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ARTICLES

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Framing the challenge of climate change in *Nature* and *Science* editorials

Mike Hulme[1*], Noam Obermeister[2], Samuel Randalls[3] and Maud Borie[4]

Through their editorializing practices, leading international science journals such as *Nature* and *Science* interpret the changing roles of science in society and exert considerable influence on scientific priorities and practices. Here we examine nearly 500 editorials published in these two journals between 1966 and 2016 that deal with climate change, thereby constructing a lens through which to view the changing engagement of science and scientists with the issue. A systematic longitudinal frame analysis reveals broad similarities between *Nature* and *Science* in the waxing and waning of editorializing attention given to the topic, but, although both journals have diversified how they frame the challenges of climate change, they have done so in different ways. We attribute these differences to three influences: the different political and epistemic cultures into which they publish; their different institutional histories; and their different editors and editorial authorship practices.

There are many ways of mapping and analysing discourses of climate change over time. Earlier studies have followed print and broadcast media[1,2], publishing trends in scientific journals[3], political speeches[4] and international negotiations[5], evolving linguistic[6] and visual vocabularies[7], public perceptions of climate risk[8], social dramas[9] and the careers of individual scientists[10,11]. However, the editorial content of leading science journals may also reveal the changing nature of the challenge climate change presents to science and society alike.

Given their status as prestigious multidisciplinary scientific journals[12], *Nature* and *Science* are routinely read not just by scientists, but also by academics more widely and by science-policy analysts, science journalists and policy advisors. For example, the science pages of influential newspapers such as *Le Monde*, *The Times* (of London) and *The New York Times* frequently refer to new research published in these two journals. *Nature* also lends its support to a media centre to brief journalists and civil servants about breaking science stories[13], and the professional body that publishes *Science* (the American Association for the Advancement of Science, or AAAS) recently launched an equivalent service (SciLine) in the USA[14]. *Nature* and *Science* therefore act as key sites for the production, interpretation and circulation of knowledge in scientific, academic and influential policy and media networks. Although processes for validating scientific knowledge continue to change, peer review remains one of the chief means through which knowledge is assessed, validated and rendered authoritative[15,16]. Peer-reviewed journals therefore actively contribute to the creation of what is accepted as reliable and authoritative knowledge[17]. *Nature* and *Science* should be thought of alongside laboratories, observatories, field sites, conferences and assessment processes as influential spaces where knowledge is not merely communicated, but actively constructed and authorized[18–20]. In this sense, leading science journals become essential nodes for communication not just between scientists, but also between science and other social worlds.

One central feature of weekly journals such as *Nature* and *Science* is the editorial. An editorial is a short article that expresses either the editor's or an invited author's opinion on a topical subject of particular interest to the journal's readership. Editorials have been present in both journals since their founding (*Nature* in 1869; *Science* in 1880) and became regular top-line weekly items in *Nature* from the 1920s and in *Science* from the early 1950s. Baldwin's history of the journal *Nature* notes the importance of the *Nature* editorial and observes how 'editorial styles might affect the reception and reputation of the journal'[21]. Editorials are distinct from other science journal content in being opinionated commentaries, and they are understood to be such by their readers. They are typically written in an informal or provocative manner, interpreting current scientific events and controversies, setting out agendas, engaging in advocacy, and passing judgement on matters of concern and political dispute. Editorials can therefore reveal some of the value-laden dimensions of science, sometimes quite explicitly, and also, perhaps less visibly, the influence of political and epistemic cultures on scientific practice[22]. In widely read journals like *Nature* and *Science*, editors or invited editorial authors have a platform to signal to elite audiences—both inside and outside science—what they believe should be the scientific and political priorities of the scientific enterprise. Editorials in *Nature* and *Science* have individual DOIs and are cited as sources in academic articles[23] (Supplementary Note 1 and Table 1).

Editorials therefore exert influence; in other words, they are 'performative'[24,25]. The backlash against *Nature*'s editorial in September 2017 on commemorative statues of deceased scientists illustrates the point. *Nature*'s editor, Philip Campbell, was forced to apologize for failing 'to rise to our standards of argument and editorial treatment'[26] and undertook to review the journal's internal editorial practices. This potential to influence professional scientists and wider public discourse makes the content of editorials in high-profile journals especially interesting to study[27]. There have been a few studies analysing editorials in medical journals. For example, Hoey and Todkill[28] commented on the politics and ethics of editorials in the *Canadian Medical Association Journal*, while Smart et al.[29] analysed how editorials in biomedical science journals sought to standardize classifications of race and ethnicity. With specific regard to *Nature* and *Science* editorials, only Waaijer and colleagues have conducted a systematic study. In a bibliometric analysis of *Nature*'s and *Science*'s editorials during the decade 2000–2009, Waaijer et al.[23]

[1]Department of Geography, University of Cambridge, Cambridge, UK. [2]Independent Researcher, London, UK. [3]Department of Geography, University College London, London, UK. [4]Department of Geography, King's College London, London, UK. *e-mail: mh903@cam.ac.uk

Table 1 | Main attributes of the journals *Science* and *Nature*

	Nature	*Science*
Creation of the journal	1869; Independent weekly journal, now published by Springer-Nature	1880; Weekly journal of the American Association for the Advancement of Science
Location of headquarters	Multi-sited; Nature Research is a global company with offices worldwide, but management and principal publishing offices are in London, New York and Tokyo	Main HQ in Washington, DC, with a European office in Cambridge, UK
2017 subscriptions	Paid = 30,628; total = 53,270 (47% in USA)	Paid = 114,126; total = 129,564 (84% in USA)
Journal impact factors (JIFs)	2011 CiteScore = 14.0; 2016 CiteScore = 13.3 (JIF = 40.1)	2011 CiteScore = 12.0; 2016 CiteScore = 14.4 (JIF = 37.2)
Editors in our study period	John Maddox 1966–1973; David Davies 1973–1980; John Maddox 1980–1995; Philip Campbell 1995–present	Phil Abelson 1962–1984; Daniel Koshland 1984–1995; Floyd Bloom 1995–2000; Donald Kennedy 2000–2008; Bruce Alberts 2008–2013; Marcia McNutt 2013–2016; Jeremy Berg 2016–present
Published editorials in our period (1966–2016)	~6,000	~2,650
Editorials in our final corpus	*N* = 333 (~5.6%)	*N* = 160 (~6%)
Editorial authorship	Always anonymous; predominantly authored by the editor	Attributed; frequently invited authors

Sources: ref. [21] (pp. 175, 188 and 224) and refs [51,52].

hint at both similarities and differences in editorial content between the two journals. A later study analysed these same journals' editorials with respect to their positioning on the challenges of pursuing careers in science[30].

In the present study we systematically analyse how *Nature* and *Science* have editorialized about climate change over the last 50 years. In particular, we ask two questions. What attention and framing patterns with regard to climate change can be detected in editorial content, and can these patterns be related to wider political or scientific events? In what ways, if any, do *Nature* and *Science* editorialize differently about climate change, and how might these differences be explained? Answers to these questions are important, because they will shed light on how science's editors represent climate change to their audiences and the extent to which these two leading science journals speak with one voice on this important public and global issue. This study breaks new ground both conceptually (through a systematic longitudinal interpretative analysis of science journal editorials) and topically (through its focus on the content of climate change editorials).

About *Nature* and *Science*

Although *Nature* and *Science* are both high-impact science journals that editorialize on a weekly basis, the origins, institutional history and editorial practices of these two journals are very different (Table 1). Of particular note is that *Nature* is an independent journal published by the Nature Publishing Group, since 2015 the academic publishing division of the international conglomerate Springer-Nature. In contrast, *Science* is the weekly flagship journal of the non-profit professional body of American scientists, the AAAS. This explains the larger number of subscribers for *Science* than for *Nature* (~130,000 compared with ~55,000; see Table 1). Headquartered in London, Nature Publishing Group has several offices worldwide, whereas *Science* is based in Washington, DC, with just one subsidiary office in Cambridge, UK.

During the period of our study *Nature* had just three editors (Maddox served two terms) and *Science* a total of seven (Table 1). John Maddox and Phil Abelson were the respective chief editors for the two journals during the earlier decades of our period, and both editors were very influential in 'modernizing' their respective journals[21,31]. During the 1970s and 1980s they professionalized editing processes and sought to position their journals within the burgeoning international and increasingly mobile community of scientists. *Nature*'s editorials have always been published anonymously, although usually written by the journal's chief editor[21], in contrast to *Science*, which has always operated a practice of named authors, frequently inviting external guests to editorialize (Supplementary Table 2). For example, President Clinton (June 1997) wrote about the promise of science in the twenty-first century and President Obama (January 2017) about clean energy. During the period of our study *Science* has published just a single editorial each week, whereas *Nature* has varied between one and three editorials weekly, with three latterly becoming the norm.

Editorial challenge and attribute frames. We extracted a relevant corpus of climate change editorials for the period 1966–2016 using the search terms 'climate', 'greenhouse', 'carbon', 'warming', 'weather', 'atmosphere' and 'pollution' as an initial filter and subjected it to frame analysis (see Methods). The final corpus consisted of 493 editorials, 333 for *Nature* and 160 for *Science*, representing for both journals between 5% and 6% of all editorials published during this period. Our frame-set distinguished between eight different 'challenges' and three different 'attributes' (Table 2). Each of the 493 editorials was allocated a single primary frame (that is, the dominant 'challenge' of climate change) and, if appropriate, any number of additional 'other' challenges selected from the frame-set. Attributes for each editorial were coded as a simple binary—presence or absence—as appropriate. Inter-coder reliability improved through two pilot exercises and collaborative coding (see Methods).

Both journals show broadly similar frequency patterns in their climate change editorializing (Fig. 1). During the first two decades very few editorials addressed climate change as an issue and, of those that did, several were written to resist or downplay environmentalist claims. For example in 1970, Fred Singer—as Chair of the Committee on Environmental Quality at the AGU—wrote a guest editorial for *Science* about the danger of 'exaggerated claims'[32], and in the following year *Nature*'s editor, John Maddox, wrote an editorial about 'the great greenhouse scare'[33]. Until the mid-1980s, many of the issues of the day—atmospheric pollution, energy security, poverty, development, internationalization of science—were editorialized in both journals with little, if any, consideration of climate

Table 2 | Final frame-set used in coding the editorials

	Challenges
ECON = Economic/financial challenge	Climate change is an externality of economic growth and/or certain modes of production/consumption and/or requires improved quantification of costs/benefits of impacts and/or policies and/or can/should be tackled through economic and financial instruments
DEV = Developmental challenge	Climate change is a by-product of pathways and patterns of socio-economic development and/or unequal development inhibits adequate mitigation, resilience and adaptation and/or causes uneven distribution of harms to human health, well-being and perceived human security
SEC = National/international security challenge	Climate change is a geopolitical security risk by introducing new dangers into inter- and intra-state relations and/or is a threat-multiplier requiring new forms of international or state-level security responses
ETH = Ethical/moral challenge	Climate change raises important questions of procedural and/or distributive justice (for example, burden-sharing) and/or people have an ethical responsibility/moral duty towards future humanity and/or nature and/or the 'poor'/the most vulnerable and/or God/deities, to mitigate climate change
TECH = Technological/energy challenge	Fossil-fuel based energy technologies are the root cause of climate change and/or technological innovation and energy transitions that aim at reducing/capturing/sequestering GHG emissions and/or solar engineering technologies are essential to tackle climate change
GOV = Institutional/governance challenge	Structural and institutional inertia/problems are a root cause of climate change and/or tackling climate change requires new/improved governance institutions and/or regulatory management of adaptation/mitigation policies is inadequate [not to be used if this governance challenge is covered by a more specific frame]
SCI = Scientific challenge	Scientific understanding of climate change is incomplete/inadequate (that is, due to complexity/uncertainty) and/or investing in science is necessary for adequate mitigation/adaptation responses
COM = Communication challenge	Climate science and climate risks is/are poorly communicated to public audiences and/or media representations of climate change are problematic/biased and/or deliberate misinformation/manufactured scepticism confuses political/public opinion
	Attributes
Global/collective scale	The editorial draws attention to the global/collective/cooperative/supra-national scales of the stated response(s) to the designated challenge(s)
Urgency	The editorial draws attention to the temporal/political urgency with which the designated challenge(s) should be addressed
Policy	The editorial draws attention to specific policy instruments and/or measures that are being implemented/or should be implemented in order to respond to the designated challenge(s)

or climate change. However, the late 1980s saw the well-established emergence of climate change as a salient public policy issue in the USA and western Europe[34] and this is clearly reflected in these journals' editorializing. 1988 was the first year in which more than two 'climate change editorials' (according to our definition) were published in both journals. The later, more global, prominence given to climate change in public arenas from the mid-2000s through to 2010[1] is also clearly reflected in editorial attention. Indeed, for every year since 2004, *Nature* has published at least 10 'climate change editorials'. *Science*'s editorializing about climate change peaked in 2007 ($n = 14$; more than 25% of all editorials that year), *Nature*'s in 2009 ($n = 31$; around 20% of all editorials) and while the decline in editorial attention after the 15th Conference of the Parties (COP15) at Copenhagen is evident in both journals, the decline was more pronounced in *Science* (notably in 2011 and 2012).

These peaks and troughs, evidenced similarly in both journals, closely track the patterns of attention to climate change found in popular media[1]. These patterns are partly driven by key scientific, political, cultural and meteorological events concerning climate change (Fig. 1), but also reflect the competition dynamics between different 'social problems' seeking access to the scarce media resources available in public arenas[35]. As leading scientific journals, perhaps of greatest interest for *Nature* and *Science* were the five major assessment reports (ARs) of the Intergovernmental Panel on Climate Change (IPCC), published in 1990, 1996, 2001, 2007 and 2013/14.

Editorial framings by era. To better reveal the changing patterns in editorial framings we periodized the data according to these publication dates, thus generating six eras: the pre-IPCC era (pre-1988) and then five 'IPCC eras', each of which commences two years prior to publication and ends two (or three) years after (Fig. 2). There has been a diversification over time in how climate change has been framed. In the earlier three eras, both journals primarily framed climate change as a scientific, energy/technology or institutional/governance challenge; 78% of all editorials before 1999 had their primary frame as one of these three categories. In the later three eras—'AR3', 'AR4' and 'AR5'—this fell to 67%.

This frame diversification was much more pronounced for *Science* (85% down to 58%) than for *Nature* (73% to 71%). Especially noteworthy was the increase in framings of climate change as a communication challenge (for example, ref. [36]), up from 7% of all editorials prior to the AR3 era to 18% since then. This move is again more noticeable for *Science* (6% to 22%) than for *Nature* (8% to 16%). In the AR5 era, the communication challenge as a primary frame is almost on a par with those of science, energy/technology and institutions/governance (Fig. 3). Two other points are noteworthy. First, climate change as an economic/financial challenge (for example, ref. [37]) was most prevalent for both journals in the AR4 era (2005–2010), coinciding with the publication of the Stern Review on the economics of climate change in 2007[38]. Second, the identification of climate change as an ethical/moral challenge (for

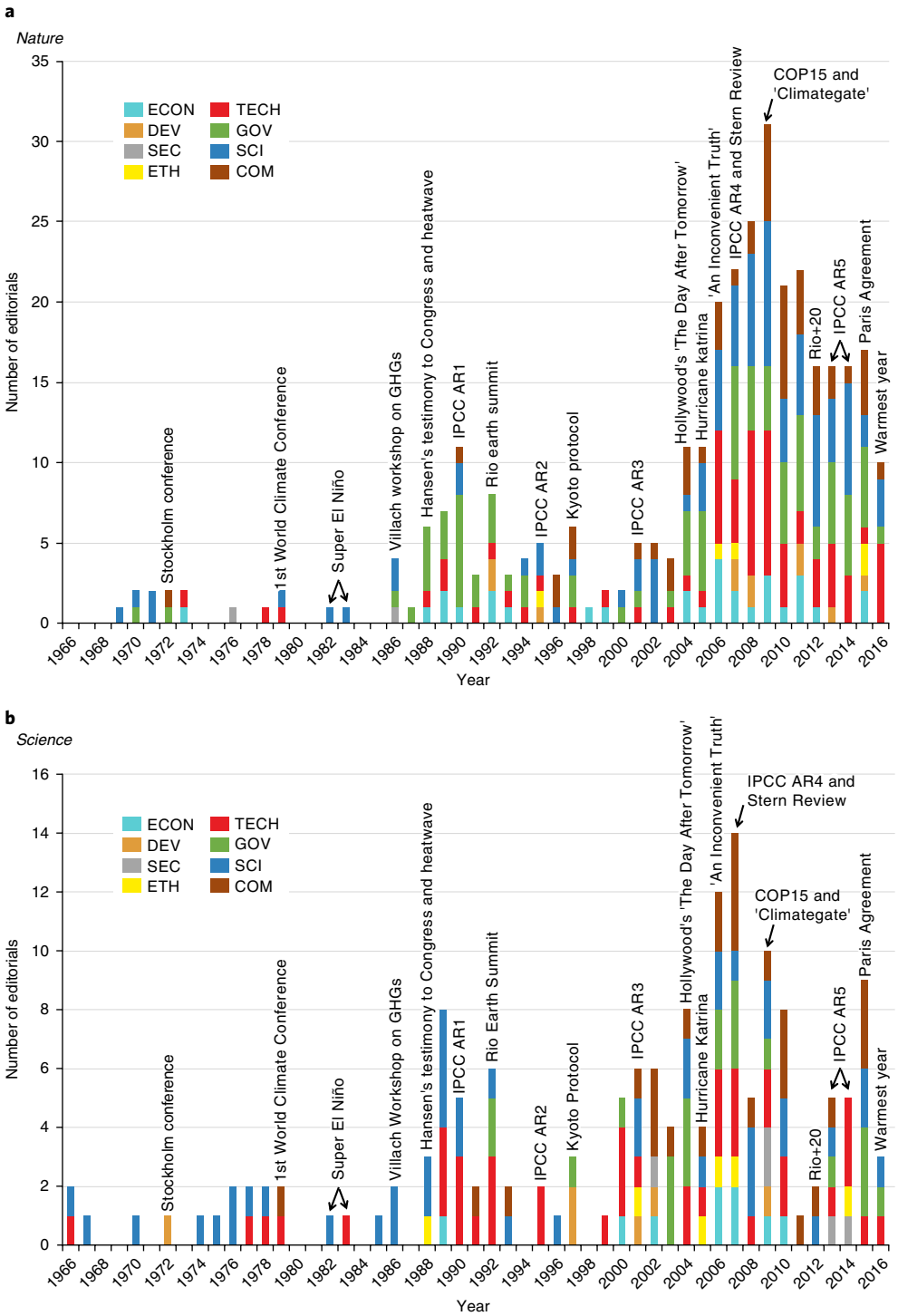

Fig. 1 | Primary challenge frames. a,**b**, Frequency of primary challenge frames by year in *Nature*'s climate change editorials ($n=333$) (**a**) and *Science*'s climate change editorials ($n=160$) (**b**). Some key scientific, political, cultural and meteorological events[1] relating to climate change are overlaid. ECON, economic/financial; DEV, developmental; SEC, national/international security; ETH, ethical/moral; TECH, technological; GOV, institutional/governance; SCI, scientific; COM, communication (see Table 2 for full frame code definitions).

example, ref. [39]) has been notable only since 2005. Since then, 6.5% of all editorials have adopted this challenge as their primary frame and a further 5.5% as an additional frame (Fig. 2).

Despite these broad similarities, there are some important differences in how these two journals editorialize about climate change. This is evident, for example, from the first attention peak during the AR1 era, 1988–1992. For *Nature*'s editorials in this period, climate change was primarily an institutional/governance challenge, whereas for *Science* it was largely either a technology/energy (42% of all editorials framed thus) or scientific (38%) challenge. In contrast to the 54% of *Nature*'s editorials during 1988–1992 framing climate change as an institutional/governance challenge, only 8% of *Science*'s editorials did so. *Nature* only began to give significant emphasis to the technology/energy challenges of climate change from the AR4

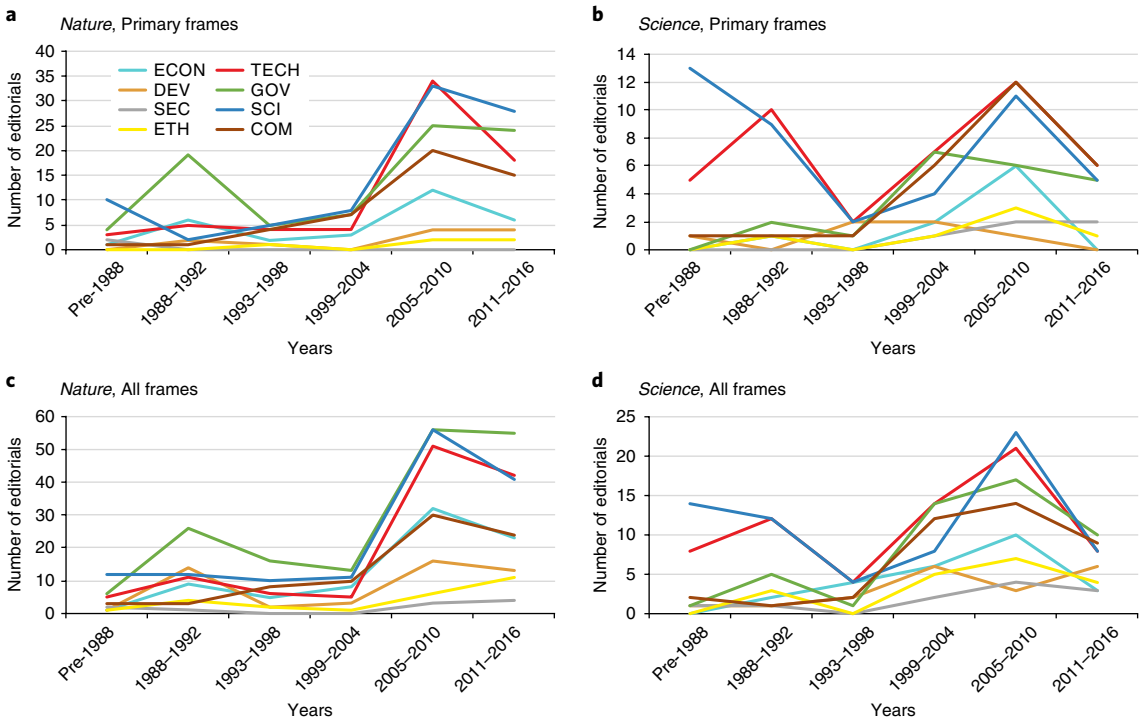

Fig. 2 | Challenge frames by IPCC era. a–d, Absolute frequencies of primary frames (**a**,**b**) and all frames (**c**,**d**) in *Nature* (**a**,**c**) and in *Science* (**b**,**d**) editorials for each IPCC era. ECON, economic/financial; DEV, developmental; SEC, national/international security; ETH, ethical/moral; TECH, technological; GOV, institutional/governance; SCI, scientific; COM, communication (see Table 2 for full frame code definitions).

era onwards, while *Science* only began seriously to emphasize the institutional/governance challenge from the AR3 era onwards (Fig. 2). Over the whole period of the study, *Nature* emphasizes the institutional/governance challenges of climate change much more than does *Science*: 51% of its editorials have this as at least one of its multiple frames, compared to only 30% for *Science*.

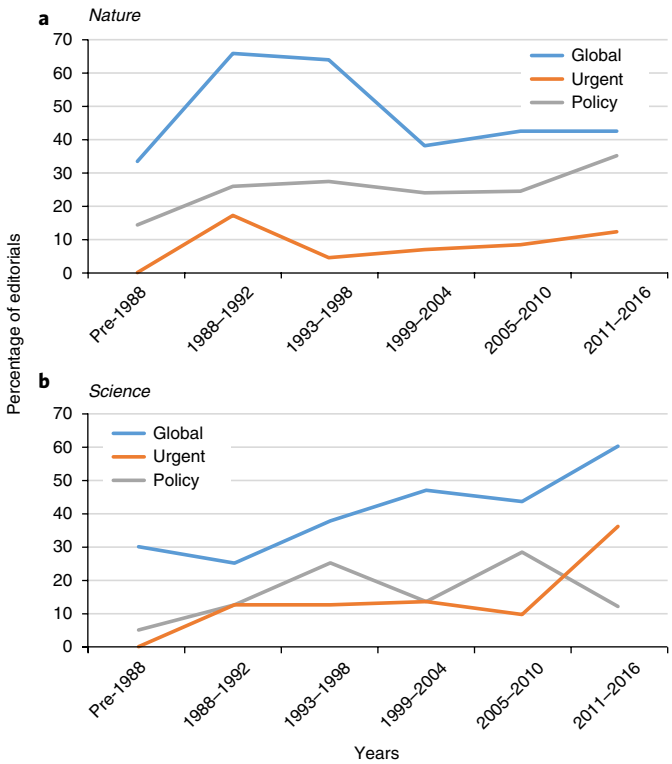

Fig. 3 | Attribute frames by IPCC era. a,**b**, Percentage of editorials in each IPCC era displaying specified attributes for *Nature* (**a**) and *Science* (**b**). For attribute definitions see Table 2.

There are also significant differences in the attributes attached to the two journals' editorials. Although both journals frequently frame climate change as a 'global' challenge, *Science* has increasingly emphasized this attribute over time, more than doubling from the AR1 era to the AR5 era its percentage of editorials so framed (Fig. 3). *Science* has also framed climate change more frequently as 'urgent', noticeably during the most recent AR5 era. Conversely, *Nature* has been much more willing to comment on policy instruments and measures (27% of editorials with the 'policy' attribute) than has *Science* (17%). In summary, while both journals frequently, and in broadly equal proportion (26% and 27%), primarily frame climate change as a scientific challenge (for example, ref. [40]), as might be expected, *Nature* pays more attention to the institutional/governance aspects of the challenge and is more engaged in discussing specific policy instruments, including economic/financial challenges. In contrast, *Science* emphasizes the technology/energy challenges of climate change and, especially latterly, the communication challenge.

Discussion

Although both journals have greatly increased their editorial attention to climate change in recent decades, this attention has been episodic, notably peaking around 1990, in the years leading up to 2009 and then again in 2015. These peaks are partly related to external events in the worlds of science (for example, IPCC reports), politics (for example, the Copenhagen Summit and the Paris Agreement), public culture (for example, films such as *An Inconvenient Truth*; controversies such as Climategate) and meteorological events (for example, the American drought of 1988). These attention patterns broadly follow those found elsewhere in popular media outlets, especially newspapers[1,34]. This suggests that *Nature*'s and *Science*'s editorial decision-making partly reflects the mainstream media's

framing of social problems. The editorials also reveal how, over time, climate change has become a sufficiently familiar matter of concern that it increasingly is used to illustrate wider issues that occupy editorial attention, for example, the relationship between science and development, the challenges of science communication, the internal organization of science, science funding and so on. This partly explains the diversification of frames noted above, especially notable in the case of *Science* (but here more diverse authorship is important; see later in this section).

Yet our results also reveal some significant differences in framings between the two journals. *Nature* has consistently emphasized the international institutional/governance challenges of climate change to a much greater extent than has *Science* and has remained more willing to comment directly on policy instruments and measures (for example, ref. [41]). In contrast, for a long time *Science* framed climate change predominantly in terms of either scientific or energy/technology challenges and yet in recent years has widened its framings considerably. It has retained a more sustained emphasis on the public communication challenges of climate change than has *Nature*, increasingly framing climate change as global and urgent (for example, refs [42,43]), while at the same time retreating in recent years from commenting directly on specific policy instruments and measures.

We suggest that the different political cultures in which these journals operate, and their different institutional histories, may partly explain these differences. *Science*'s editorializing is influenced by the polarized cultural politics of climate change found in the USA and by certain conceptions of the role and legitimization of science in society. These local influences on *Science* are reinforced by the journal's role as the 'house magazine' for the professional association of American scientists, which is the primary audience for its editorials. In contrast, *Nature* has no comparable institutional audience and yet it too operates within a distinctive political and epistemic culture. Its editorializing about climate change seems to reflect a more cosmopolitan perspective on science in general[21] and a more internationalist perspective on climate change in particular. This latter position is shaped by the distinct British/European self-perception of its 'climate change leadership'[44] extending back to the late 1980s. Although both journals report developments in international science and publish new science from all around the world, in this sense seemingly offering on climate change a 'view from nowhere'[45], neither journals' editorializing escapes the pull of their respective operating cultures. The differences in climate change framings found in these scientific journals have some similarities with those found in comparative trans-Atlantic studies of newspaper framings of climate change. US media frame climate change more as a scientific puzzle to be understood, compared to UK media, which engage more directly with solutions and policies[46].

Yet differences in political cultures are only part of the explanation for differences between *Nature* and *Science*. Also significant are the personalities, priorities and practices of the specific editors who commission or author individual editorials and the differences in the author profiles between the two journals. *Nature*'s editorials are always unsigned, leaving it ambiguous as to the specific authorial voices being expressed in each case. We know that *Nature*'s editor is 'ultimately accountable for *Nature*'s content'[26], and yet the cloak of anonymity is rarely if ever removed. On the other hand, *Nature* editor John Maddox's provocative stance with regard to environmentalism in the 1970s[21] undoubtedly influenced some of this journal's early editorial content on climate change[31], and Campbell's tenure as editor since 1995 means that he has commissioned (if not written) 80% of *Nature*'s climate change editorials. Campbell, an astrophysicist who first started working for *Nature* in 1979, has therefore exerted significant personal influence in developing *Nature*'s editorial stance on climate change over the last 25 years.

Science's practice of attributed editorials is in sharp contrast to *Nature* and means that it is possible to analyse authorship patterns and profiles (Supplementary Note 2). Around 57% of editorials have been authored directly by editors or other AAAS staff, but this still leaves a significant diversity of voices speaking for science through the editorials of *Science*. Only 16% of these authors had affiliations outside the USA. The influence exerted by specific editors at *Science* can also be traced, whether it be Abelson's focus on 'energy/technology' and 'science' challenges, the significant attention Kennedy gave from 2000 to climate change's 'communication' and 'institutional/governance' challenges, or McNutt's very deliberate foregrounding between 2013 and 2016 of female authorship (Supplementary Table 2). Inviting guest editorials is a practice that has become more common at *Science*, as too has co-authorship, and probably contributes to explanations of why its editorial framings of climate change have diversified more than those of *Nature* (Fig. 2). That *Science*'s editorials are always attributed is also significant with regard to their subsequent visibility. Although both journals' editorials have similar salience in terms of Altmetric scores, *Science*'s editorials are much more likely to be formally cited in academic literature (Supplementary Note 1), probably because attribution allows them to be traced more easily and unambiguously.

There are a number of limitations to this study. As with all framing analysis, unambiguous and fully objective frames are not attainable, although our careful iterative construction of the frame-set and our separation of 'challenges' from 'attributes', and of 'primary' from 'other' frames, affords a robust interpretative framework for analysis (see Methods). We have not been able to study at first hand, either through ethnography or interviews, the editorial decision-making processes that operate within these two journals. Such approaches might offer further insights into the boundary-ordering work[47] performed by these editorials. Also, there have been significant changes during the study period in scientific publishing culture and audience reach and attention that we have not analysed.

Our study offers a first sight of how editorializing attention and framing works in the case of climate change for *Nature* and *Science*. We suggest that scientific journal editorials could be studied more closely to reveal some of the ways in which science and society shape each other. They reveal some of the tensions between global kinds of knowledge brought forward by science and the local meanings of such universal knowledge when inserted into specific political cultures[48]. Editorials in science journals make important interventions across the boundaries of science, society, ethics and politics, whereby science stakes both its claim to epistemic authority and its relevance for policy-making. Yet these claims never entirely escape the centripetal pull exerted by the journals' institutional histories and political geographies. As geographers of science have frequently shown, 'place' matters in the making and interpreting of scientific knowledge[15,49,50]. However, this study has also shown that the profile and priorities of individual editors matter for the way in which, through their editorializing, these two leading science journals give shape and meaning to a challenge like climate change. Science never can nor ever does speak for itself, not least unto the worlds of climate politics and public policy. Understanding science's editorial filters, as exemplified here in the case of *Nature* and *Science*, also shows that science's editors never speak with one voice.

Methods

Methods, including statements of data availability and any associated accession codes and references, are available at https://doi.org/10.1038/s41558-018-0174-1.

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Author contributions

M.H. initiated and designed the study and led the writing of the manuscript. N.O. and M.H. extracted the corpus. M.H., N.O., S.R. and M.B. contributed to coding, analysis, interpretation and improvements to the text. N.O. and S.R. contributed statistical analysis and graphics. M.B. conducted a literature review, analysed citations and Altmetric scores, and extracted author details from *Science* editorials.

Competing interests

The authors declare no competing interests.

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Correspondence and requests for materials should be addressed to M.H.

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Methods

Establishing the preliminary corpus. One of the co-authors followed a strict protocol in which they went through every single issue of both journals from 1966 to 2016 and, using generous criteria of relevance, opened all editorials that could conceivably be related to climate change. Once in the document, they performed an initial keyword search to identify one or more of the following words: 'climate', 'greenhouse', 'carbon', 'warming', 'weather', 'atmosphere', 'pollution'. (Keyword searches for *Nature* editorials prior to 1998 were not possible because the digital copies of these editorials were scans of the print versions; these editorials were read in their entirety.) If one of these keywords was present the editorial was then read carefully to make a determination as to whether it could potentially be relevant for the study. Editorials were then saved in either a 'certain' or a 'maybe' folder. A triangulation was then performed against a 'corpus of opportunity' that the lead author had maintained in real time since 2003 (and back-dated to 1966) using a more subjective judgement of climate change relevance. This triangulation between two independent methods yielded a preliminary corpus with $n = 428$ for *Nature* and $n = 180$ for *Science*, accounting for between 6 and 7% of all editorials published by either journal. A further check on the corpus identification was enabled through comparison with ref. [23] (see 'Confirming the final corpus' section below).

Identifying frames and attributes. We adopted frame theory and analysis[53] in order to scrutinize systematically the ways in which *Nature*'s and *Science*'s editorials described and communicated climate change to their readerships. Frame analysis is a discourse analysis method, suitable for dissecting how an issue is defined and problematized. 'Frames' are interpretative storylines, created by authors and communicators, that help identify what is at stake in an issue; a frame reveals what an author feels is important about an issue. For this reason framing is never 'ideologically neutral'. Frame analysis therefore offers a rich way to explore how different actors (in our case, editorial authors) define an issue in strategic ways, offering common points of reference and meaning between author and reader[54]. Frames strongly hint at an assumed 'problem–solution formation'[53]. For instance, if climate change is presented principally as a technology/energy challenge, addressing climate change then becomes primarily a matter of mitigating emissions through energy systems transitions and innovation, rather than by attending to considerations about, for example, justice, governance, adaptation or resilience.

For the purpose of this research we constructed eight 'issue-specific' frames (that is, specific to the issue of climate change as engaged by *Nature* and *Science*) through a mixed inductive–deductive approach[54,55]. Before the coding commenced we formulated, deductively, eight candidate frames (and their definitions) drawing upon four frame criteria[56]: identifiable conceptual and linguistic features; commonly observed; easily distinguished from other frames; recognizable by others. The frames and definitions were then refined iteratively during the two pilot phases (see next section) as we inductively sought to apply the above four criteria. Working collaboratively together through small samples of the corpus helped the four authors identify areas where frames either overlapped or lacked clarity of definition.

This led us to make various changes to our initial (deductive) frame-set. First, we conceived of our frames as 'challenges' to better reflect the 'problem–solution formation' evident in many of the editorials. Second, we distinguished between 'challenges' and what we called 'attributes': that is, 'global', 'urgent', 'policy' (Table 1). These were attributes of the challenge rather than a distinct frame of their own and their presence or not in an editorial was identified using a binary classification. Third, following from the above considerations, we adjusted our frame-set by reclassifying one frame ('policy challenge') as an attribute and adding a new eighth challenge ('moral/ethical'). Finally, we decided to distinguish between the one 'primary' (that is, dominant) frame (challenge) of an editorial and any number of 'other frames'.

Pilot coding. For the purpose of testing and refining the frame-set and the coding framework, two pilot exercises were conducted. For each pilot, 15 editorials were extracted at random from each journal giving a pilot set of 30 editorials. All four authors then coded independently using a simple binary system (0 or 1) for the presence/absence of each frame and attribute. After the first pilot, the authors deliberated collectively on how to modify the frame-set and frame captions (see previous section). The readjusted (and final) coding scheme was then retested in the second pilot. Following this second pilot the authors resolved any remaining ambiguities in the frame captions and agreed on how to proceed with coding the whole corpus (see next section). Fleiss kappa scores (kappa scores adjusted for use with multiple coders rather than just two[57]), were used to measure inter-coder reliability between the four coders (authors) in each of the two pilots (Supplementary Table 5). Reliability scores increased between the two pilots, although they remained only moderate to fair. For this reason each author used an agreed colour code to flag editorials in the full corpus that they deemed particularly difficult to code and these were resolved through group deliberation (see next section). Coding 'attributes' was considerably more reliable than coding 'challenges' and kappa scores here revealed substantial agreement.

Coding the corpus. For coding of the full preliminary corpus, each of the 608 editorials was randomly allocated to one of the four authors. Each author had common instructions to highlight in red the editorials they judged should definitely be removed from the corpus, in orange the editorials that might be considered 'out of scope' and where a collective determination should be made, and in blue the editorials that were particularly difficult to code. In determining between the primary and 'other' frames of an editorial, authors interpreted the editorials in their historical context. In cases where an editorial referred to specific external documents or reports—which themselves framed climate change in particular ways—the authors coded the frames used by the author of the editorial, not the frames of the external source. Similarly, for editorials where climate change was mentioned as a substantive example of a wider issue, the authors judged the frame in which climate change was placed, not the framing of the wider issue (which on occasions could be at odds with each other). Finally, in coding 'other frames', the authors erred on the side of inclusion rather than exclusion (that is, if in doubt about the relevance of an 'other frame' the coders would include it).

Confirming the final corpus. The authors resolved through collective deliberation the coding decisions for all editorials that had been flagged red, orange or blue. Where the authors could not come to a consensus regarding the inclusion of particular editorials in the final corpus (less than 10 instances) the lead author made a final decision. The orange editorials that were included in the final corpus (28 for *Nature* and 11 for *Science*) were all coded collaboratively. All four authors also discussed and coded collaboratively each blue flag in the preliminary corpus (that is, where frame identification was judged particularly difficult). This subset consisted of 29 editorials in *Nature* and 17 in *Science*. Combining these two subsets meant that 85 of the more challenging editorials to code (57 in *Nature* and 28 in *Science*; around 17% of the final corpus) were coded collaboratively, thus assuaging to some degree the relatively modest kappa scores secured in the second pilot. The series of iterative processes described above were designed to reach consistent decisions regarding inclusion/exclusion of editorials in the final corpus and consistent judgements about frame codes.

The final corpus carried forward for analysis comprised 333 editorials for *Nature* (a loss of 30% of editorials compared to the preliminary corpus) and 160 editorials for *Science* (9% loss). The final corpus for the decade 2000–2009 was compared with that extracted by Waaijer and colleagues[23]. These authors extracted all *Nature* and *Science* editorials and, through an automated word search and subsequent cluster analysis, identified those that were deemed to be concerned with 'climate change' (note: their study was not concerned with climate change per se). For this decade Waaijer identified 80 such editorials in *Nature* and 65 in *Science*. This compared with 136 *Nature* editorials in the final corpus used in this study (70% more than Waaijer) and 74 for *Science* (15% more). These differences reflect the different methodologies—automated versus interpretative—and the fact that the current authors carefully read each candidate editorial before reaching a decision. This study also retained editorials in which climate change was a substantive example of a wider issue or concern, whereas Waaijer's analysis was designed to allocate all editorials to just one of 15 exclusionary editorial clusters.

Data availability. All the editorials analysed in this study are available through *Nature* and *Science* website archives. The details (date, title, volume, DOI) of the final corpus of 493 editorials designated 'climate change' are available at the public data repository FigShare, https://doi.org/10.6084/m9.figshare.5878303.v1.

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