Global and Planetary Change 74 (2010) 43–48

Contents lists available at ScienceDirect

Global and Planetary Change

journal homepage: www.elsevier.com/locate/gloplacha

Short communication

Geoscience meets the four horsemen? Tracking the rise of neocatastrophism

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ARTICLE INFO

Article history:
Received 24 March 2010
Accepted 4 July 2010
Available online 3 August 2010

Keywords:
geology
geoscience
geomorphology
catastrophism
neocatastrophism
uniformitarianism
disaster science

ABSTRACT

Although it is acknowledged that there has been an exponential growth in neocatastrophist geoscience inquiry, the extent, chronology and origin of this mode have not been precisely scrutinized. In this study, we use the bibliographic research tool *Scopus* to explore 'catastrophic' words replete in the earth and planetary science literature between 1950 and 2009, assessing when, where and why catastrophism has gained new currency amongst the geoscience community. First, we elucidate an exponential rise in neocatastrophist research from the 1980s onwards. We then argue that the neocatastrophist mode came to prominence in North America during the 1960s and 1970s before being more widely espoused in Europe, essentially after 1980. We compare these trends with the EM-DAT disaster database, a worldwide catalogue that compiles more than 11,000 natural disasters stretching back to 1900. The findings imply a clear link between anthropogenically forced global change and an increase in disaster research ($r^2 = 0.73$). Finally, we attempt to explain the rise of neocatastrophism by highlighting seven non-exhaustive factors: (1) the rise of applied geoscience; (2) inherited geological epistemology; (3) disciplinary interaction and the diffusion of ideas from the planetary to earth sciences; (4) the advent of radiometric dating techniques; (5) the communications revolution; (6) webometry and the quest for high-impact geoscience; and (7) popular cultural frameworks.

1. Introduction

Earth-shaping catastrophic events at various temporal and spatial scales have long focused the attention of the earth sciences (Clube and Napier, 1982; Albritton, 1989; Baker et al., 1993; Ager, 1993; Chapman and Morrison, 1994; Glen, 1994; Palmer, 1999; Courtillot, 1999; Gould, 2000; McGuire et al., 2000; Palmer, 2003; Hallam, 2004). Whilst the dominant paradigm in modern geology is that of uniformitarianism – an inductive theory stipulating that long-term incremental processes have shaped our environment – the past few decades have seen a substantial, but unquantified, rise in neocatastrophist inquiry. Catastrophism is the doctrine that many of the major changes in the earth's history have resulted from episodic cataclysms rather than gradualist processes. Unlike the inductive bastions of uniformitarianism (e.g. gradualism, actualism), catastrophism is underpinned by a system of logical inference, where hypotheses regarding events in the earth's history are formulated retroductively (Baker, 1998). The theory strongly shaped the nascent field of geology during the 1600–1800s, when pioneering European savants such as Cuvier pieced together mounting observational evidence for catastrophic events in the rock record (Rudwick, 2007, 2008).

During the mid to late 19th century, catastrophism as an overarching geotheory fell from primacy as Lyell's steady-state interpretative paradigm and Darwin's theory of 'gradual' evolutionary change gained momentum (Anderson, 2007; Rudwick, 2007). Gould (1987) has shown how Lyell, who trained as a lawyer, used rhetorical tricks to promulgate his geotheory, branding catastrophist detractors as religious fanatics. In this way, and although Lyell's gradualist ideas sat uneasily with a great deal of catastrophist evidence of the day, actualism – the understanding of present processes to make inferences about the past – grew to become the geosciences grand unifying theory during the 20th century.

Over recent decades, and in an effort to redress some of the straitjacket limitations of the classic uniformitarian model (Baker, 1998), neocatastrophism has been coined to describe a new integrated view that gradual changes in the earth's history have been punctuated by catastrophic events. Present emphasis on hazard mitigation means it is arguably one of the most important geoscience interpretative paradigms to influence the public and political spheres. Palmer (2003) has ascribed the origin of the term to Schindewolf (1963), a German palaeontologist who postulated that cosmic radiation caused the phases of rapid extinction and species turnover at the end of the Palaeozoic and of the Mesozoic. Around the same

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doi:10.1016/j.gloplacha.2010.07.005

time, seminal work by the planetary geologist Shoemaker demonstrated the importance of 'catastrophic' impacts on the moon and planets.

By the 1970s, these nascent neocatastrophist undercurrents led Brown (1974) to note '[…] a serious rejuvenation of catastrophism in geological thought'. However, it was not until the early 1980s that the new doctrine moved into mainstream geological thought, notably led by the Alvarez et al. (1980) theory to explain the extinction of the dinosaurs at the Cretaceous–Tertiary (KT) boundary. Catastrophism, or neocatastrophism, has since been reformulated by various scholars (e.g. Ager, 1993; Huggett, 1988, 1989, 1997) who increasingly realised that the rigidity of standard uniformitarianism could not explain all of the episodic particularities attested in the rock record. Some commentators have gone so far as to describe neocatastrophism as a paradigm shift, far more than plate tectonics for instance, the latter being in essence a fully gradualist conceptual framework and not as revolutionary as it is generally considered (e.g. Davis, 1996). In addition, overpopulation is significantly increasing the vulnerability of modern society to natural hazards. Despite these general trends, little attention has been paid to quantifying, or even systematically debating, the important shift in research paradigms during the past 30 years.

2. Methods

We used *Scopus* to research a non-exhaustive list of catastrophic words (*avalanche, catastrophic, disaster, earthquake, flood, hazard, landslide, storm, tsunami, asteroid impact, hurricane,* and *wildfire*) in the title, abstract and keywords of geoscience literature. *Scopus* is presently the largest abstract and citation database of peer-reviewed titles, cataloguing more than 16,500 peer-reviewed journals with more than 40 million records stretching back to 1823. We restricted the search to 'articles and review papers' in the 'earth and planetary sciences' with a time-series spanning 1950–2008 (Fig. 1). Searches before this date did not yield a statistically significant number of hits. We performed a second run of searches, refined to 'earth and planetary sciences' and 'author affiliations' to constrain the geographical origin of papers. We formed two data groups, North America (Canada and the USA) and Europe (France, Germany, Italy and the UK). All data are presented as percentages of the total hits to facilitate direct comparisons. Searches were restricted to English keywords only, a possible source of data bias that must be borne in mind when interpreting the data. It should also be noted that *Scopus* is a dynamic database that is continuously updated and expanded with new journal titles. Because disasters have an implicit human dimension, we compared and contrasted these trends with results from the EM-DAT, a worldwide database on natural catastrophes maintained since 1988 by the Centre for Research on the Epidemiology of Disasters at the *Université catholique de Louvain* (http://www.emdat.be/). The database, which is compiled from UN agencies, NGOs, insurance companies, research institutes and press agencies, contains ~11,500 natural disasters from 1900 to the present (Scheuren et al., 2008).

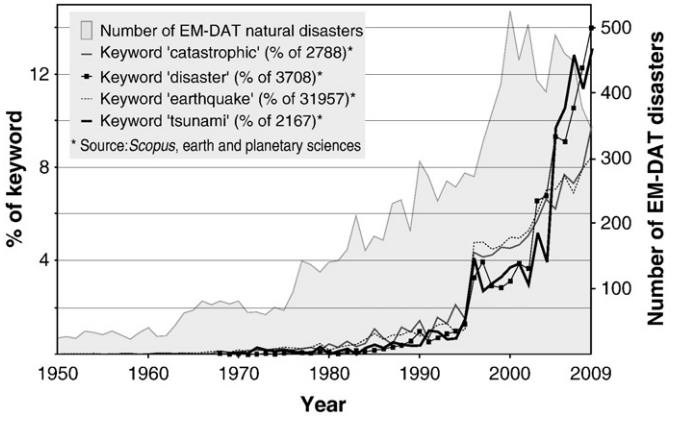

Fig. 1. EM-DAT natural disasters and selected *Scopus* keywords for the period 1950–2009.

3. Results and discussion

When? For the period 1950–2009, the bibliographic data show an exponential rise in catastrophic literature after 1990 (Fig. 1). For example, the keyword *disaster* generated a total of 3708 hits. Of these, 98% of the papers were published between 1990 and 2009 compared to a mere 2% between 1950 and 1989. The years 2003–2008 account for 69% of the total hits for the 59-year period. The keyword *catastrophic* generated 2788 hits, of which 91% are attributed to the period 1990–2008. The highest number of papers containing the latter word was published in 2009 (271 or 10 of total hits) and since 1990 literature containing the keyword *catastrophic* has grown at an average annual rate of 22%.

The most significant changes have occurred in relation to catastrophes that have received widespread media coverage. The Sumatra earthquake (December 2004), for instance, has prompted an unprecedented explosion in tsunami science. For the years 2005–2009, the keyword *tsunami* generated 58% of the total hits. We found that the number of tsunami papers more than tripled from 86 in 2004, the year of the disaster, to 211 in 2005, 229 in 2006 and 278 in 2007.

The EM-DAT disaster data also show a steady rise in the number of reported events, totalling 24 in 1950 against 378 in 2008. The upward trend has mainly been driven by an increase in the number of reported hydro-meteorological disasters, which totalled 272 in 2009 against a mere 17 in 1950.

What is the epistemological grounding for this new catastrophism trend? For the period 1970–2009, the keyword *catastrophic* generated a total of 2788 hits and shows an exponential rise in the number of papers after 1970. Since this time the number of *catastrophic* papers has grown at an average annual rate of 25%. Our view is that at present many geoscientists study catastrophic events without necessarily recognizing the broader neocatastrophist interpretative framework they are adhering to.

Where? We reanalyzed the data, refining searches to author affiliations. Who are the drivers of this neocatastrophist trend? We performed searches for Canada, the USA, Germany, France, Italy and the UK grouping these into North America and Europe in order to better discriminate the chief scientific protagonists of the shifting paradigm (Fig. 2). In most investigated cases, we found that the mode was born in North America, before moving across the Atlantic to Europe. There are also strong differences in the degree of increase, possibly resulting from research funding politics. For example, between 1950 and 1980, the keyword *hazard* generated 41 papers by North American geoscientists against 16 for Europe. The keyword *asteroid impact*, for the period 1960–1980, produced a total of 35 hits for North America against 4 for Europe. In nearly all cases, we established that catastrophic research terms coined in the North American literature during the 1960s–70s gradually permeated European geosciences, essentially from the late 1980s onwards. It is also important to bear in mind the role of regional differences in hazard types that can influence research agendas and funding. For instance, hurricane research has traditionally been more important in North America (1950 and 2009 hits = 1809) than Europe ($n = 286$) because the US' south-eastern seaboard lies in an active cyclone track.

Why? What is driving this new catastrophist literature? We ascribe the elucidated trends to seven factors.

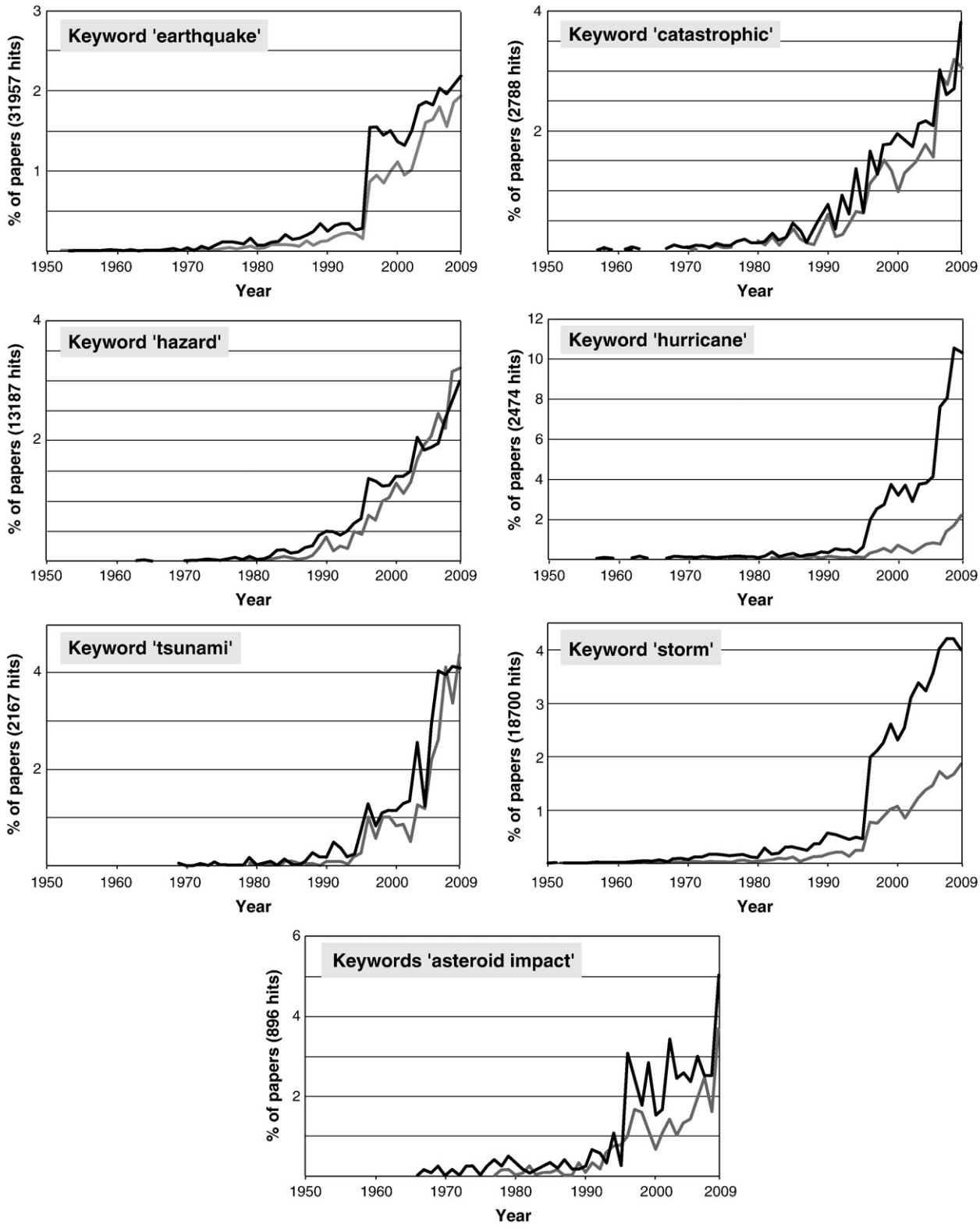

Fig. 2. Catastrophic keywords in the geosciences, grouped by geographical areas North America and Europe. Source: *Scopus*, earth and planetary sciences 1. North America (black line) = USA and Canada; 2. Europe (gray line) = France, Germany, Italy and the UK.

3.1. The rise of applied geoscience

Modern geoscience is an applied discipline that has become critical to explaining, predicting and alleviating natural hazards (Bryant, 2005). According to figures from the EM-DAT, between 1950 and 2009 a total of ~7 million souls perished in ~11,000 natural disasters, the vast majority of losses being attributed to developing countries. By multiplying research in these areas, it is hoped that methods to predict and warn of natural catastrophes will help alleviate the loss of human life. In 2009 alone, ~172 million people were affected by 345 natural disasters, with economic damage totalling some ~41 billion US dollars (http://www.emdat.be/, data extracted 04/06/2010).

Between 1950 and 2005, world population increased from 2.55 billion to 6.625 billion, and demographic pressures mean that more people than ever before live on lands subject to hazards (UNFPA, 2008). Around half a billion people, for instance, live on or close to deltas (McGranahan et al., 2007; Syvitski and Saito, 2007). A recent study by Syvitski et al. (2009) demonstrated that 85% of the world's deltas have suffered severe flooding during the past decade. They predict that under present IPCC sea-level rise estimates, delta surfaces susceptible to flooding could increase by up to 50% during the 21st century. To this end, the sharp upturn in neocatastrophist geoscience during the early 1990s coincided with the United Nation's International Decade of Natural Disaster Reduction (Lechat, 1990). It also underlines that policy makers and research funding bodies are increasingly influencing research directions in the geosciences.

Also, EM-DAT data suggest that there has been a rise in climate change related hazards since the 1950s. For example, of the ~11,000 reported natural disasters recorded between 1950 and 2009, 3% took place between 1950 and 1959 compared to 40% between 2000 and 2009. For the period 1950–2009, we obtained a good positive correlation ($r^2 = 0.73$) between the annual number natural disasters and the sum of twelve disaster-related keywords used in the earth-science literature (Fig. 3). Many scholars attribute this increase to rapid, anthropogenically forced, global change (e.g. IPCC, 2007a,b) although it is important to bear in mind that there have also been significant improvements in recording natural disasters, in addition to the societal imprints that underpin data collection and reporting (Bouwer et al., 2007).

While our interpretations posit that there is a link between anthropogenically forced global change and neocatastrophist science, we would also like to highlight six other contributory factors.

3.2. Inherited geoscience epistemology

From its origins through to present day, one of geology's defining concepts has been the characterisation of unconformities, be it in the traditional stratigraphic sense (Hooykaas, 1959) or from the standpoint of sequence stratigraphy (Catuneanu, 2006). We argue that the geological record of catastrophes closely mirrors scholarly focus on stratigraphic boundaries, namely characterising and understanding the mechanisms driving transitions from one geological era or period to another. For some commentators, the classic uniformitarian model, though widely accepted and integrated into present geoscientific frameworks, has long sat uneasily with the reality of the rock record (Ager, 1993). Neocatastrophism, therefore, provides a new self-contained framework in which both uniformity of process and atypical episodic events can be married into a more tightly integrated system, based on retroductive reasoning. Because no parametric controls are imposed a priori, this recast paradigm avoids the rigidities of probabilistic inference. It effectively circumvents any opposition between practical knowledge and imposed theoretical expectation by accommodating multiple working hypotheses.

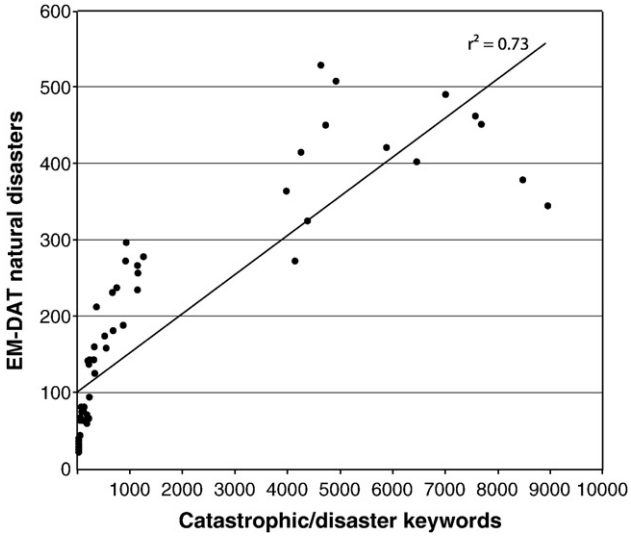

Fig. 3. Scatterplot of EM-DAT catalogued natural disasters versus sum total of twelve catastrophe-related keywords (*avalanche, catastrophic, disaster, earthquake, flood, hazard, landslide, storm, tsunami, asteroid impact, hurricane*, and *wildfire*) for the period 1950–2009.

3.3. Development of planetary geology and impact neocatastrophism

Since the pioneering work of Shoemaker during the 1960s, it has become widely accepted that most solid solar system bodies are covered with impact craters (Shoemaker, 1977; Mark, 1987). Increasing interactions between planetary and earth scientists, driven by a rise in multidisciplinary research, has led many of these ideas to filter through to the earth sciences (Glikson, 1999; Alvarez, 2003; Morrison, 2006; Chapman and Morrison, 2006). Indeed, the rise of early impact work in the planetary sciences effectively paved the way for the increasing acceptance of the KT impact scenario. For Allègre (1992), the inductive rigidities of uniformitarianism made it almost impossible to envisage an earth radically different from today, assembled by innumerable giant collisions. Seen in this light, neocatastrophism, therefore, has largely emerged to overcome these limitations and represents a more holistic paradigm to understand the history of the earth.

3.4. The radiometric dating revolution

One of the central Enlightenment debates regarding catastrophism related to geological versus young-earth creationist timescales (Rudwick, 2007). By the 1800s, and despite the strictures of religious orthodoxy, most eminent savants acknowledged that sufficient natural evidence was in place to discredit the young-earth theory as a factual absurdity (Knell and Lewis, 2001; Rudwick, 2007, 2008). Although strands of creationist science have been resuscitated in North American culture (e.g. Numbers, 1993; Schmidt, 1996), the democratisation of isotopic chronologies since the 1960s has allowed the age of episodic events recorded in the geological record to be precisely quantified (Allègre et al., 1995). Significantly, present geoscience is characterised by the substitution of relative chronostratigraphies, based namely on biostratigraphy and correlative geomorphological units (e.g. moraines and river terraces), by geoscience metrics (e.g. Jourdana et al., 2009). We argue that this technological advancement – the ability to precisely date catastrophic events in the rock record – has not only stimulated a growth in this research area (Courtillot, 1999) but also reinforced the scientific validity of neocatastrophism as a robust, empirically based, interpretative paradigm. This new stance is an inheritance of logical positivism, which posits that authentic scientific knowledge can be solely based on verifiable empirical data.

The replacement of relative stratigraphies by absolute chronologies is a fundamental facet of neocatastrophist progress because it makes it possible to determine the actual duration of geological events, some of which have been found to be much briefer than uniformitarianism would predict. For instance, the KT boundary at Gubbio in Italy is a clear case in point (Alvarez et al., 1990). Quantification of geological time has therefore significantly impacted upon the theory and practice of modern geology, and renders impossible a rigid adherence to Lyellian uniformitarianism.

3.5. The Internet revolution

The Internet has led not only to the globalisation but also standardisation of research modes and evaluation. It has brought about a disintegration of inward looking national schools of geoscience, long hampered by language and communication barriers. English is today the *lingua franca* of scientific discourse and cyberspace has transgressed national frontiers to greatly facilitate the exchange of research ideas and modes (Orme, 2002). For instance, we investigated 195 countries by author affiliation for the keyword *catastrophic* to elucidate an exponential growth in the number of nations producing papers from 1990 onwards (Fig. 4). We attribute this trend to the communications revolution. From 1 to 16 countries between 1970 and 1990, the number increased to 17 or more after 1991 and has been consistently greater than 30 since 1998. We found that the most diverse year for catastrophic production was 2009 (54 different countries). This spatial diffusion of neocatastrophism is also taking place within the context of a strong development of geoscience literature in general, which includes the emergence of new global players such as China and India, who were respectively ranked 5/101 and 11/101 for total geoscience production by the 2008 *Journal Citation Reports*.

3.6. Scientific production and the 'broad audience' race

With the development of bibliometry during the 1960s, and the revolution of webometry since the mid-1990s (Garfield, 2006), we suggest that the quest for high-impact geoscience has also played a role in the development of neocatastrophism. The 'shock doctrine' – at whatever temporal and spatial scales – has broad readership appeal. This trend has been emphasized by increasing difficulties in obtaining research grants and an evolution towards applied geoscience, in a world perceived to be increasingly vulnerable to global change. The geoscience community is quintessentially adapting to shifting socio-political demands of the discipline, a central tenant of which is establishing the probabilities of natural hazards.

The politics of high-impact journals (*Nature, Science* etc.) is particularly revealing (Bollen et al., 2006). These well-respected publication forums are in the hands of full-time professional editors, invariably with a PhD background in their field of expertise, but nonetheless holding the function of a journalist with a media agenda. As Hecht (2009) recently stressed 'few editors can resist a disaster story […]. Reporters tend to find slow (geological) change boring, and focus on dramatic events such as earthquakes.' Pressure on young scientists to publish in high-impact journals (Weingart, 2005; Maslin, 2006) renders neocatastrophism a particularly attractive area of the earth sciences in which to undertake research. Current emphasis on citation indices to gauge scholarly production has further accentuated this trend (Hirsch, 2005; Ball, 2005).

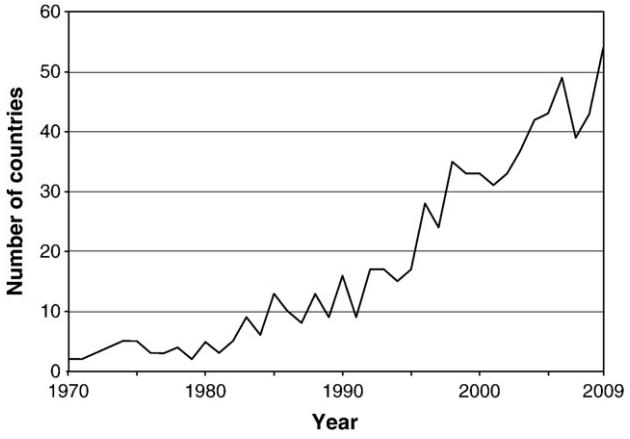

Fig. 4. Number of different countries having produced literature containing the keyword *catastrophic* since 1970. We searched a total of 195 different countries, 97 of which produced a positive hit of one or more. Since 1998, more than 30 nations have annually produced literature containing the keyword *catastrophic*. In 2009, the most productive neocatastrophist countries were ranked (1) the USA, (2) China, (3) Italy, (4) the UK, and (5) France and Germany (keyword *catastrophic*).

3.7. Cultural frameworks

The heightened public perception of large-scale environmental disasters is equally significant in framing public consciousness of catastrophes. This idea follows the 'risk society' thesis popularised in the 1990s (Beck, 1992): increased access to knowledge (through internet media, for instance) of disasters in modern societies creates neither a state of hysteria, nor of apathy, but rather societies organising 'around', and accommodating with, the catastrophe: from repeated media rhetoric to developments in urban design (Buell, 2003; Coaffee, 2008). Perhaps, therefore, 'risk society' has become 'apocalyptic society': public and academic prioritisation of catastrophes is premised not only upon access to knowledge of their occurrence, but their all-pervasiveness in mediatised social discourses (Hulme, 2008). The use of disaster imagery has also been powerful in shaping both popular and academic focus on neocatastrophism.

In terms of the history of their relationship to crises, we also argue that New World perceptions of nature are inherently different to those in Europe. For instance, EM-DAT data demonstrate that, between 1950 and 2009, North America was subject to 851 natural disasters compared to 377 in Western Europe. A heightened awareness of a certain *geology* of catastrophe in the place one lives, in other words – Davis' (1998) study of the catastrophic landscape of Los Angeles since the 1990s is a good example – shapes not only scientific research and policy, but cultural and popular imagination.

4. Conclusion

Does the catastrophism of today have the same meaning as in the past? Catastrophism has undergone unusual permutations in meaning from its traditional sense and at present there is no universally accepted definition, or even an absolute or relative scale, of what constitutes *catastrophic* or *neocatastrophism*. Indeed, Babin (2005) notes that the vocabulary has become inherently polysemic and axioms such as *episodism* and *convulsive events* have all been advanced to describe the new approach. The growth of geoscience history since World War 2 has significantly refocused attention on Early Modern and Enlightenment geological thought, and more specifically the catastrophist ideologies that underpinned the discipline throughout this period (Oldroyd, 2002; Rudwick, 2007, 2008).

Since the 1980s, we argue that there has not only been an exponential rise in the reporting of disasters but also a significant downscaling of episodic geological events from global (e.g. the Alvarez et al. asteroid theory) to regional (e.g. the 2004 Sumatra earthquake), or even local (e.g. the 2009 Abruzzi earthquake) catastrophes. These reflect the different ecological impacts, physical processes, human casualties and levels of energy involved. Whilst uncertainty can undermine scientific authority in socio-political spheres, neocatastrophism is unique in that it has exploited the 'uncertainty' of risks and hazards to harness significant research funding (Mellor, 2010). We suggest that much of catastrophism's newfound popularity reflects not only the rigidities of the classic uniformitarian model (Baker, 1998), but also socio-political anxieties in the face of global change. The reporting of catastrophes is undoubtedly increasing in reply to a plethora of social, economic, political and cultural drivers and to address these acute societal concerns, the geoscience community is adapting and responding accordingly. The role of the geosciences in predicting and alleviating

the impact of natural hazards is, at present, one of the discipline's key challenges.

Acknowledgements

We wish to thank W. Alvarez, C. Babin, V. Baker, O. Bellier, C. Koeberl, P. Leveau, M. Provansal, I. Stewart and an anonymous for their fruitful remarks on earlier versions of this manuscript. This work was supported by ANR PALEOMED, CNRS PEPS SHS and CNRS PEPS INEE.

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