliability of climate science and outright denial of climate change's existence decreased during COP27, possibly due to the global spotlight on climate issues during the event. Anyway, the narratives related to arguments attacking the integrity of climate science and scientists '(Climate science is unreliable (conspiracy)' and 'Solutions do not work') remain dominant in both periods but are slightly more frequent during COP27-period (73.2 versus 68.1%).

The belief that climate change is not caused by human activity remains similar across both periods, though slightly less frequent during COP27 ('Climate change exists but is not anthropogenic' narrative; 6.9% and 6.2%, respectively). The 'Climate change is not bad' narrative appears at comparable levels in both periods. In contrast, the 'Greenwashing' narrative is more prevalent during COP27 (2.1% versus 0.6%, respectively). The analysis of program typologies and narrative taxonomy for the regular and COP27 periods reveals both differences and common patterns (figure 6(b), (c); table 3). During COP27, detected programs included Mystery & Other Realities, Humour & Entertainment, Magazine & Variety, and Politics, Economics & Opinion. In contrast, all categories except Magazine & Variety were present in the regular period. During the COP27-period la climate misinformation regarding scepticism about the effectiveness of climate solutions enhance remarkably on Magazine & Variety programmes. Politics, Economics & Opinion programs accounted for the highest percentage of misinformation claims during the COP27 period (72.2%) but ranked second during the regular period (39.7%). On this type of programmes during the COP27-period all the narratives enhance regarding the regular-period (figures 6(b)–(c)).

During the COP27 climate summit, the Intelligence Unit of the Climate Action Against Disinformation (CAAD 2022) coalition was tracking misinformation trends that pose a risk to national climate efforts and broader summit negotiations. Among their findings, it was pointed out that the proportion of public who believe that a significant number of scientists disagree on the cause of climate change ranged between 29% (Brazil) and 37% (Australia). The average of the five considered countries (also German, England and USA) was 33.4%. This statement, scientists disagree on the cause of climate change, can be related to our narrative 'Climate change is not anthropogenic', which was detected in 6.2% of the claims during the COP27-period, percentage very similar to that obtained during the regular-period (figures 5(b)–(c)). The frequency of this narrative increased during the COP27-period in programs labelled as Politics, Economy & Opinion compared to the regular period (figures 6(b)–(c)), although it was also detected in Mystery & Other Realities programs. It should be noted that, as reported by CAAD (2022), climate disinformation impacts public perception. For example, in Germany, 36% of the general public believes that scientists disagree on the causes of climate change. However, among consumers of a media outlet where disinformation has been detected, this percentage rises to 50%.

In the CAAD (2022) study, Brazil—the only South American country analysed—had the lowest percentage of the public believing that scientists disagree on the causes of climate change (29%). In our study, during the COP27-period, the number of programs containing misinformation from South America increased notably compared to the regular period (figures 6(b)–(c)). Additionally, during the COP27-period, the highest number of misinformation claims corresponded to a program broadcast in South America (Colombia). Thus, it is possible that the percentage of the public who consume podcasts frequently associated with climate disinformation in these countries exceeds the 29% detected by CAAD (2022) among the general public.

As it has been mentioned in the results, among all the claims detected during the COP27 period in the podcasts, only one explicitly mentioned COP27, linking it to hypocritical behaviour. Instead, many podcasts referred to the event indirectly, using alternative expressions. This contrasts with the climate disinformation found in the examples analysed by CAAD (2023) on Facebook, Twitter, and Instagram.

5. Conclusions

In today's digital age, the abundance of information sources is accompanied by a growing prevalence of climate change mis-/disinformation. While previous studies have explored climate mis- and disinformation on social media, they have primarily focused on written formats. To the best of the author's knowledge, this is the first study to analyse the content and narratives of climate mis-/disinformation in audio formats, specifically radio podcasts.

In order to combat climate mis-/disinformation, the present study monitored Spanish-speaking podcasts for eight months (from June 2022 to February 2023). The analysis of the content of the podcasts was conducted over more than five months (from June 21 to November 30, 2022) and a total of 629 fragments of podcasts were analysed, encompassing more than 241 h of listening time (>). The study period was coincident with the 27th Conference of the Parties to the United Nations Framework Convention on Climate Change (COP 27; November 6–18, 2022).

In methodological terms, the podcast selection phase has been identified as the most critical stage of the designed workflow process. The data highlight the importance of this phase and the relevance of: i) the previous preparation in order to improve the efficiency of the algorithms. ii) the periodically update of the detection tools in agreement with Meddeb *et al* (2022). This is partly due to the fact that the format of a podcast can vary significantly in complexity and presentation style. A potential avenue for future research could be the development of artificial intelligence capable of analysing not only the words themselves but also other aspects of speech, such as the commentator's tone.

The narratives defined in this project have been developed, on the one hand, largely based on the work of Cook (2016, 2019) and Coan *et al* (2021), and on the other, as our analysis of claims progressed. In addition, however, a sixth narrative was required('Greenwashing'). The majority of the messages detected in this study constitute disinformation rather than misinformation, although this distinction is not always obvious.

The most frequently observed climate misinformation narrative was 'Climate science is unreliable (conspiracy),' accounting for more than 50% of the claims identified. The next two most predominant narratives were 'Climate change does not exist' and 'Solutions do not work' (19.0% and 17.6%, respectively). The distribution of the remaining common narratives was: 'Climate change exists but is not anthropogenic', 6.8%; 'Climate change is not bad', 4.3% and 'Greenwashing', 1%. These data, which align with the general findings of Coan *et al* (2021), point out that the most frequent messages of climate mis-/disinformation in podcasts are associated with narratives challenging the science and questioning the reliability of climate science, with significant portions also denying either the existence or the human causes of climate change. One of the most frequent arguments associated with the Climate change denialism was 'Climate's changed in the past'.

The majority of the mis-/disinformation was detected in programs self-labelled as Politics, Economy & Opinion and Mystery & Other Realities. And Greenwashing narrative it has been detected exclusively in programs labelled as Politics, Economy & Opinion.

An increase in climate change misinformation was detected during the COP27-period. Trends to more climate disinformation have been observed at the beginning as well as at the end of the COP-27 period. This observation is in agreement with those pointed out by CAAD (2023) on Facebook and Twitter.

Regarding the distribution of the narratives detected during the COP27-period, the most frequently observed was the same as during the regular-period: 'Climate science is unreliable (conspiracy)'. However, the COP27-period on podcasts saw heightened scepticism about the effectiveness of climate solutions, nearly doubling from the regular-period and, conspiracy-driven scepticism about the reliability of climate science and outright denial of climate change's existence decreased during COP27, possibly due to the global spotlight on climate issues during the event. 'Greenwashing' narrative was higher during the COP27-period than during the regular-period.

Once the principal denialist narratives have been identified, education concerning the most closely related concepts—as well as the methods by which they are taught—can be strengthened, both within academic settings at all levels and in public engagement initiatives. Future research could explore the public's vulnerability to the various identified narratives, as well as examine how the prevalence of these narratives may change over time and the factors that might influence such variation. The dissemination of studies concerning the various evolutions of climatic regionalities may also contribute to reducing the vulnerability of the general public, given that climate

does not change uniformly across all regions despite the widespread trend of ongoing warming. (Neukom *et al* 2019).

Overall, the data indicate that climate change is the subject of complex mis-/disinformation narratives. Adequate climate literacy and policies against mis- and disinformation could help reduce the general public's vulnerability (Abellán-López 2021). Specifically, in the case of podcasts, auditory alerts could serve as an effective tool to address misinformation in this medium (Pathiyan Cherumanal *et al* 2024).

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Data availability statement

All data that support the findings of this study are included within the article (and any supplementary files).

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