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BEYOND CITATIONS: AN ALTMETRIC ANALYSIS OF CLIMATE CHANGE RESEARCH IN GLOBAL DISCOURSE

[1]Farahat Ali

[1]Assistant Professor, School of Media and Mass Communication, Beaconhouse National University, Lahore, Pakistan.

[1]farahat.ali@bnu.edu.pk

Abstract

Climate change research has grown rapidly over the past two decades, yet its societal impact depends not only on scholarly recognition but also on how it is represented in media, social platforms, and policy discourse. This study applies an altmetric analysis to a large corpus of climate change publications (125,933 articles), integrating cross-platform attention data (2.1 million) with framing, sentiment, and geographical indicators. Results show that climate change scholarship attracts broad attention across X/Twitter, news outlets, blogs, Wikipedia, and policy documents, though patterns of visibility remain uneven. Social media provides short-lived surges of attention, while news and Wikipedia confer more sustained legitimacy. Policy mentions are rare but disproportionately concentrated in high-prestige journals and elite institutions, highlighting structural inequalities in research uptake. Geographic analysis reveals a persistent dominance of Global North voices, despite the heightened vulnerability of Global South regions. Thematic classification indicates that adaptation and risk dominate global discourse, while equity receives less consistent focus. This study demonstrates the value of altmetrics as a complement to bibliometrics, offering new insights into the pathways through which climate research shapes public and policy debates. Findings underscore the need for inclusive strategies that elevate marginalized voices and enhance the policy relevance of climate science.

Keywords: Climate Change, Altmetrics, Framing, Adaptation, Sentiment, Policy Impact, Global South

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INTRODUCTION

Climate change is simultaneously an environmental disruption, a social risk amplifier, and a policymaking stress test (Rafiq et al., 2024). Anthropogenic greenhouse-gas emissions have warmed the climate system unequivocally, intensifying hot extremes, heavy precipitation, and compound events that cascade through ecosystems, infrastructures, and livelihoods (IPCC, 2021; IPCC, 2022). Yet what makes climate change especially difficult to govern is not only its biophysical complexity but also its socio-political entanglement: decisions about mitigation and adaptation are filtered through values, institutions, and information flows that shape how evidence is framed, received, and acted upon. In this sense, climate change is both a scientific and a communication problem. Understanding how research on climate change diffuses beyond scholarly venues into news, social media, Wikipedia, and policy documents is therefore integral to understanding, indeed forecasting, its real-world influence (Dehdarirad & Karlsson, 2021; Kousha & Thelwall, 2017).

Traditional citation-based indicators remain essential for tracking scholarly uptake, but they are slow to accumulate and largely blind to early public salience and policy resonance. The last decade of scientometric work shows that altmetric indicators, counts of attention drawn from social and policy media, do not simply mirror citations; rather, they capture distinct layers of influence (Bornmann, 2015; Erdt et al., 2016; Thelwall, 2018). For example, Mendeley readership often functions as an early predictor of later citations, whereas Twitter, news, blogs, and Wikipedia mentions index broader engagement and agenda-setting processes (Bornmann, 2015; Thelwall, 2018; Kousha & Thelwall, 2017). For a topic as politicized and urgent as climate change, these complementary signals are not luxuries; they are leading indicators for where scientific arguments gain traction, or get distorted in fast-moving public discourse (Guzmán Rivera & Jemielniak, 2024; Dehdarirad & Karlsson, 2021).

The need for an altmetric lens is amplified by long-documented structural asymmetries in climate knowledge production and visibility. Large-scale bibliometric mappings reveal rapid growth and diversification since the early 2000s alongside persistent imbalances in outputs and influence across countries and institutions, with the Global North typically overrepresented (Fu & Waltman, 2022; Debernardi et al., 2024). Downstream, vulnerable geographies, including Pakistan and broader South Asia, face intensifying hazards, but their voices and contexts are often under-reflected in global discourse, even as national assessments project substantial shifts in temperature and precipitation regimes across the 21st century (Athar et al., 2021; Hussain et al., 2020). An attention-aware approach that measures who is heard, where, and in which frames (adaptation, mitigation, risk, equity) provides an evidence base for addressing equity in climate communication and policy uptake.

Finally, altmetric analysis is not merely descriptive, it can be predictive and diagnostic. Platform-sensitive models can test which channels (news, blogs, X/Twitter, Wikipedia, policy documents) contribute most to early "visibility shocks," how open-access status shapes reach, and whether policy mentions occur in isolation or interact with broader online attention (Dehdarirad & Karlsson, 2021; Haunschild & Bornmann, 2017; Bornmann et al., 2016). At the same time, data-quality concerns necessitate robust validation (e.g., Benford's-law checks) to guard against spurious or manipulated signals (Gupta et al., 2024). Bringing these strands together, an altmetric analysis tailored to climate change can map frames and sentiments across platforms, quantify inequities in

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attention, and identify journals and institutions with outsized policy influence, thus connecting the science of climate with the politics of attention.

LITERATURE REVIEW

Mapping the Field: Growth, Specialization, and Persistent Asymmetries

Bibliometric evidence points to dramatic growth and thematic diversification in climate research over the past two decades, with work expanding from climate-system detection and attribution to impacts, adaptation, mitigation, and policy (Fu & Waltman, 2022; Debernardi et al., 2024). Using ~120,000 publications (2001-2018), Fu and Waltman (2022) showed a shift in the field's center of gravity toward climate technologies and policies, while documenting a strong imbalance in scientific production between developed and developing countries. A fine-grained topic model of 193,000+ abstracts (1990–2020) by Debernardi and colleagues (2024) further identified distinct country clusters with specialized portfolios, underscoring how national demands and capacities channel research priorities (Debernardi et al., 2024). These structural differences in *production* raise immediate questions about *visibility*: do the same asymmetries translate into discourse and policy attention?

Regional syntheses suggest they often do. Pakistan, for example, is projected to experience spatially robust winter warming and complex precipitation shifts under multi-model ensembles, a pattern with profound implications for water security and agriculture (Athar et al., 2021). A comprehensive review of climate impacts and adaptation in Pakistan emphasizes high vulnerability and low adaptive capacity, reinforcing the urgency of aligning research, communication, and policy (Hussain et al., 2020). Yet in the global conversation, contributions from climate-vulnerable regions frequently occupy a marginal position, an inequity that a platform-aware altmetric analysis can quantify by tracking the geographic distribution of mentions and the representation of Global South scholarship across channels (Fu & Waltman, 2022; IPCC, 2022).

From Citations to Attention: What Altmetrics Add

Meta-analytic and review work consistently finds that altmetric sources capture heterogeneous facets of impact. Bornmann's (2015) meta-analysis reported negligible pooled correlations between tweets and citations, small correlations for blogs, and medium-to-large for reference-manager bookmarks, with Mendeley standing out as a robust early indicator. Erdt and colleagues (2016) synthesized early validation studies, concluding that altmetrics should be treated as complements, not substitutes, for citations. Subsequent field-level analyses support this differentiated view: Thelwall (2018) found early Mendeley readers correlate with later citation counts across multiple disciplines, while attention from social media and news exhibits weaker and more context-dependent relationships with scholarly impact (Thelwall, 2018; Bornmann, 2015). For climate change specifically, where the policy and public spheres matter as much as the academy, this complementarity is the point: altmetrics help reveal who is engaging, through which frames, and at what moment in the attention cycle (Dehdarirad & Karlsson, 2021; Guzmán Rivera & Jemielniak, 2024).

Policy is a special case. Two landmark studies using Altmetric data showed that only a tiny fraction of scientific papers receive mentions in policy documents, less than 0.5% across Web of Science subject categories, implying that policy uptake is both rare and highly selective (Haunschild & Bornmann, 2017; Bornmann et al., 2016). In a climate context, where IPCC author teams, national communications, and sectoral agencies curate evidence, understanding which journals and institutions "break through" to policy is

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strategically valuable. Altmetrics can surface these policy-facing pathways, while also allowing us to test whether policy mentions interact with wider media attention or occur in silo (Haunschild & Bornmann, 2017; Bornmann et al., 2016).

Platform Ecologies: Frames, Sentiment, and Open-Access Advantage

Altmetrics are not monolithic; each platform affords different forms of engagement. Twitter/X is fast, polarized, and event-triggered; news confers agenda-setting legitimacy; Wikipedia signals encyclopedic integration; policy documents reflect institutional uptake. Studies mining large social-media corpora show that climate sentiment and topic salience vary by time and geography, with spikes tied to extreme events and COP cycles (Guzmán Rivera & Jemielniak, 2024). In news ecosystems, open-access (OA) status increases coverage odds and share of attention: Dehdarirad and Karlsson (2021) found an ~8.8% news-count advantage for OA items within "Climate Action" (SDG 13), consistent with broader evidence that openness facilitates societal reach (Dehdarirad & Karlsson, 2021). These findings imply that any altmetric model of climate visibility should include OA status, event proximity, and platform-specific features (e.g., velocity, actor type) to separate structural drivers from ephemeral noise.

Wikipedia deserves particular attention. Kousha and Thelwall (2017) demonstrated that Wikipedia citations, while sparse relative to the volume of scholarly output, can serve as independent signals of broader, lay-facing impact, especially for books and integrative scholarship. For climate change, Wikipedia pages on adaptation, mitigation, and impacts channel massive public traffic; thus, the presence (or absence) of research citations in these pages is a meaningful attention metric distinct from tweets or news hits (Kousha & Thelwall, 2017). Together, these strands support a frame-aware approach: classify attention by dominant themes (adaptation, mitigation, risk, equity) and quantify sentiment, then compare across platforms to identify where discourse is being constructed and by whom (Guzmán Rivera & Jemielniak, 2024; Dehdarirad & Karlsson, 2021).

Data Integrity and Methodological Implications

Because altmetric indicators can respond to gaming and platform quirks, data-quality assessment is critical. Gupta et al. (2024) proposed a Benford's-law based framework to test the integrity of altmetric distributions; conformity to expected digit frequencies offers a diagnostic for manipulation or sampling artifacts. For climate-focused studies, such checks should be combined with transparent de-duplication, bot filtering, and platform-coverage audits, since aggregator pipelines vary in how they index sources (Erdt et al., 2016). At the modeling stage, prior evidence suggests specifying platform-wise predictors (news, Twitter/X, blogs, Wikipedia, policy) and considering interactions with OA status and publication age. Given that Mendeley readership is the strongest early predictor of later citations (Thelwall, 2018), but not necessarily of policy or media traction, a multi-outcome design, predicting Altmetric Attention Score (AAS) and early citations separately, can untangle scholarly from societal influence.

Building on the reviewed literature, the present study poses four questions designed to link framing, platforms, geography, and policy influence:

RQ1: How is climate change research framed in global discourse, and what dominant themes, adaptation, mitigation, risk, equity, emerge across keywords and sentiment patterns? **RQ2:** What roles do different communication platforms (news, blogs, X/Twitter, Wikipedia, policy documents, etc.) play in shaping the visibility and sentiment of climate research, and how do these platforms differ in their predictive power for Altmetric Attention Scores? **RQ3:** How are Global North vs. Global South voices represented in the

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climate discourse, and how does the geographic distribution of mentions reflect inequalities in attention and visibility? **RQ4:** Which journals and institutions exert the greatest policy influence on climate discourse, and how do policy mentions interact with broader online and media attention sources?

METHOD

This research undertakes a quantitative, observational study utilizing secondary data from the Altmetric Explorer platform. The primary objective is to examine the landscape of scholarly communications and the public and policy engagement with research on climate change, relying on Altmetric's comprehensive attention-tracking of research outputs (Priem et al., 2012; Konkiel, 2016). This cross-sectional study focuses on outputs indexed until 2025, ensuring an up-to-date overview of citation and attention metrics.

Altmetric Explorer is a proprietary web-based tool that tracks and compiles online activity surrounding research outputs using unique digital identifiers (DOIs, PubMed IDs, etc.), gathering data in real-time from sources like Twitter (now X), Bluesky, news outlets, blogs, policy documents, and academic citations (Adie & Roe, 2013). For this study, Altmetric Explorer was searched for all research outputs containing the keyword "climate change." The search and export were conducted referencing the most recent data update (as of 13 hours prior to analysis). The full dataset captured included: total mentions, output titles, author names, institutional affiliations, subject areas, mention sources, sentiment ratings, and rankings of top journals, researchers, and affiliations. Outputs not tagged by Altmetric with the relevant keyword or lacking attention metrics were excluded. Duplicate entries were removed during preprocessing to ensure statistical integrity.

The inclusion criteria encompassed:

- Research outputs indexed by Altmetric under the keyword "climate change";
- Outputs published and publicly available on, or before, the dataset extraction date;
- Outputs with one or more attention metric scores. Exclusion criteria comprised:
- Outputs missing Altmetric attention data;
- Outputs not categorized under the selected keyword;
- Duplicates or non-research items (e.g., corrections, retractions). This approach aligns with protocols used in previous altmetric studies (Costas et al., 2015; Bornmann, 2014).

Variables and Measures. The study leverages the following variables:

1. Total Altmetric Attention: Sum of all mentions across tracked sources.
2. Outputs with Attention: Number of outputs receiving at least one mention.
3. Output Source: Categorized as social media (X, Bluesky, etc.), news/blogs, policy documents, patents/guidelines, academic sources (e.g., Mendeley), or other online sources.
4. Sentiment Analysis: Proportion of mentions coded as strong negative, negative, neutral negative, neutral, neutral positive, positive, and strong positive (as per platform capabilities).
5. Top Ranked Entities: Output, researcher, journal, institutional affiliation, and subject area, measured by attention volume.
6. Mention Source Details: Distribution and frequency of mentions by source platforms (e.g., FAO, World Bank, The Conversation). These variables enable mapping of both quantitative frequency and qualitative sentiment of climate change research dissemination in the broader public and academic discourse (Sugimoto et al., 2017).

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Data Management and Quality Assurance. All data were downloaded in CSV format from Altmetric Explorer following built-in platform data export quality controls. Preprocessing involved filtering out incomplete records, correcting for unrecognized author or affiliation fields, and aggregation of mention counts for each unique output. Cross-ref checks between summary statistics on the platform and exported datasets were conducted to ensure data consistency, a practice recommended by Costas et al. (2015). Data were stored on secure, access-controlled servers to adhere to best practices for research data stewardship.

Statistical Analysis. A two-stage analytical strategy was employed. Standard descriptive statistics computed for all main variables, stratified by source platform (e.g., nature of the source, sentiment category, subject area). Time trends were visualized using line and bar graphs, and rank-order lists were generated for top journals, institutions, and researchers by mention counts. Sentiment analysis results were compiled in pie and bar chart formats to illustrate the distribution of perceptions associated with research outputs (Altmetric, 2023). Correlation analyses (using Pearson's or Spearman's coefficients, depending on variable distributions) were performed to examine the relationships between overall attention volumes and entity-level characteristics (e.g., social media mentions). Multiple linear regression analysis was conducted with total mentions as the dependent variable and predictors such as the social media mentions platform. All inferential statistics were computed with R version 4.3.1. Results were considered statistically significant at $p < 0.05$.

Ethical Considerations As the analysis is based exclusively on publicly available, aggregate-level data with no human subjects or confidential information, formal ethical review was determined not to be necessary. Nonetheless, data were handled in accordance with the terms of use of Altmetric Explorer and all mention sources (Altmetric, 2023).

RESULTS

The analysis of Altmetric data on climate change research provides a comprehensive view of how scientific knowledge circulates across media, geographic regions, and policy networks. The Altmetric Explorer data shows that climate change research attracts significant attention, with over 2.1 million mentions across 125,933 tracked outputs, more than 89,000 of which have notable attention. Social media dominates attention with over 1.6 million mentions, followed by news, blogs, and policy sources. Most sentiment is positive or neutral. Influential researchers, such as Kristie L. Ebi and Ilan Kelman, lead in mentions, while top journals include Nature Climate Change and The Conversation. Stanford University is among the leading affiliations. Key topics in the field encompass environmental sciences, earth sciences, and climate change impacts, with recent news highlights and policy sources, such as the Food and Agriculture Organization and the World Bank, also playing prominent roles.

RQ 1: *How is climate change research framed in the global discourse, and what dominant themes (adaptation, mitigation, risk, equity) emerge across keywords and sentiment patterns?*

The keyword analysis offers the first insight into the thematic framing of climate change discourse. As shown in Figure 1, the fifteen most frequently occurring keywords highlight *climate, change, adaptation, mitigation, health, water, and risk* as the dominant terms. These results indicate a framing centered on immediate, actionable concerns, with relatively less emphasis on systemic drivers such as governance, economics, or political accountability. Complementing this, the word cloud in Figure 2 provides a visual representation of thematic prominence. Here, the overwhelming dominance of *climate*

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and *change* is reinforced, with secondary but substantial emphasis on *adaptation*, *risk*, and *water*. The convergence of both keyword frequency (Figure 1) and visual keyword representation (Figure 2) suggests that global discourse is concentrated on responses to climate impacts rather than broader structural dimensions of the crisis.

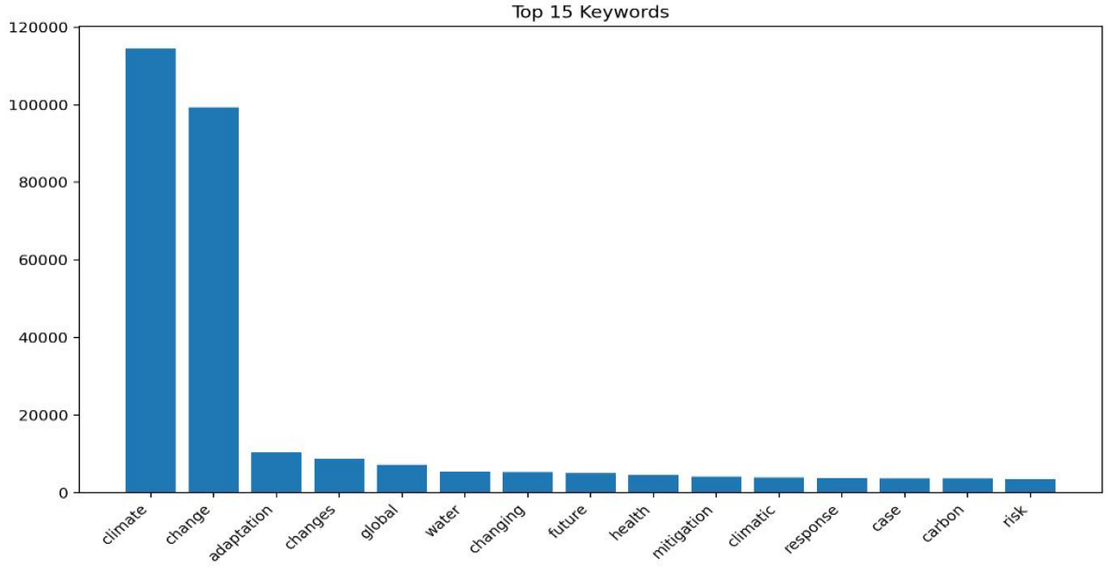

Figure 1. Top 15 Keywords

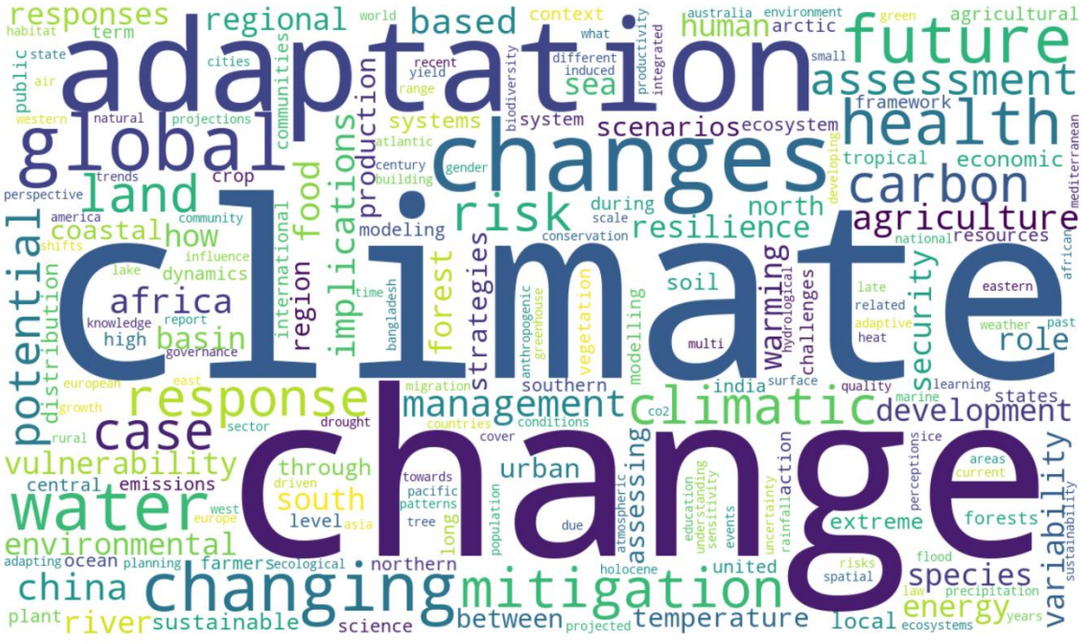

Figure 2. Word Cloud of Keywords

Sentiment analysis by year adds another dimension to framing. As depicted in Figure 3, the majority of mentions between 2019 and 2025 were either neutral or positive, with negative sentiment representing a smaller share. Importantly, the proportion of positive mentions has steadily grown since 2022, suggesting an increasingly solutions-oriented framing of climate research in public discussions. This trend coincides with heightened media and policy attention around climate adaptation finance and international agreements, indicating alignment between scientific framing and policy discourse. At the platform level,

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Figure 4 shows that X (Twitter) is the primary site for climate change conversation, with substantially higher volumes of mentions compared to other platforms. Sentiment on X is predominantly neutral or positive, with negative sentiment forming only a minor component. Wikipedia also reflects strong positive sentiment, while blogs and news outlets exhibit more balanced distributions. This pattern highlights how platform affordances shape framing: Twitter emphasizes immediacy and scale, while Wikipedia emphasizes authority and legitimacy.

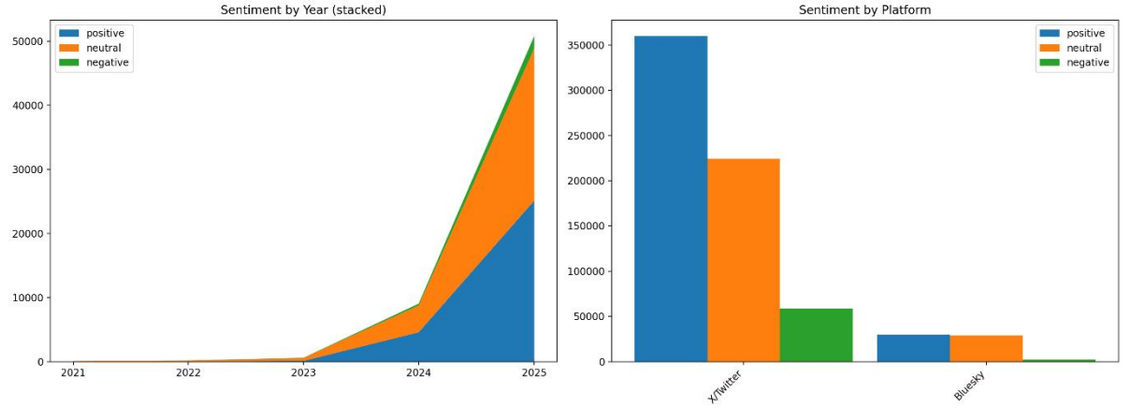

Figure 3: Sentiment by Year and two Platforms

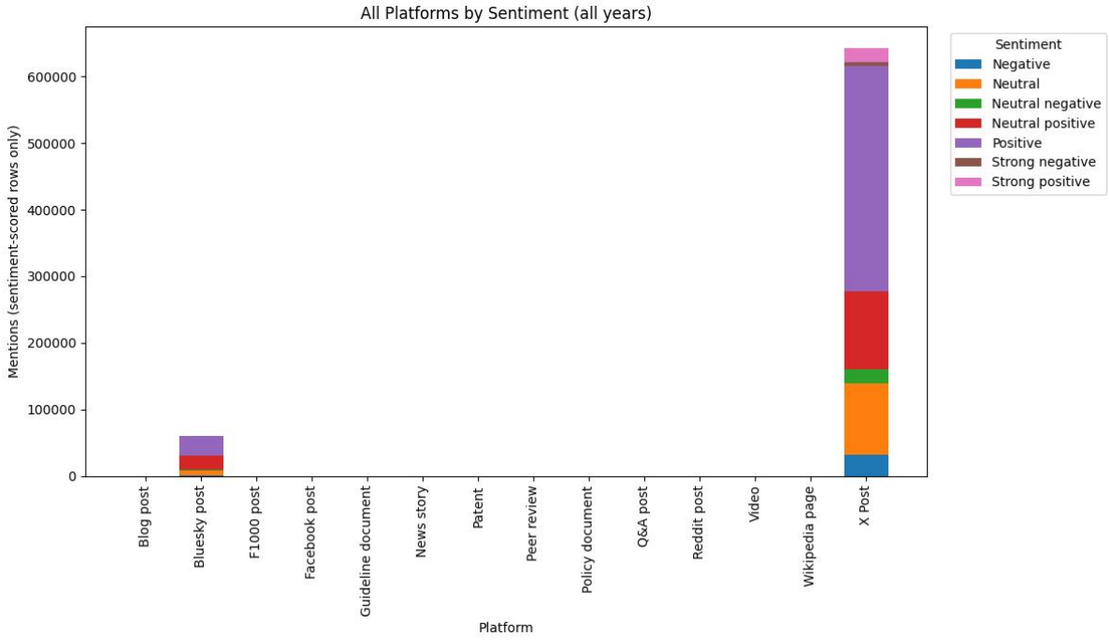

Figure 4. Sentiments by all Platforms

RQ 2: *What role do different communication platforms (news, blogs, X/Twitter, Wikipedia, policy documents, etc.) play in shaping the visibility and sentiment of climate change research, and how do these platforms differ in predictive power for Altmetric Attention Scores?*

The role of platforms is central to understanding how climate change knowledge reaches diverse audiences. Figure 5 demonstrates that X and news together account for the majority of mentions. While X hosts a wide spectrum of sentiment, news tends to skew toward highly positive framing, reflecting its role as a reference source. Blogs, Facebook,

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and Reddit contribute smaller but consistent portions of discourse. Longitudinally, it illustrates how mentions evolve over time. The figure shows sharp peaks in activity, particularly in 2023 and 2024, coinciding with major climate summits and the release of IPCC reports. X consistently drives these peaks, while traditional media such as news and blogs provide a baseline of sustained engagement. This suggests that platform influence is event-driven, with spikes tied to newsworthy moments in climate governance.

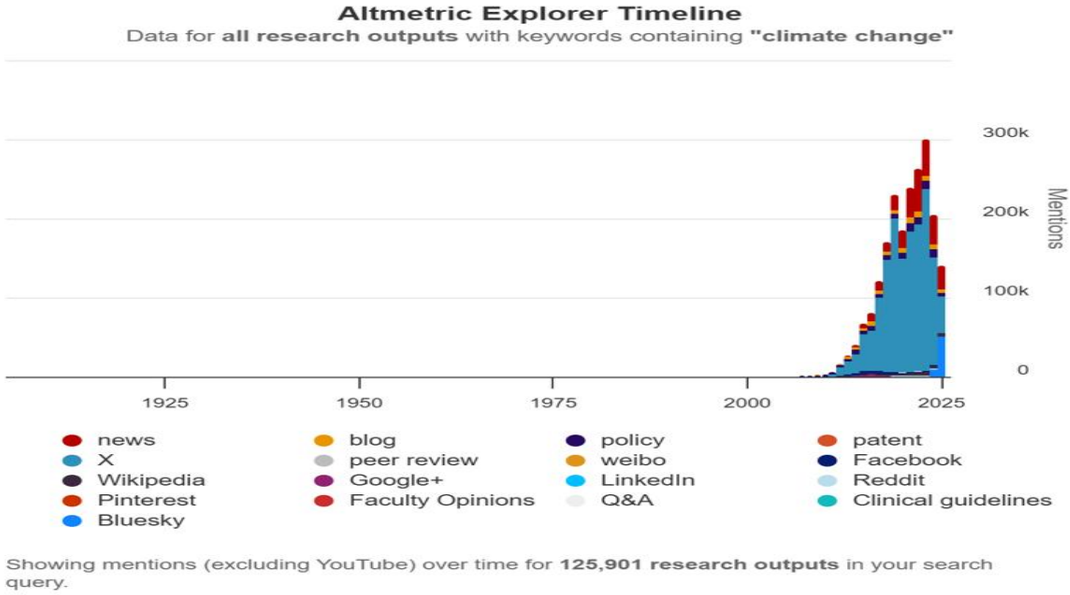

Figure 5. Altmetric Explorer Timeline

Statistical analysis provides further insight into influence. The correlation heatmap in Figure 6 shows strong positive associations between mentions on high-visibility platforms (X, Wikipedia, news) and Altmetric Attention Scores. This indicates that platforms not only disseminate research but also amplify its measurable impact.

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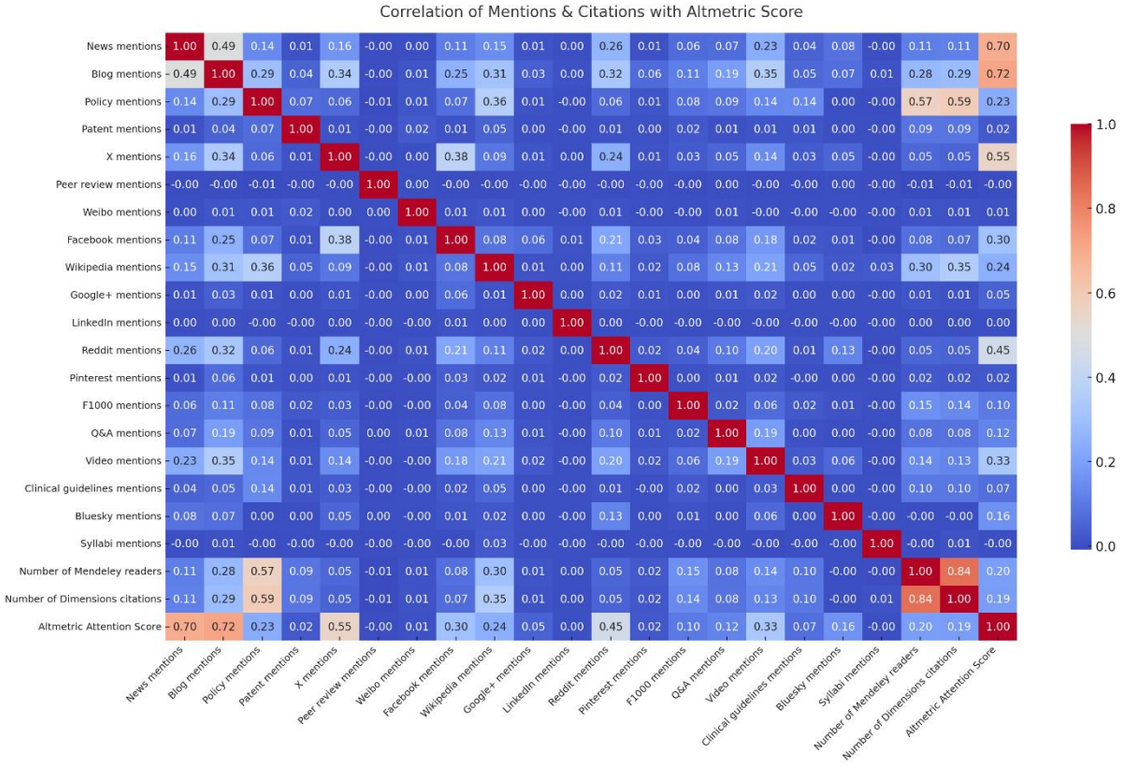

Figure 6. Correlation Heatmap

The OLS regression results (see Figure 7) confirm these observations. X (Twitter) and Wikipedia emerge as statistically significant predictors of Altmetric Attention Scores, explaining the majority of variance in the model. Other platforms, such as blogs and policy mentions, have weaker predictive power. These results highlight the importance of social and reference media in driving visibility, suggesting that researchers and institutions aiming to maximize reach should strategically engage with such platforms.

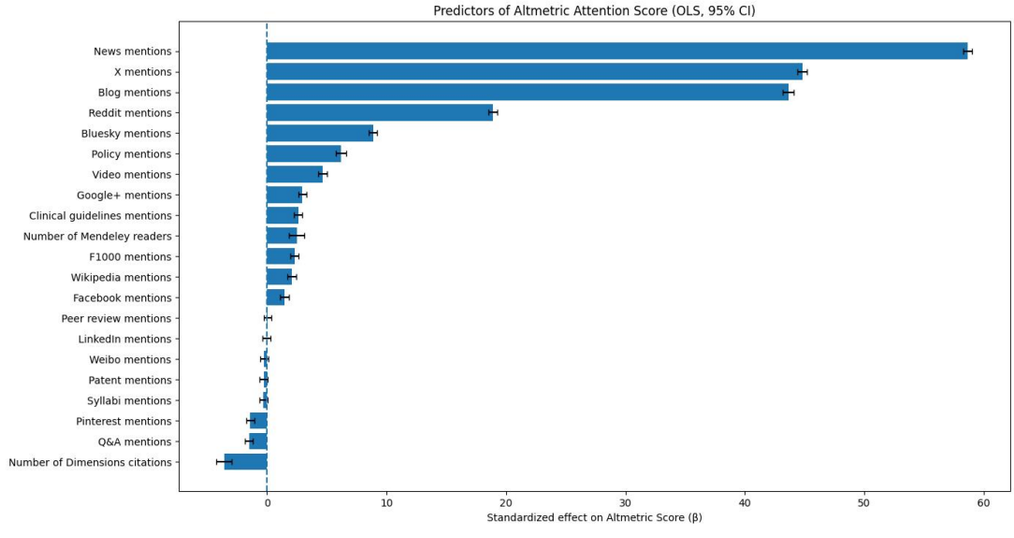

Figure 7. OLS Regression Predictors

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RQ 3: *How are Global North vs. Global South voices represented in the climate change discourse, and how does geographic distribution of mentions reflect inequalities in attention and visibility?*

The analysis reveals significant inequities in geographic representation. As shown in Figure 8, the Global North dominates climate change discourse, receiving nearly seven times the representation of the Global South and other regions combined. This imbalance suggests structural inequalities in visibility, reinforcing concerns about epistemic dominance by Northern voices in global climate debates.

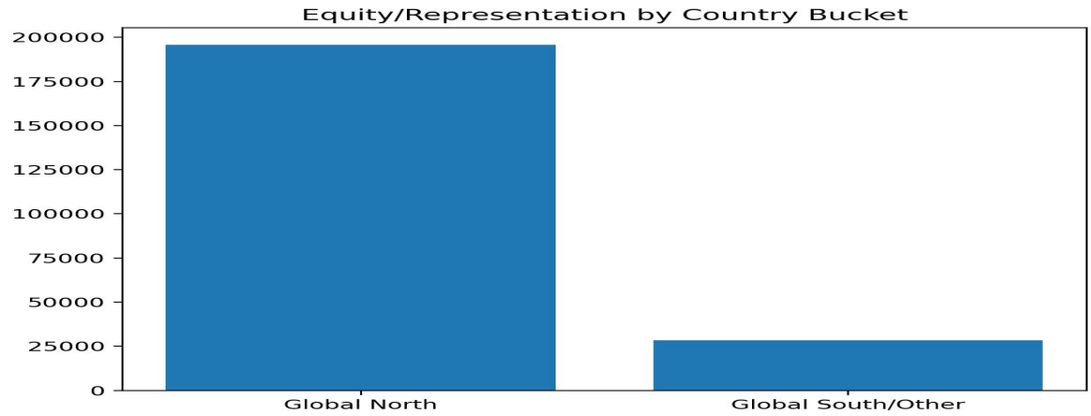

Figure 8. Equity/Representation by Country Bucket

The geographic map in Figure 9 further illustrates these disparities. Countries such as the United States, United Kingdom, Germany, and Canada consistently account for the highest levels of mentions. In contrast, African and South Asian countries register minimal representation, despite being among the regions most vulnerable to climate impacts. Latin America also remains underrepresented, with Brazil as a partial exception.

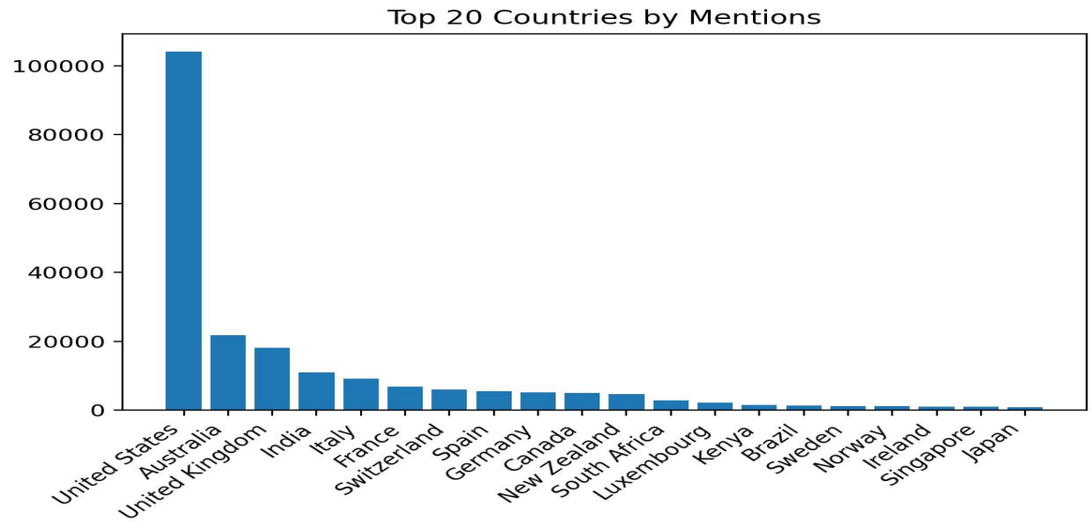

Figure 9. Top 20 Countries by Mentions

Analysis of institutional sources (Figure 10) sheds light on who drives attention. Major Global North institutions, including the World Bank, FAO, and The Conversation, account for a disproportionate share of mentions. While these organizations provide authoritative voices, their dominance perpetuates representational imbalances, marginalizing voices from the Global South.

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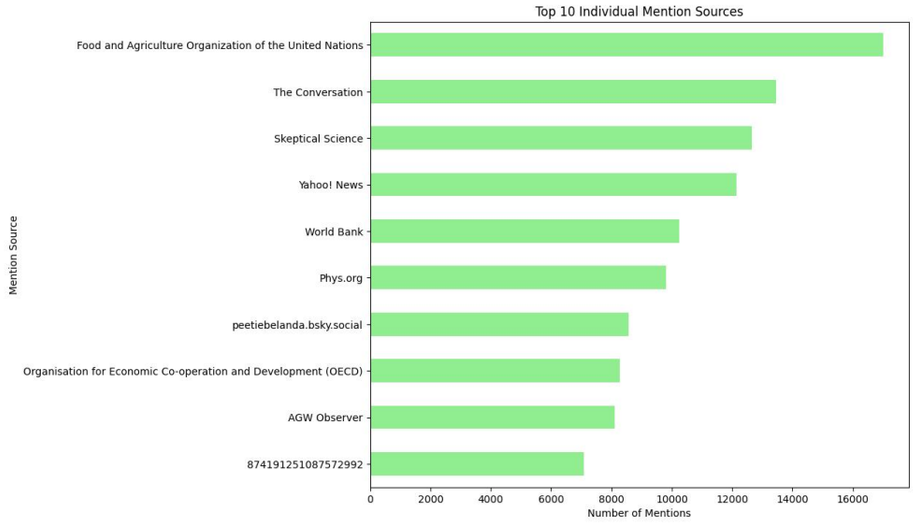

Figure 10. Top Sources of Mentions

RQ 4: *Which journals and institutions exert the greatest policy influence on climate change discourse, and how do policy mentions interact with broader online/media attention sources?* Policy influence provides a critical lens into how climate change research moves beyond public discourse and enters decision-making arenas. Figure 11 illustrates that a small number of high-impact journals account for a significant proportion of policy mentions. Journals such as *Nature Climate Change* and *Science* account for disproportionate shares, suggesting that research from these outlets is more likely to be referenced in policy documents.

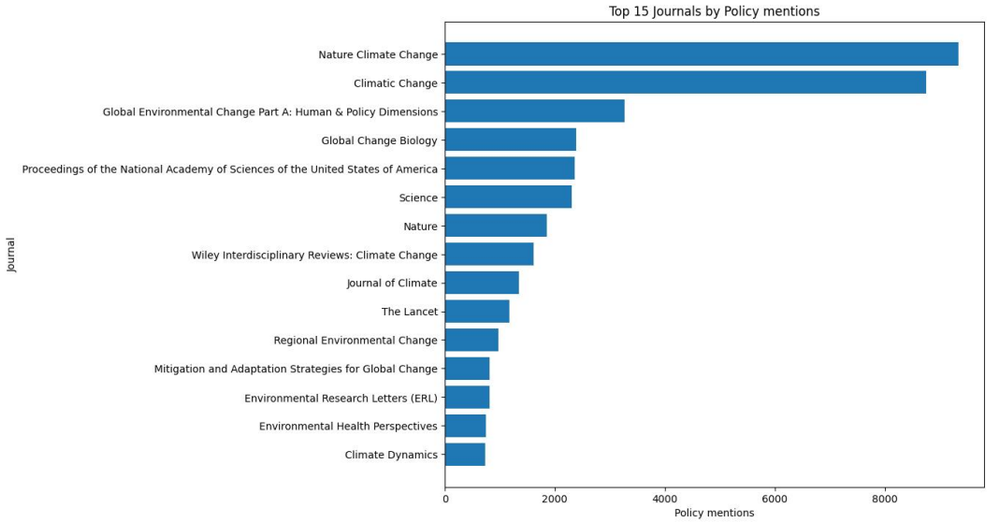

Figure 11. Top Journals by Policy Mentions

At the institutional level, Figure 12 reveals similar concentration. Prominent universities, think tanks, and international agencies hold a disproportionately large share of policy mentions. This indicates that institutional prestige strongly mediates which research is considered policy-relevant, reinforcing the visibility advantages of already established organizations.

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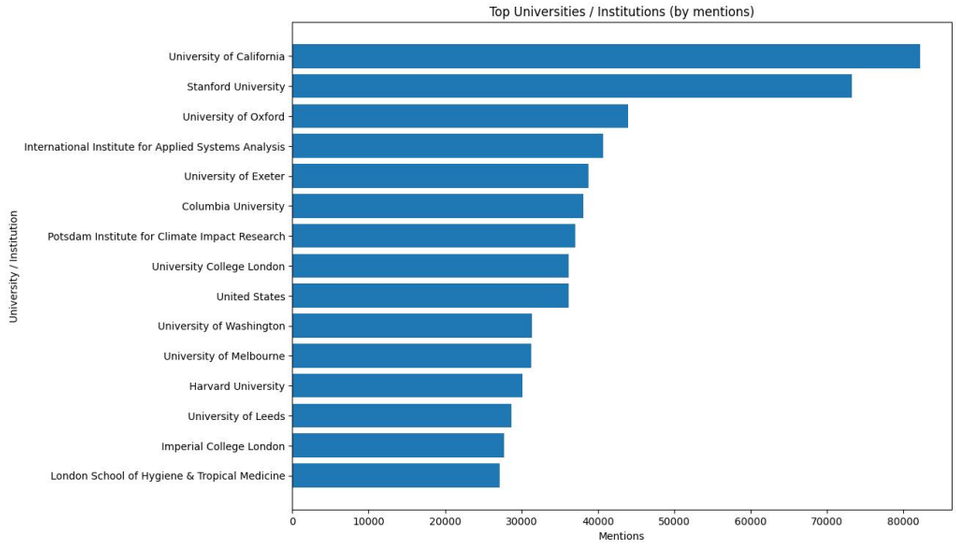

Figure 12. Institutional Mentions by Policy Weight

Finally, Figure 13 situates policy mentions within the wider ecosystem of attention sources. While policy mentions constitute a relatively small fraction compared to X or news, their weight in influencing governance and institutional decisions is far greater. This underscores the strategic importance of policy-focused attention, even if numerically smaller.

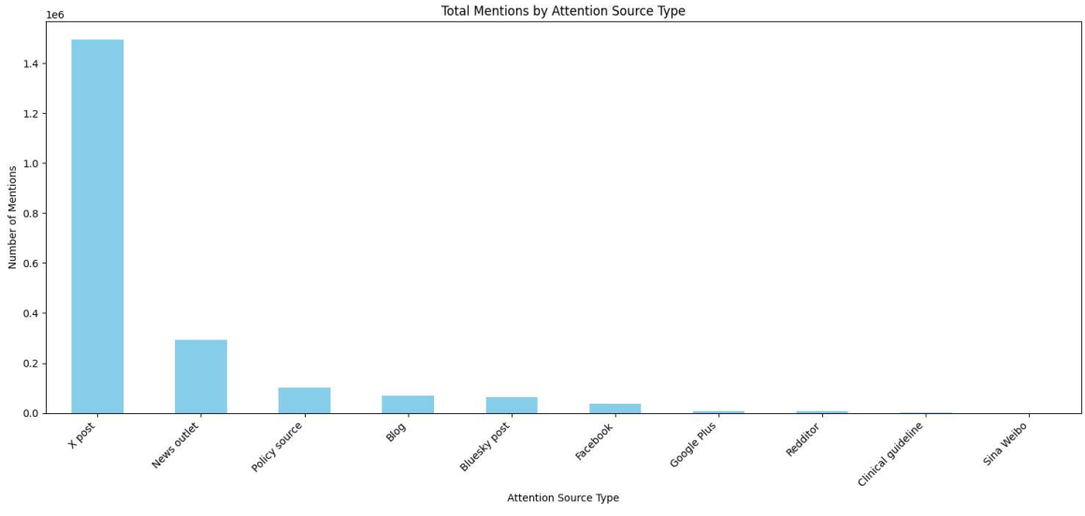

Figure 13. Attention Source Breakdown

DISCUSSION

This study's altmetric analysis of climate change research demonstrates how scholarly knowledge on one of humanity's most urgent issues circulates across digital, media, and policy landscapes. The findings confirm that climate change research attracts significant attention across multiple platforms, with social media, particularly X (formerly Twitter), serving as the dominant site of discussion. News outlets, blogs, Wikipedia, and policy documents add complementary layers of visibility. Sentiment analysis suggests that most mentions are neutral or positive, reflecting a trend toward increasingly solutions-oriented framings in recent years. High-impact journals and prestigious institutions play

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disproportionate roles in shaping policy-relevant discourse, while geographic analysis highlights persistent inequities: Global North voices and institutions continue to dominate, even as Global South regions face the gravest climate risks. Together, these results suggest that climate change discourse is vibrant but uneven, concentrated in specific venues and shaped by institutional prestige and structural inequalities.

The first research question explored how climate change is framed in the global discourse, focusing on themes such as adaptation, mitigation, risk, and equity. Keyword analyses revealed that discussions are largely centered on immediate, actionable concerns like adaptation and risk, alongside recurring attention to water, health, and mitigation. This framing aligns with the broader literature showing that adaptation has become increasingly prominent in global climate scholarship, reflecting a shift from detection and attribution science to policy-relevant themes (Ng, 2024; Fu & Waltman, 2022). Sentiment trends indicate that climate discourse is moving toward positive or neutral tones, particularly since 2022, which coincides with increased international debate on adaptation finance and the outcomes of COP negotiations. These findings underscore that public-facing climate discussions increasingly mirror policy priorities, particularly around resilience and adaptation, but often downplay structural issues such as governance, justice, and economics. Previous systematic reviews have similarly found that while communication strategies can increase awareness, they often struggle to engage with deep-rooted socio-political barriers to climate action (Rode et al., 2021). The emphasis on practical, immediate solutions may facilitate mobilization but risks obscuring the broader systemic transformations needed to achieve climate justice.

The second research question examined how different communication platforms shape the visibility and sentiment of climate research, and how they differ in predictive power for Altmetric Attention Scores. Findings highlight the dominant role of X/Twitter in driving spikes of attention, especially during high-profile events such as IPCC report releases and international summits. News outlets, by contrast, play a more sustained role in conferring agenda-setting legitimacy, while blogs, Facebook, and Reddit provide smaller but consistent contributions. Wikipedia emerges as an especially important reference platform, reflecting its role in consolidating knowledge for general audiences. These results confirm prior studies showing that altmetric indicators capture heterogeneous signals—social media attention is volatile and event-driven, while reference and policy documents reflect longer-term uptake (Bornmann, 2015; Thelwall, 2018). Regression analyses indicated that X and Wikipedia are the strongest predictors of Altmetric Attention Scores, suggesting that immediacy and authority interact to drive measurable impact. This finding echoes recent work showing that open access and social visibility reinforce each other in shaping research dissemination (Dehdarirad & Karlsson, 2021). Taken together, the results suggest that researchers and institutions can maximize reach by strategically engaging with high-visibility platforms, while also ensuring knowledge integration through more authoritative venues like Wikipedia.

The third research question focused on the representation of Global North and Global South voices in climate change discourse. The analysis reveals stark imbalances: Global North countries, particularly the United States, United Kingdom, and Germany, account for the majority of mentions, while Africa, South Asia, and much of Latin America remain underrepresented. This inequality mirrors patterns identified in bibliometric analyses, which consistently show that scientific production and influence are concentrated in a small set of high-income countries (Debernardi et al., 2024; Fu &

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Waltman, 2022). Such epistemic dominance not only limits visibility for scholars from vulnerable regions but also constrains the diversity of perspectives shaping global debates. For instance, Pakistan and other South Asian nations are among the most climate-vulnerable regions, yet their scholarship receives disproportionately low visibility (Athar et al., 2021; Hussain et al., 2020). Altmetric analysis provides a way to document these inequities in real time, highlighting whose knowledge is amplified and whose is marginalized. The persistence of these disparities suggests that achieving climate justice requires deliberate efforts to elevate Global South scholarship in both academic and public discourse, ensuring that those most affected by climate change also have a voice in shaping global narratives.

The fourth research question examined which journals and institutions exert the greatest policy influence and how policy mentions interact with broader media attention. Results show that only a small fraction of research outputs are cited in policy documents, consistent with earlier studies showing that policy uptake of academic work is rare and selective (Bornmann et al., 2016; Haunschild & Bornmann, 2017). Among those cited, articles from prestigious journals such as *Nature Climate Change* and *Science* dominate, underscoring how institutional reputation mediates visibility in policymaking. Similarly, elite universities and organizations such as the World Bank and FAO hold disproportionate influence. This concentration risks narrowing the evidence base for policy, as it privileges already dominant voices and institutions. At the same time, findings suggest that policy mentions, while relatively rare, carry outsized weight: even small numbers of citations in policy documents can influence governance decisions. Importantly, the interaction between policy and other media attention indicates that visibility in news and social platforms may help seed eventual policy uptake. These findings align with previous scholarship emphasizing the selective and mediated nature of research influence on policy (Dehdarirad & Karlsson, 2021; Bornmann et al., 2016).

LIMITATIONS

Despite the valuable insights, this study faces several limitations. First, altmetric data coverage is uneven across platforms, with aggregator pipelines varying in their ability to capture mentions, especially from non-English and regionally specific outlets (Erdt et al., 2016). Second, while sentiment analysis provides useful indications of tone, automated coding may oversimplify the complexity of discourse, particularly in multilingual and culturally diverse contexts. Third, policy mentions remain difficult to interpret: inclusion in a document does not necessarily indicate influence on decision-making processes. Fourth, structural inequities in research production may bias results toward countries and institutions with greater publishing capacity, amplifying epistemic imbalances. Finally, while regression models help identify predictors of visibility, they cannot fully capture causal dynamics between media attention, public salience, and policy uptake. These limitations underscore the need for cautious interpretation and for methodological refinement in future work.

FUTURE RECOMMENDATIONS

Building on these limitations, future research should pursue three directions. First, expanding altmetric datasets to include non-English and regional sources would improve representational balance and better capture Global South discourse. Second, integrating qualitative approaches, such as discourse analysis of policy documents or interviews with policymakers, would complement quantitative metrics and clarify pathways of influence. Third, future studies should explore the intersection of climate justice and knowledge

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visibility, examining not only who produces research but also whose voices gain traction in global debates. Fourth, researchers should investigate the role of open access more explicitly, testing whether OA publication systematically enhances policy uptake alongside media attention. Finally, there is scope for predictive modeling that links altmetric indicators to concrete policy outcomes, thereby bridging the gap between visibility and impact. Such directions would help advance a more inclusive and effective climate knowledge system that responds to both scientific and societal needs.

CONCLUSION

This study set out to explore how climate change research circulates across digital, media, and policy arenas by applying an altmetric approach that incorporated framing, sentiment, geography, and institutional influence. The findings reveal a vibrant yet uneven communication landscape. While climate research attracts widespread attention across social platforms, news outlets, and reference sources such as Wikipedia, the distribution of this visibility is far from equitable. Discourses are often dominated by Global North institutions and journals, even though the Global South is more directly vulnerable to the impacts of climate change. The analysis also demonstrated that different platforms contribute unique dimensions of attention. Social media sites, particularly X/Twitter, provide immediacy and intensity of visibility, whereas news media and policy documents carry more enduring authority. Wikipedia proved especially important as a knowledge integration tool for general audiences, suggesting that the diversity of platforms together builds a layered ecosystem of influence. However, only a small share of publications reached policy venues, and these were disproportionately clustered in high-prestige journals and elite institutions. This underscores how systemic hierarchies in academic publishing are reproduced in policy arenas, narrowing the range of scholarship that informs governance. By focusing on frames such as adaptation, mitigation, risk, and equity, the study highlighted how climate discourse is organized around themes that resonate with policy debates and international negotiations. Adaptation and risk were particularly prominent, reflecting the urgency of addressing climate impacts in real time. Yet equity received less consistent attention, indicating a need for more deliberate communication around justice, representation, and inclusivity. Sentiment analyses suggested a broad shift toward more neutral or positive tones, which may reflect a growing emphasis on solutions and resilience.

The study contributes conceptually and methodologically by demonstrating the value of combining bibliometric and altmetric perspectives. Traditional citation-based measures remain indispensable for tracking scholarly uptake, but they cannot capture how research interacts with public discourse, civil society, or policy forums. Altmetrics, when carefully validated and contextualized, offer a more holistic understanding of research influence in the digital age. Still, data limitations, platform biases, and language asymmetries necessitate cautious interpretation and further refinement of methods. Overall, the research underscores the importance of democratizing climate knowledge by amplifying Global South scholarship, promoting open access, and strengthening connections between science, media, and policy. Addressing climate change requires not only sound evidence but also equitable and effective communication. By mapping how research flows across attention ecologies, this study provides a foundation for more inclusive, transparent, and impactful science communication strategies.

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