Conflicts of Interest, Funding Support, and Author Affiliation in Peer-Reviewed Research on the Relationship between Climate Change and Geophysical Characteristics of Hurricanes

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ABSTRACT

We analyzed 82 peer-reviewed articles on the relationship between climate change and the geophysical properties of hurricanes published between 1994 and 2023 to determine whether conflicts of interest (COI) disclosures, funding support, or author affiliation are associated with study outcomes or recommendations. Non-governmental organization (NGO) funding was a significant predictor for an article to find a positive association between climate change and geophysical characteristics of hurricanes as a research outcome (OR = 8.72; range = 1.23 to 61.81; p-value = 0.03). Other significant predictors of this outcome were publication year 2016 or later (OR = 9.19; p-value =0.002) and journal impact factor (OR = 1.08; p-value = 0.004). First author having an academic affiliation was a significant predictor of making a policy recommendation in the article (OR = 9.6; p-value = 0.01). There were no associations between COI disclosures and study outcomes or recommendations because none (0) of the 331 authors disclosed COIs. Since COI disclosures in other areas of research, such as bioscience, range from about 17% to 33%, we suspect that some authors had COIs that they did not disclose. To promote objectivity, transparency, and trust in climate science, journals that publish this research should clearly state that authors must disclose financial and non-financial COIs and provide clear processes for doing so. Scientific societies and journals should foster COI disclosure as a norm of professional ethics through policy development, education and peer modeling.

1. Introduction

Conflict of interest (COI) in scientific research emerged as a topic of public concern in the mid-1980s, when journalists published exposés on fraud and deception in science and the U.S. Congress held hearings on misconduct, bias, and financial interests in federally-funded science (Broad and Wade 1982; US Congress 1990; Shamoo and Resnik 2022). Since then, government agencies, universities, professional societies, and journals have adopted policies for disclosing COIs and funding support, and scholars studied how financial interests can influence decisions concerning research design, data analysis, data interpretation, and data sharing and publication (Sismondo 2008; Institute of Medicine 2009; All European Academies 2017; Resnik et al. 2017; Daou et al. 2018; International Committee of Medical Journal Editors 2024). In the last decade, an increasing number of researchers and scholars have raised awareness about the impact of non-financial COIs, such as involvement with political interest groups or litigation, and on scientific integrity

(Viswanathan et al. 2013; McKinney and Pierce 2017; Wiersma et al. 2018; Saver 2021; Resnik 2023). Non-financial COIs, like financial COIs, have the potential to bias data and results, and undermine the public's trust in science (Resnik 2023).

While most of the scholarship and public debate concerning COIs in research has focused on how they impact the biomedical sciences (Oreskes et al. 2015), COIs are also an important concern in environmental science, especially in research related to the risks posed by pesticides, waste, and industrial chemicals (Bero et al. 2016; Schäffer et al. 2023). We suspect that COIs, including non-financial ones, may also be an important concern in climate change research, given the political controversy surrounding this topic. In 2015, several journals that publish research on climate change began to consider strengthening their COI policies after some authors failed to disclose their financial ties to the energy industry (Tollefson 2015). The same year, Oreskes et al. (2015) published a commentary in an environmental science journal advocating for stronger disclosure rules in all scientific research.

The following is a list of select controversies concerning climate change research that suggests the need for strong disclosure standards in this area of research:

- Since the 1990s, oil companies have funded scientists, thinktanks, and lobbyists to refute climate change research and influence climate change policies (Michaels 2008; Oreskes and Conway 2010; Cohen 2022).
- Likewise, left and progressive leaning philanthropies work in highly strategic networks to fund research and influence energy and climate policy (Nisbet 2018).
- In 1998, Danish economist Bjørn Lomborg (2001) published a controversial book, *The Skeptical Environmentalist*, which challenged some of the predictions made by climate scientists and argued that there are more important and pressing environmental and public health issues in the world than climate change, such as infectious diseases, scarcity of drinkable water, and pollution. The Danish Committee on the Conduct of Science found him guilty of misconduct, but this conviction was overturned due to misapplication of the misconduct rules (Jowitt 2010).
- In 2006, President George Bush's administration censored government reports on climate change and tried to prevent NASA researcher James Hansen from communicating his views about climate change to the public. President Bush and

Vice President Cheney both had significant ties to the oil industry (Mooney 2005; Revkin 2006; Resnik 2009a).

- In the fall of 2009, someone hacked into the email server the University of East Anglia's (UK) Climatic Research Unit (CRU). Researchers at the CRU have contributed a great deal to our understanding of the causes and consequences of climate change, and their work has been heavily cited in reports from the Intergovernmental Panel on Climate Change (IPCC). The hackers distributed thousands of emails to the media. Most were to and from CRU head Phil Jones and several other CRU researchers. The emails portrayed the CRU researchers in a less than glowing light. The researchers had refused to share data and computer codes with climate change skeptics even though they were required to share data under the UK's freedom of information laws. They also told colleagues not to submit their work to journals that publish papers written by climate change skeptics. Independent reviews of the incident found that while the CRU researchers did not commit misconduct or otherwise manipulate data, they did violate the ethical principles of openness and transparency as well as freedom of information laws. The IPCC took the matter seriously and affirmed the importance of openness and transparency in climate change research (McKie 2019).
- In early 2010, the then chairman of the IPCC, Rajendra K. Pachauri, became embroiled in controversy regarding his financial and non-financial conflicts of interest (Rosenthal 2010). An independent review cleared Pachauri of financial wrongdoing (Monbiot and Randerson 2010) and the IPCC instated COI policy in 2011 however, author disclosures remain inaccessible to the public (IPCC 2024).
- In 2016, WikiLeaks released hacked emails of political strategist, John Podesta. The emails revealed a political activist group collaborating with scientists to discredit a researcher whose work on disaster losses and climate change did not align with preferred political messaging (Legum 2014).
- In 2019, several whistleblowers, including National Park Service climate scientist Maria Caffrey, alleged that officials working for President Donald Trump's administration had removed references to anthropogenic climate change from government reports (Holden 2019).
- In 2022, the National Academies of Science sanctioned Jane Lubchenco for failure to recuse herself from editing a 2020 article co-authored by her brother-in-law in the

Proceedings of the National Academy of Science (*PNAS*, Travis and Wadman 2022). At the time, Lubchenco was the deputy director of climate and environment for the White House Office of Science and Technology Policy. *PNAS* retracted the article (Cabral et al. 2020). The, now retracted, article served as input for a subsequent article co-authored by Lubchenco, which claimed relevance to the social movement aiming to protect 30% of the ocean by 2030 (Sala et al. 2021). This goal was central to a 2020 high-profile report co-authored Lubchenco and supported by the influential NGO, World Resources Institute, and a venture capital firm (Stuchtey et al. 2023), and it was an important component to one of President Biden's first executive orders (Biden, Executive Order 14008). Concurrent with the sanction, Lubchenco co-led development of government scientific integrity guidelines under the Biden Administration (NSTC 2022).

As one can see from these controversies, it is possible that financial and political interests are impacting climate change research. We conducted the study described in this article to better understand the potential effects of financial and non-financial interests on climate change research. Given the scope and breadth of climate change research, we decided to focus our analysis on the relationship between climate change and geophysical characteristics of hurricanes published in peer-reviewed journals because it is an area of protracted scientific debate with financial, economic, and policy relevance (Weinkle 2020). Our specific aims were to: 1) determine whether the author's affiliation, reported research funding, or reported COI are associated with a finding of a positive association between climate change and geophysical characteristics of hurricanes; 2) determine whether the author's affiliation, reported research funding, or reported COI are associated with a recommendation concerning climate change policy; 3) collect data relevant to understanding the role of financial and non-financial interests in climate change research. Here is an example Fig. 1.

2. Methods

We reviewed and analyzed the peer-reviewed literature on the relationship between climate change and the geophysical characteristics of hurricanes for the potential impact of COI and funding sources. We developed a protocol for our study prior to conducting our review and analysis finalized on May 30, 205 (See Appendix A). We modelled our protocol on methods for studying COIs in published research developed by Bero et al. (2016) and Guillemaud et al. (2016). Our search intentionally did not place strong restrictions on

researchers' chosen methodology so that a wider net could be cast in this initial examination of author COI in the climate literature.

a. Literature Search

The literature search was specifically designed in the context of the detection and attribution framework used by the Intergovernmental Panel on Climate Change (IPCC). By doing so our analysis considers a body of literature salient for policymaking and public discussion about weather extremes and climate change (Seneviratne, et al. 2021). This orientation also provides for findings relevant for ensuring high standards of scientific integrity and research ethics for a field that is regularly a centerpiece of scientific and political controversy (e.g., Pielke 2024, Lucas et al. 2024) and so-called climate litigation (e.g., climateattribution.org).

The IPCC (2024) provides the following definitions for detection and attribution:

- **Detection** of change is defined as the process of demonstrating that climate or a system affected by climate has changed in some defined statistical sense, without providing a reason for that change. An identified change is detected in observations if its likelihood of occurrence by chance due to internal variability alone is determined to be small, for example, <10%
- **Attribution** is defined as the process of evaluating the relative contributions of multiple causal factors to a change or event with an assessment of confidence.

We conducted the literature search in Scopus on May 13, 2024. See protocol (Appendix A) for search sting.

The search string requires studies to include a term to indicate the research covered hurricanes, as well as climate change, trend, and detection, attribution or observation in the title, abstract or keywords. Climate change was covered by including all English derivations of climate change, changing climate, and global warming using wildcard characters or common phrases such as climate warming, warming world, warming climate. These phrases were chosen based on author judgement and familiarity with the literature. Though the IPCC (2024) offers specific definitions for "global warming" and "climate change" the terms are frequently used interchangeably and the use of these and related terms evolve alongside contemporary culture and politics (Leiserowitz et al 2014, Nisbet 2019). Our search requires

studies to contain a derivation of the term, trend, staying in line with common nomenclature of IPCC reporting on extreme event detection and attribution (Seneviratne, et al. 2021).

This manuscript uses the term, hurricane, to remain consistent with common North America vernacular. More specifically, however, a hurricane refers to a tropical cyclone with maximum 1-minute average sustained surface wind greater than or equal to 74 mph (NHC 2024). Our search also includes tropical storms, a subcategory of tropical cyclones weaker than hurricanes.

We limited the search to Scopus document types: Article or Review in order to avoid commentaries, editorials or other publications less likely to contain original data.

The date range for the search was January 1, 1994- December 31, 2023. The starting date reflects the beginning of a reinsurance industry partnership with academic and government researchers in hurricane and climate change science (Michaels et al. 1997).

b. Screening

Our search query yielded 346 results. Considering the time constraints of our research team, we limited the search results further by excluding publication titles for which Scopus returned only one record thereby focusing our efforts on publication arenas in which researchers are more actively engaged on the topic. Of the 158 journals identified in the original search, 47 publications had 2 or more results, accounting for 68% of the total.

Our final sample used for initial review contained 236 results. The top eight journals account for 53% of the results (Figure 1). The top 9 authors are associated with 41 articles or 17.4% of the total sample and each of these authors contributed to 7 or more articles (Figure 2).

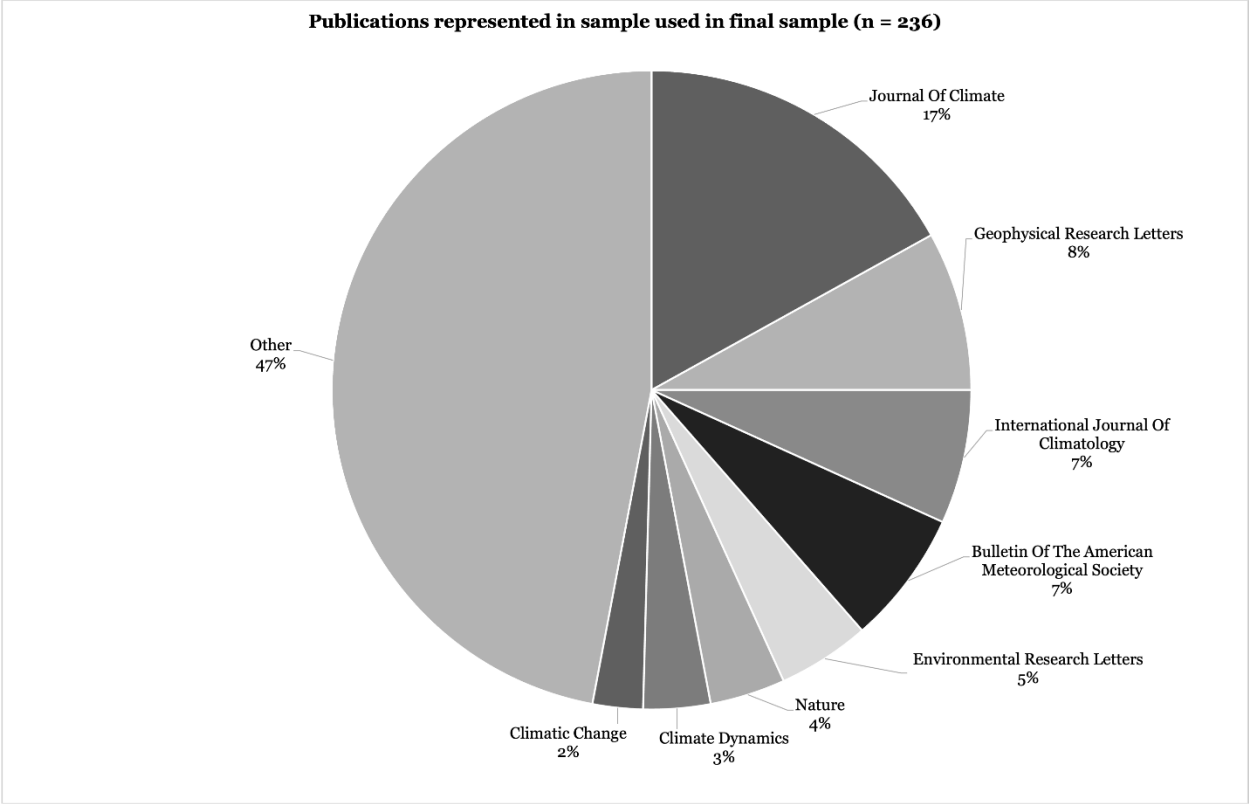

Figure 1: Breakout of the top 8 journals and the percentage of articles represented by each

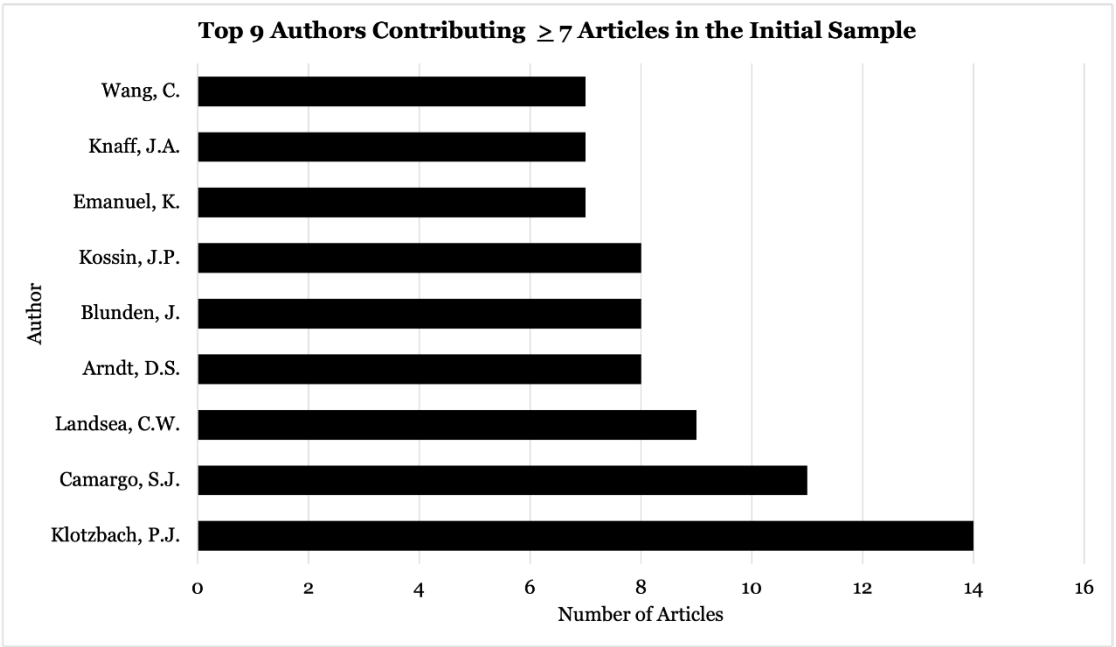

Figure 2: Top Contributing Authors to the Final Sample

Two independent reviewers examined each article for relevance using each listing's title and abstract with all other article details removed. Discrepancies between independent

reviews were discussed to decide whether to include the study. The criteria for relevance limited the evaluation of studies to those that:

- Search for and/or demonstrate that observed geophysical hurricane characteristics has changed in some defined statistical sense. That is, the researchers seek to 'detect' change.
- Situate findings into a climate change attribution statement either positive, negative, or undetermined.

Criteria for relevance do not discriminate by methodology (e.g., use of observed or synthetic hurricane tracks, partitioning of the hurricane record). However, the criteria requires that an article make a claim about observed hurricane behavior in respect to climate change as opposed to focusing on projecting hurricane behavior under assumptions about future climate change. We did not exclude so-called extreme weather attribution studies that evaluate singular events.

Examples of studies part of the initial sample of 236 and excluded after review for lack of relevance include: studies that examined precipitation trends in general (e.g. Feng et al 2016), studies providing an overview of annual meteorological events of all kinds (e.g. Hartfield et al 2018); studies that focus on extratropical storms (Varino et al 2019); studies that analyze economic trends related to hurricanes (e.g. Pielke et al 2005); and studies that evaluate model performance or do not develop detection and attribution findings regarding historical record (e.g. Song et al 2022).

After screening at the title and abstract level for relevance, we identified 83 documents with which to proceed for the study. In data coding, one additional study was excluded for not aligning with relevance criteria. Specifically, the study (Krencker et al. 2015) used paleoclimatology methods to develop observational data from the Jurassic period. We found this approach to be beyond the intent of our relevance criteria. Thus, our results reflect an analysis of 82 documents (Figure 3).

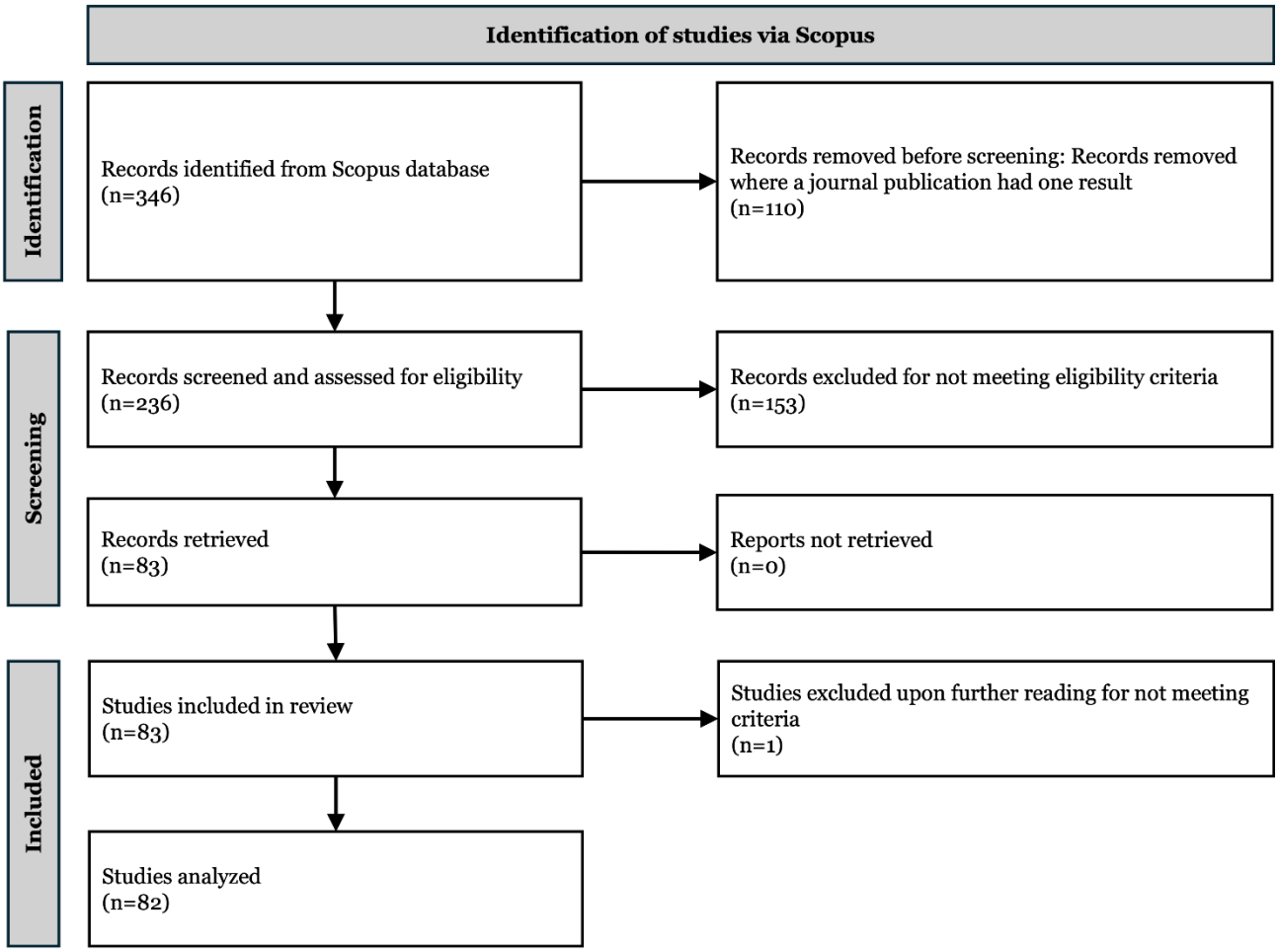

Figure 3: Flow diagram of article selection process

The 82 articles were then coded. The coding framework and study protocol is available as online supplemental information.

The coding framework was based on variables used in the literature on COIs in biomedical research (see, for example, Bekelman et al. 2003; Friedman and Richter 2004; Sismondo 2008; Bero et al. 2016; Guillemaud et al. 2016). Most of these studies collect data on author affiliations, funding, COI disclosures, and study outcomes. We chose first author affiliation and last author affiliation variables of interest for this study because 1) first and last authorship position are recognized as a high-status positions in science; 2) the first and last authors usually play an essential role in designing the study and writing the first draft of the manuscript in climate research; 3) there is a precedent in the bibliometric literature for using first author and last author as variables of interest for in studies of publication ethics (Brück 2023).

We chose articles published in 2016 or later as a variable of interest because the Paris Agreement on Climate Change was signed on December 12, 2015, and became effective on

November 4, 2016, events which sparked renewed interest in climate change from governments, private companies, and NGOs (United Nations 2024). We included NGO as a variable of interest because NGOs play a prominent role in climate change research, policy analysis, and activism (Gough and Shackley 2001).

Two members of the research team independently coded data for COI disclosures and the two dependent variables for our study, "study finding" and "policy recommendation" as reported in the abstract and concluding sections of the article. This coding process captures statements of detection, attribution, and policy recommendations that fall in the range of very general to very specific. As well, the coding process takes author statements at face value and does not account for discrepancy between documented research results and authors' narrative claims. These methods provide for an initial evaluation of COI disclosure practices and the relationship between author COI and author research claims (Bero 2017) .

Importantly, however, our work should not be taken as a technical assessment of the literature on climate change detection and attribution in tropical cyclones. We evaluated the association between COI variables and the outcome. We did not evaluate the validity of the outcomes assessed in the underlying research.

After coding the data independently, the coders resolved disagreements through discussion. Inter-rater agreement was 100% for "COI disclosure"; 76.8% for "study finding" (Cohen's Kappa = 0.552); and 82.9% for "policy recommendation" (Cohen's Kappa = 0.281).

c. Statistical Analysis

We used statistical software R (version 4.3.2) in our data analyses. For categorical variables, we showed counts and percentages and for continuous variables we showed mean, standard deviation (SD), median and range. We used multivariate logistic regression to assess factors associated with the two main outcomes (dependent variables): 1) Finding a positive association; 2) Policy recommendation. The following predictors were entered simultaneously in both logistic regression models: publication year of 2016 and after, first author had a government affiliation, last author had a government affiliation, academic funding, government funding, industry funding, non-government organization funding, journal impact factor, and number of authors. We also included finding a positive association as a predictor when assessing factors associated with policy recommendation. We showed

odds ratios (ORs) and their 95% confidence intervals (CIs) and p-values of the regression results.

3. Results

As shown in Tables 1 and 2, most of the articles (61%) were published in 2016 or later (range 1994-2023). The mean journal impact factor was 9.27 (SD = 12.99; range = 0.68 to 50.5). The mean number of authors per article was 4.34 (SD = 2.82; range = 1 to 13). 70.7% of first authors had an academic affiliation, 43.9% had a government affiliation, 2.4% had an industry affiliation and 1.2% had an NGO affiliation.[1] 65.5% of last authors had an academic affiliation, 41.5% had a government affiliation, 1.2% had an industry affiliation, and 1.2% had an NGO affiliation. 76.8% of the articles reported government funding, 26.8% reported academic funding, 11% reported NGO funding, 2.4% reported industry funding, and 1.2% reported other funding. None of the 82 articles reported COIs. 39% of the articles made a finding of a positive association between climate change and geophysical characteristic of hurricanes and 15.9% made policy recommendations.

Multivariate logistic regression analysis has identified significant association with several predictors while adjusting for all other variables (Tables 3-6). Because there were no COI disclosures, there was no association between COI disclosure and our two dependent variables (finding of a positive association and making a policy recommendation). However, NGO funding was a significant predictor for an article to find a positive association between climate change and geophysical characteristics of hurricanes (first author treated as predictor: OR = 8.72; p-value = 0.03; last author treated as predictor OR = 8.97; p-value = 0.03). Other significant predictors of positive association between climate change and geophysical characteristics of hurricanes included publication year 2016 or later (first author treated as a predictor, OR = 9.19; p-value =0.002; last author treated as predictor, OR = 9.3; v-value = 0.002) and journal impact factor (first author as a predictor, OR = 1.08; p-value = 0.004).

[1] Percentages for author affiliation total more than 100% because these categories are not mutually exclusive.

First author having an academic affiliation was a significant predictor of making a policy recommendation in the article (first author as a predictor, OR = 9.6; p-value = 0.01).

Table 1: Categorical variables

Variable	Count	Percent (%)
Publication year of 2016 and after	50	61
First author affiliation		
Academic	58	70.7
Government	36	43.9
Industry	2	2.4
NGO	1	1.2
Last author affiliation		
Academic	53	65.6
Government	34	41.5
Industry	1	1.2
NGO	1	1.2
Funding		
Government	63	76.8
Academic	22	26.8
NGO	9	11
Industry	2	2.4
Other	1	1.2
COI disclosure	0	0.0
Finding a positive association	32	39
Making a policy recommendation	13	15.9

Table 2: Continuous variables

	Mean	SD	Median	Range
Journal impact factor	9.27	12.99	4.8	0.68, 50.5
Number of authors	4.34	2.82	4	1, 13

Table 3: Results of logistic regression with finding a positive association as the outcome and first author's affiliation as one of the predictors

Predictor variable	OR (95% CI)	P-value
Publication year of 2016 and after	**9.19 (2.22,38.02)**	**0.002**
First author had a government affiliation	0.86 (0.27,2.78)	0.80
Academia funding	1.8 (0.49,6.6)	0.37
Government funding	0.49 (0.14,1.77)	0.27
Industry funding	0.62 (0.02,16.2)	0.77
Non-government organization funding	**8.72 (1.23,61.81)**	**0.03**
Journal impact factor	**1.08 (1.03,1.15)**	**0.004**
Number of authors	0.84 (0.67,1.06)	0.15

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329 **Table 4: Results of logistic regression with policy recommendation as the outcome**
330 **and first author's affiliation as one of the predictors**

Predictor variable	OR (95% CI)	P-value
Publication year of 2016 and after	1.01 (0.15,6.64)	0.99
First author had a government affiliation	**9.6 (1.72,53.64)**	**0.01**
Academia funding	1.39 (0.25,7.55)	0.71
Government funding	0.26 (0.05,1.38)	0.11
Industry funding	35.13 (0.59,2080.3)	0.09
Non-government organization funding	0.64 (0.06,7.06)	0.72
Journal impact factor	0.96 (0.9,1.03)	0.23
Number of authors	1.28 (0.97,1.69)	0.08
Finding a positive association	**10.12 (1.42,71.99)**	**0.02**

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332 **Table 5: Results of logistic regression with finding a positive association as the**
333 **outcome and last author's affiliation as one of the predictors**

Predictor variable	OR (95% CI)	P-value
Publication year of 2016 and after	**9.3 (2.23,38.82)**	**0.002**
Last author had a government affiliation	0.63 (0.18,2.18)	0.47

Academic funding	1.74 (0.47,6.39)	0.41
Government funding	0.51 (0.14,1.87)	0.31
Industry funding	0.66 (0.03,15.11)	0.79
Non-government organization funding	**8.97 (1.26,63.74)**	**0.03**
Journal impact factor	**1.08 (1.03,1.14)**	**0.004**
Number of authors	0.87 (0.68,1.11)	0.26

Table 6: Results of logistic regression with policy recommendation as the outcome and last author's affiliation as one of the predictors

Predictor variable	OR (95% CI)	P-value
Publication year of 2016 and after	0.98 (0.17,5.68)	0.99
Last author had a government affiliation	4.17 (0.82,21.16)	0.09
Academic funding	1.4 (0.27,7.26)	0.69
Government funding	0.3 (0.07,1.36)	0.12
Industry funding	9.27 (0.12,706.82)	0.31
Non-government organization funding	0.72 (0.08,6.34)	0.76
Journal impact factor	0.96 (0.91,1.03)	0.26
Number of authors	1.16 (0.9,1.5)	0.25
Finding a positive association	**8.5 (1.38,52.41)**	**0.02**

4. Discussion

Our most important finding is that none of the 82 papers (0.0%) had a financial or non-financial COI disclosure from at least one author. This is a very unusual finding when compared to medical research. For example, Grundy et al. (2018) took a random sample of 1650 articles published in 332 biomedical journals in 2016 and found that 22.9% had at least one COI disclosure from an author. While we think this is an important finding, it is difficult to interpret, because we are not aware of any published studies that estimate the percentage of climate change papers that have COI disclosures. While there is evidence that a notable percentage of climate researchers have financial or non-financial COIs (Tollefson 2015, Weinkle 2020), it is not known whether these would qualify as disclosable COIs according to most journal policies. Thus, we are not sure whether the fact that none of the papers had COI

disclosures represents a deviation from the disclosure norms in climate research. Clearly, this issue requires further investigation.

It is possible that some authors in our study did not disclose COIs because the journal did not have a COI policy when the article was published[2] or did not clearly define the interests that should be disclosed or the authors misunderstood the journal's policy. For example, in their acknowledgements, Knutson et al. (2010) stated that:

> The authors constitute an expert team established by the World Meteorological Organization to provide advice to national meteorological and hydrological services on tropical cyclones and climate change. T.K. and J.L.M. are co-chairs of this team (Knutson et al. 2010: 7).

The authors also declared that they had "no competing financial interests (Knutson et al. 2010: 7)." In our opinion, being part of an expert team established by the World Meteorological Organization would be a competing non-financial interest for an author because it could undermine their objectivity, since they could be biased in favor of theories and policies endorsed by the World Meteorological Organization. Although the authors disclosed this interest in the acknowledgements section, they also affirmed that they had no competing interests, which, in our opinion, suggests that journal's policy lacked clarity concerning what constitutes a COI. In the year the article was published, Nature journals did not require authors to disclose non-financial COIs.

This policy was changed in 2018, and *Nature* now requires disclosure of all interests that could cloud objectivity. *Nature Geosciences* current policy reflects this change:

> For the purposes of this policy, competing interests are defined as **financial and non-financial** interests that could directly undermine, or

[2] Some publication dates were as early as 1994. Although some journals did not have COI policies in the 1990s, today, nearly all do now (Resnik et al. 2017; de Lotbiniere-Bassett et al. 2019).

> be perceived to undermine the objectivity, integrity and value of a publication, through a potential influence on the judgements and actions of authors with regard to objective data presentation, analysis and interpretation (Nature Geosciences 2024; emphasis added).

To accurately estimate the proportion of climate scientists who are not disclosing COIs, one would need access to an independent and validated source of COI data, such as the database established by the Physician Payments Sunshine Act, which requires pharmaceutical and biotechnology companies to report payments to physicians (Dunn et al. 2016). Although there is no such database for climate science, there is ample anecdotal evidence that climate science authors are not disclosing financial and non-financial COIs. Of the articles analyzed for this study we can point to the following instances of undisclosed COI:

- An author holds a patent (Ravela and Emanuel 2010) relevant to the research reported (Emanuel 2021) and is an advisor to a risk analytics firm (First Street 2024) and a financial company (Integral ILS 2021)
- An author is an advisor to a climate risk analytics firm (Lee et al. 2023; Jupiter Intelligence 2021)
- An author is a non-resident scholar for an insurance industry association (Klotzbach et al. 2021; III n.d.)
- Authors with government and academic affiliations also had a multi-year consulting relationship with private industry (Guo et al. 2021; TCS 2021)
- One or more authors developed research methods and lead an NGO to advance liability litigation against the fossil fuel industry (Oldenborgh et al. 2017; Luu et al. 2021; Mathiesen 2021, worlweatherattribution.org). The initiative dovetails with work of co-authors' affiliated NGO which advances climate change messaging in the media and provides fee based climate risk analytic services (climatecentral.org).

Looking beyond our analyzed sample, one can see that there is a dynamic world of undisclosed COIs in climate science:

- An article's author and its editor work for the same climate analytics firm (Wehner and Kossin 2024; First Street 2024). Concurrently, the editor works with at least one financial firm (Integral ILS 2021) and contributed to White House reporting on supporting industry interests in climate analytics (PCAST 2023).

- A paper with industry affiliated co-authors was submitted to a journal the day after a prominent industry data and analytics firm appointed its lead author to its technical advisory council (Bruyère et al. 2022; Verisk 2022).
- A prolific, high-profile scientist works closely with political party campaigns and media organizations (Mann 2024b; 2024a)
- A scholar with a high-profile voice in advocacy for liability litigation against fossil fuel companies publishes in the scientific literature on this topic and holds various relationships with organizations and law firms related to this area of litigation (Schwartz 2016; Oreskes 2020; Supran and Oreskes 2020)
- A comment in a top journal is co-authored by two government researchers who support the development of the US National Climate Assessment (NCA), a White House official, and an additional scientist who is a frequent author of the (NCA; Easterling et al. 2024). Legislation guiding the production of the NCA situates the report under direct supervision of the White House (USGCRP 2024). The two government authors have current or recent advisory relationships with private climate risk analytics firms relevant to the substance of the comment (Verisk 2022; TCS 2022).

Given the growing confluence between government, academia, industry, and NGOs in climate research, many researchers may have non-financial COIs they are not disclosing. Moreover, formal government-industry partnerships (NOAA 2023) increases the complexity of author COI. To promote objectivity, transparency, and trust in climate science, journals that publish this research should clearly state that authors must disclose financial and non-financial COIs (Wiersma et al. 2018; Resnik 2023). Further investigation into the interests of climate change researchers would enhance our understanding of the prevalence of COIs in this field inform disclosure policies.

Another important finding of our study is that NGO funding was positively associated with a finding of a positive association between climate change and geophysical characteristics of hurricanes. This finding was statistically significant ($p = 0.03$), and the effect size was large ($OR = 8.72$). This finding suggests that environmental and industry-oriented NGOs may be influencing climate science to promote a political agenda much in the same way that pharmaceutical and biotechnology companies have influenced biomedical and public health research to promote their own profits (Resnik 2007; Michaels 2008; Dunn et al.

2016; Krimsky 2017). However, more research is needed to determine whether and how NGOs are influencing climate research.

A third important finding is that first author having an affiliation with a government agency was associated with making a policy recommendation in the article. This finding was statistically significant ($p = 0.01$), and the effect size was large (OR = 9.6), though policy recommendations were often very general. While there is a tendency to think of government science as more objective than academic or industry science, this is not always the case (Resnik 2009a). Government agencies are inherently subject to the political priorities of the executive branch and agency administrators are formally directed to identify and increase the scrutiny (Guidelines for Ensuring and Maximizing 2002) of "influential scientific information" defined as research that "will have or does have a clear and substantial impact on important public policies or private sector decisions" (Final Information Quality Bulletin 2005). And, of course, individual researchers can hold financial and non-financial conflicts even if employed by the government. Moreover, as noted earlier, the Bush and Trump administrations censored reports on climate change. More recently, the Biden Administration legitimized emissions scenarios commonly used by the climate risk analytics industry (White House 2023) but acknowledged as outdated by climate change scientists (Hausefather and Peters 2020, Burgess et al. 2020). However, more research is needed to understand the role of government agencies, and industry and advocacy coalitions in shaping climate science and policy.

Finally, we would like to note that only a small percentage of studies (2.4%) reported industry funding, which stands in sharp contrast to other fields of science and engineering. About 61% of total research and development (R & D) funding in the U.S. comes from businesses (National Science Foundation 2022). What this suggests to us is that private companies are not (yet) especially interested in funding climate research because they do not see how this type of R & D investment can benefit them financially. It may also be the case that private companies are funding climate research indirectly by supporting private foundations that fund climate research (Resnik 2009b), supporting university initiatives that fund climate research (Gelles 2022), and advising or lobbying policymakers to support government funding of industry relevant research and tools (PCAST 2023).

a. Strengths

Our work establishes a transparent and accessible protocol for researchers interested in replication studies of this work and expansion of the study of COI, funding bias, and research ethics in climate science. Historically, awareness of undisclosed COI in published research originated with anecdotal evidence from close observers of niche areas of research, such as in the medical sciences (e.g. Smith 1994). The greatest strength of the work here is its structured approach to examining researcher COI statements thereby placing anecdotal evidence of author non-disclosure of COI into a broader context. Thus, our findings demonstrate an entrenched condition of researcher non-disclosure than that otherwise suggested by anecdotal evidence alone.

b. Limitations

Our research has several limitations. First, we did not analyze the COI policies of the journals included in our study to determine whether they clearly specified (at the time of submission) the types of interests that should be disclosed. Due to time constraints, we did not collect this data, since most of the data extraction and coding was done by three summer interns, who had only a couple of months to work on this project. We suspect that this data may not be available in most cases, since it is not likely that journals will have maintained records of their policies going back more than ten years. Thus, while our data indicate that no authors disclosed COIs, it is not clear whether lack of disclosure represents indicates that authors have violated journal policies. Second, our search strategy was not independently validated and relied only on the SCOPUS database. As a result, it is possible that some relevant studies may have been omitted from our analysis. Third, since we focused on a particular area of climate research, i.e., geophysical characteristics of hurricanes, our findings may not be generalizable to other types of climate research. Fourth, our search captures articles that reference the search terms in an article's Title, Abstract, and Keywords but does not capture articles where these terms are referenced only later in the article. As a result, there may be other articles that discusses trends in hurricane geophysical characteristics in relation to the detection and attribution of climate change but do not note research orientation as an overarching topic. Fifth, search does not include the term, typhoon, the common term for referring to tropical cyclones in the Indian and western Pacific oceans. As a result, this study is biased towards research on the North Atlantic Ocean, the Eastern Pacific Ocean, or those

researchers using the more encompassing term, tropical cyclone, for their work anywhere in the world. Finally, this study did not include journals with only one study that matched search terms potentially skewing the proportion of papers represented by top authors. However, undisclosed COI among top authors in a field also has the potential to bias representation of the state of knowledge about a subject.

5. Conclusion

COIs are an important ethical concern in all areas of science, including climate science. Although we found no evidence that COIs are impacting climate research, this study had limited ability to detect a potential impact because none of the 331 authors in our study disclosed COIs. We are uncertain whether none of the authors disclosed COIs because none of them had COIs or because some of them had COIs but did not disclose them because the journal's policy did not clearly require disclosure. To promote objectivity, transparency, and trust in climate science, journals that publish this research should clearly state that authors must disclose financial and non-financial COIs.

It is very possible that climate scientists are unaware of best practices for COI disclosures in research and publication. We suggest that academic journals and professional organizations should help to promote ethical publication practices by developing, refining, and publicizing COI policies. Journals can implement a common reporting form such as that developed by the International Committee of Medical Journal Editors (ICMJE 2021). Universities, professional organizations, and other institutions can participate in a central disclosure system such as Convey, (convey.org), as a benefit of researcher membership and to reduce time burden in article submissions.

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Data Availability Statement.

A complete list of the articles used in this study and the compiled coding data are available by contacting the corresponding author.

Ethics Statement

JW is a Senior Fellow at The Breakthrough Institute and receives pay for contributions to their online newsletter. JW received no fees or funding support for the research reported in this manuscript, and The Breakthrough Institute was not involved in this work. JW has provided pro bono assistance on improving author disclosure practices to the publications commission of the American Meteorological Society.

APPENDIX A

Study Protocol

Study on funding, financial interests, and author affiliations related to peer reviewed research on climate change and the geophysical characteristics of hurricanes

This protocol was developed prior to conducting the study. Some modifications (noted below) were made during the study. The protocol was reviewed by members of the research team, but it was not posted online or peer reviewed.

Date of original protocol: May 14, 2024

Date of modifications: May 30, 2024 and July 26, 2024

Research Protocol

1. **Aims/objectives:**
    a. To determine whether there are (in the peer-reviewed literature on climate science) statistical associations between:
        i. disclosed funding sources, conflict of interest (COI) disclosures and institutional affiliations of authors, and journal impact factor and
        ii. a finding of a positive association between climate change and the geophysical characteristics of hurricanes.
    b. To determine whether there are (in the peer-reviewed literature on climate science) statistical associations between:
        i. disclosed funding sources and conflict of interest (COI) disclosures and institutional affiliations of authors and journal impact factor and
        ii. making a climate adaptation or mitigation policy recommendation.

2. Search methods

a. Database [Scopus]

b. Search terms

i. (TITLE-ABS-KEY (hurricane* OR "tropical cyclon*" OR "tropical storm*") AND TITLE-ABS-KEY ("climat* change*" OR "chang* climat*" OR "climate warming" OR "warming climate" OR "warming world" OR "global warming*") AND TITLE-ABS-KEY (detect* OR observ* OR attribut*) AND TITLE-ABS-KEY (trend*)) AND LANGUAGE (english) AND PUBYEAR > 1993 AND PUBYEAR < 2024 AND (LIMIT-TO (DOCTYPE , "ar") OR LIMIT-TO (DOCTYPE , "re"))

c. Inclusion criteria

i. Search for and/or demonstrate that observed geophysical hurricane characteristics has changed in some defined statistical sense. That is, the researchers seek to 'detect' change.

ii. Situate findings into a climate change attribution statement either positive, negative, or undetermined.

d. Exclusion criteria

i. Studies that do not seek to detect change in geophysical hurricane characteristics in some defined statistical sense.

ii. Studies that focus non-geophysical trends related to hurricanes such as economic losses from hurricane landfalls.

iii. Studies that focus on extratropical storms.

e. Two members of the research team will independently screen papers for relevance and resolve disagreements.

3. Data extraction entities/ Coding

a. Citation for the paper [from Scopus]

b. Year of publication

c. Impact factor of the journal as of July 2024 [from Scopus]

d. Institutional affiliations of all authors [coded by research team members]

i. Academic

ii. Private industry

iii. Government
iv. Non-governmental organization [e.g., NGO; i.e., a nonprofit, such as a charity or political interest group, which is independent of the government]
v. Combination of the above
vi. Other

e. Reported funding sources [coded by research team members]
   i. Academic
   ii. Private industry
   iii. Government
   iv. Non-governmental organization [NGO; i.e., a nonprofit, such as a charity or political interest group, which is independent of the government]
   v. Other

f. Reported conflicts of interest disclosures
   i. Disclosure of a COI
   ii. Disclosure of no COI or no disclosure of COI

g. Reported conflicts of interest or other disclosures [coded by research team members]
   i. Stock/equity
   ii. Consulting fees
   iii. Speaking fees
   iv. Leadership position
   v. Intellectual property
   vi. Expert witnessing
   vii. Other

h. Study finding (dependent variable) [coded by researcher team members]
   i. Finding of any **positive association** between climate change and changes or trends in hurricane geophysical characteristics (e.g., frequency, intensity, translational speed [ideally would also want effect size and p-value but this might not be possible to get or code properly]
   ii. No finding of a positive association

Note: To simplify the coding and data analysis, we made this a bivariate variable [finding of a positive association vs. no finding].

i. Overall policy recommendation (dependent variable)
    i. Authors make a specific or general policy recommendation, such as mitigation, adaptation, or implementing risk analysis
    ii. Authors make no policy recommendation. Authors that make recommendations pertaining to further research needs is **not** considered a policy recommendation.

j. Overall policy recommendation (dependent variable) [coded by researcher team members]
    i. Recommending climate mitigation or adaptation policy(s)
    ii. No recommendation

4. Coding method

a. Two members of the research team will independently read and code the papers and resolve their disagreements.
b. Inter-rater agreement will be assessed statistically.

5. Data analysis plan

a. Relationships between variables will be analyzed statistically to determine whether there are association between institutional affiliation, funding sources, COI and research outcomes and recommendations. Our null hypotheses will be that there are no associations between the independent and dependent variables.
b. We will use statistical software R (version 4.3.2) in our data analyses.
c. We will use logistic regression to assess factors associated with the two main outcomes: 1) Finding a positive association; 2) Policy recommendation. The following predictors will be included in both models: publication year of 2016 and after, first author had a government affiliation, academia funding, government funding, industry funding, non-government organization funding, journal impact factor, and number of authors.

6. Modifications to the protocol during analysis

a. During the Search Methods stage when reviewing papers for inclusion/exclusion in the study, we found that several papers focused on extratropical storms. These papers were excluded from our study because extratropical storms are not tropical cyclones. [Date of modification: May 30, 2024]

b. We initially planned to use the North Atlantic basin as an additional categorical variable in which to code positive association or no finding of a positive association. However, during the Data Extraction/Coding phase we found it difficult to evaluate papers for basin specific findings and decided to simplify our data collection by coding for any claim of positive association or no finding of a positive association. [Date of modification: July 26, 2024]

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