

Claiming and adjudicating on Mt Kilimanjaro's shrinking glaciers: Guy Callendar, Al Gore and extended peer communities

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In Press with *Science as Culture*

Revised version submitted 15 July 2009

Abstract

Climate change has mutated from being a physical phenomenon to be studied to an idea to be contested. The sites of adjudication between competing truth claims have therefore moved from the secluded academy and scientific peer review to the vociferous agora and the extended peer community. This move is illustrated here using the case of the shrinking glaciers of Mt Kilimanjaro. Both the British engineer Guy Callendar, in 1944, and the American campaigner Al Gore, in 2006, claimed that the primary cause of this glacial recession was rising world temperature. Both were passionate believers in the reality of human-induced global warming, but they had very different resources at their disposal to advance these beliefs. While Callendar's claim was revealed only to the editor of the science journal *Nature*, Gore's claims were visible to millions through his film *An Inconvenient Truth*. While the force of Callendar's claim was weighed and adjudicated by one peer reviewer, the validity of Gore's claim was tested very publicly in the British courts. Both claims about the cause of Kilimanjaro's retreating glaciers were found wanting. The paper argues that this simple, but powerful, comparison between identical claims-making drawn from two different eras of science, yet with contrasting processes of truth-adjudication, illuminates the different 'post-normal' world of science climate change now inhabits. The case study is used to reflect on the role of the extended peer community in establishing and validating scientific knowledge about climate change: who participates, how trust is stabilised and whether science is thereby democratised.

Keywords post-normal science, Kilimanjaro glaciers, global warming, adjudicating truth claims, extended peer communities

"A thick veil of snow had settled on Kilimanjaro ... over breakfast, we gazed at the peak filling the sky above the palm trees of our hotel courtyard in Moshi ... it was as Hemingway described it: "as wide as all the world, great, high, and unbelievably white in the sun.

*Four days later, when we reached 19,340-foot Uhuru, the highest point on Kibo, we beheld snow and ice fields so enormous as to resemble the Arctic. It looked nothing like the photographs of Kibo nearly denuded of ice and snow in the Al Gore documentary *An Inconvenient Truth*. Nor did it seem to jibe with the film's narrative: "Within the decade, there will be no more snows of Kilimanjaro."*

As it turned out, we had simply been lucky ... several weeks of heavy rain and snow preceded the arrival of our group. That made for a freakishly well-fed snow pack and the classic snowy image portrayed on travel posters, the label of the local Kilimanjaro Premium Lager and the T-shirts hawked in Moshi's tourist bazaars. But to many climate scientists and glaciologists who have probed and measured, the disappearance of the summit's ice fields is inevitable and imminent.

Descending the final 4,800 feet of elevation to ... the Keys Hotel in Moshi that night, the local lager was the official beverage of our victory celebration. On its label, at least, Kilimanjaro's snows would never disappear."

Modie,N. (2008)

Introduction

Ernest Hemingway's 1936 short story *The Snows of Kilimanjaro* gave global visibility to the anachronistic tropical glaciers sitting on top of Africa's highest mountain: 'As wide as all the world, great, high, and unbelievably white in the sun, was the square top of Kilimanjaro' (Hemingway, 1938). These glaciers feed the rivers of the local Chagga farmers, act as a consummate symbol of Tanzania and – partly because of the juxtaposition of glaciers and Equatorial heat - possess worldwide iconic and aesthetic appeal. But Kilimanjaro's glaciers have also become the site of scientific contestation over claims regarding their future prospects of survival in a warming world.

In Al Gore's 2006 film *An Inconvenient Truth*, the snows of Kilimanjaro were given new prominence through being offered as a powerful visual symbol of the effects of global warming on the natural world. The performative role of these disappearing tropical glaciers in Gore's climate change narrative offers a poignant appendix to their literary and metaphorical deployment in Hemingway's novel. But Al Gore was not the first to claim that the glaciers of Mt Kilimanjaro were shrinking because of global warming. More than sixty years earlier in 1944, Guy Callendar - the first person to publish scientific claims of the association between rising atmospheric carbon dioxide concentrations and warming world

temperatures - also contended that the observed retreat of the ice on Tanzania's 'shining mountain'¹ was due to a rise in global temperature.

Both Gore and Callendar were making similar claims about cause and effect – a warmer world was leading to melting Kilimanjaro ice. And both men were passionate about the underlying truths they believed were at stake. In Gore's case it was the 'truth' that humanity was changing global climate on a grand scale and that purposeful and immediate political interventions were necessary to arrest the portentous consequences. In Callendar's case it was the 'truth' that rising atmospheric concentrations of carbon dioxide were leading to a warming of the world's temperature with observable consequences for geophysical phenomena.

The two claims about Kilimanjaro's glaciers – made over sixty years apart - were both rejected as unsound. Gore's claim came under public scrutiny in the British Courts and was adjudicated by a publicly appointed High Court judge. The repercussions of this judgement were for high school education in England and for the scientific credentials of a high-profile documentary film. Callendar's claim was adjudicated privately through an exchange of letters with a nominated peer-reviewer. The repercussions were only for Callendar's publishing portfolio.

This paper investigates these two claims about Kilimanjaro's shrinking glaciers, in particular the two contrasting processes of adjudication to which they were subject. This investigation is placed in the context of 'post-normal science' (Funtowicz & Ravetz, 1993) and its idea that 'extended peer communities' are deployed in the construction and quality assurance of knowledge. The adjudication of Gore's claim is used to examine aspects of participation, trust and democratisation in the operation of extended peer communities. Three questions in particular are addressed: Who participates in an extended peer community and how do they gain entry? Given its heterogeneity of norms and practices, how is trust established and stabilised within the peer community? And, thirdly, does the engagement of an extended peer community contribute to a democratisation of science?

The case of Kilimanjaro's glaciers is of notable interest in the politics of climate change knowledge. These physical glaciers have become a virtual site which can be invoked for the (in)validation of scientific knowledge about climate change impacts (this paper), for the visualisation of climate change (Doyle, 2006) and for the adoption of cultural icons in the public communication of climate change (O'Neill & Hulme, 2009).

The paper first introduces the idea of extended peer communities as envisaged within the practice of post-normal science and considers the ways in which scientific knowledge is validated in different institutional settings. It then summarises the two cases of claims-making and truth adjudication involving Gore and Callendar from, respectively, 2007 and

¹ The etymology of the word 'Kilimanjaro' is obscure. Various alternative translations include 'the little mountain', 'the great mountain' and 'the mountain of caravans' (Hutchinson, 1965).

1944, these two narratives linked by a résumé of the current status of scientific understanding of Kilimanjaro's glaciers. I then discuss the contexts in which these two adjudications were undertaken – similarities, differences and consequences – before returning to the idea of extended peer communities.

Post-normal science and extended peer communities

It is no longer possible to view science in the autonomous, self-governed way that Polanyi idealised in his 1962 article 'The Republic of Science' (Polanyi, 1962a). Neither is it possible to see scientific knowledge unproblematically as the neutral outcome of a steadily advancing pursuit of an objective and universal truth. Where science is practised, in what era, by whom and for what purpose, affects the knowledge that science produces. Science not only has its methodologies, but it also has its histories, geographies and sociologies (Shapin, 1998). And how scientific knowledge travels within and across societies, how it is mobilised and deployed by different social actors, has a significant bearing on its status and cultural authority.

This changing appreciation of the nature of science and its role in society is particularly evident in the environmental sciences. Grasping the significance of this change is essential if we are to understand what science is able to tell us about climate change. Science is being called upon to do more than answer questions such as: 'Is the world getting hotter?' and, if so, 'Why?' These are hard enough questions which tax the observing systems, routine measurements, physical theories and computer models of conventional science. Climate change has emerged as a phenomenon which asks much more demanding questions than just these. It is framed as an environmental risk of global proportions in which humans are implicated both as perpetrator and as victim and where political judgements and policy decisions need, urgently, to be made. Climate change has become a classic example of what philosophers of science Silvio Funtowicz and Jerry Ravetz have termed 'post-normal science' (Funtowicz & Ravetz, 1993; Ravetz, 1999). Normal science - science as guided by sociologist Robert Merton's four norms of scientific practice: scepticism, universalism, 'communism', disinterestedness (Merton, 1973) - is no longer fit for purpose.

One specific concession that Polanyi's republic of science has now therefore to make is in respect of expertise. The 'post-normal' character of climate change demands that a wider range of experts are entitled to bring forward evidence of relevant knowledge and that new institutional arrangements and settings should be found for adjudications about the validity of such knowledge. Scientists do not exhaust the sources of expertise or authority to which society may turn in seeking legitimate evidence to inform decisions (Wynne, 1996) and the peer-review practises of Polanyi's republic do not exhaust the means by which truth claims can be adjudicated (Scott, 2007).

The definition of who counts as an expert in the creating, handling, authenticating and communicating of scientific knowledge therefore needs careful scrutiny. Or as Harry Collins

puts it, how do we distinguish between ‘those who know what they are talking about’ and those who don’t? (Collins & Evans, 2007: 2). For example, when Al Gore presents scientific claims about climate change in his film *An Inconvenient Truth* is he speaking as a politician, a lay expert or as a spokesperson for science – and does it matter if, as has been claimed, he gets some aspects of the science wrong? The scientific academy carefully polices its membership and internal debates through the conventions of formal qualifications, election to professional societies and through the operation of the peer-review system. Yet even here there are different types of expertise at work. In their extended essay on the nature of expertise, Collins and Evans (2007: 14) introduce the idea of ‘interactional’ expertise as a complement to the more conventional ‘contributory’ expertise. Contributory expertise is ‘what is needed to do an activity with competence’, whereas interactional expertise is ‘the ability to master the language of a specialist domain’ with or without contributory expertise. Thus Gore may claim to be an interactional expert, but he is not a contributory one. Both forms of expertise, it is claimed, are at work in the conventional scientific peer review system.

Questions of expertise with respect to climate change have become more contentious in recent years if only because of the ‘high stakes’ and ‘urgent decisions’ characteristics of post-normal science. In their 1993 article ‘Science for the Post-normal Age’, Funtowicz and Ravetz foresee four strategic roles for an enlarged community of experts in post-normal science practice: in commissioning research, in knowledge construction, in knowledge adjudication and in quality assurance. Developing what they termed ‘extended peer communities’ is therefore beneficial both to the resolution of complex policy issues which required scientific inputs and also to the actual processes of scientific investigation.

Others too have advocated greater lay expertise to operate in the governance of science in order to democratise science (Wynne, 2006) and give greater credibility to the unwritten contract that exists between science and society. The supposed benefits of including lay expertise in the governance of science – upstream engagement (Wilsdon & Willis, 2004) - include ‘ensuring researchers are addressing the right questions, incorporating the knowledge of these non-academic experts in the analysis, and testing the validity and practicality of any prescriptions researchers are proposing’ (Scott, 2007: 829).

Upstream engagement is the mode of public participation in science that Demeritt (2006) describes as ‘Beck₂’, in which the public take on a normative rather than an epistemic role. Demeritt is seeking to clarify Ulrich Beck’s earlier call for the public to take on the role of an ‘open upper chamber’ in the parliament of science (Beck, 1992). Upstream engagement contrasts with the mode of participation Demeritt designates ‘Beck₁’, a mode which seems to imply that ‘the role for public participation is to double-check the adjudications of fact and truth performed by the lower house of science’ (Demeritt, 2006: 450). This epistemic role of ‘discursive checking’ of scientific results by an extended peer community has a number of problems associated with it, as elaborated by Demeritt and also by Collins and

Evans (2007). It also places a high premium on maintaining ‘trust’ within the extended peer community (Healy, 1999).

Trust, too, is central in the legal adjudication of knowledge and in the ways in which the legal system offers new sites for the extended peer community to reach judgements on the validity of scientific truth claims. Most visibly in the fields of medicine, biotechnology, patents and forensics, but now increasingly in the environmental sciences, the worlds of science and law are mutually at work shaping each other (Jasanoff, 2008a). How courts admit and handle scientific ‘truth’ and how in turn legal processes shape scientific ‘truth’ is a crucial part of the story of how knowledge stabilises social order. As Jasanoff (2008a: 762) claims, ‘... the law is now an inescapable feature of the conditioning environment that produces socially embedded science’. The judiciary too are part of science’s extended peer community.

So the extended peer community and its role in the commissioning, constructing, adjudicating and quality assuring of scientific knowledge certainly seems a long way from Polanyi’s 1962 self-governing autonomous republic. But we should perhaps be cautious in drawing too bold a distinction. It is questionable whether science ever operated quite in the way that Polanyi described (Jha, 2002; Turner, 2008) and it is also questionable whether Polanyi himself ever fully believed it did. Fischer and Mandell (2009) have recently argued that Polanyi’s greatest contribution to the philosophy of science – the idea of personal or ‘tacit’ knowledge (Polanyi, 1958) – takes science in the direction of requiring ‘a multicultural perspective and a cultural democratic orientation’, both elements of the extended peer community articulated by post-normal science.

Let us now turn to the case of the snows of Kilimanjaro and introduce the two claims made by Gore and Callendar about the cause of the shrinking glaciers. We will then be in a position to consider how this case illuminates the changing nature of truth adjudication in science and how an extended peer community has operated in the case of climate change knowledge claims.

Al Gore’s claim

In May 2006, the film *An Inconvenient Truth* was put on general release, initially in the United States and later world-wide. It is a documentary film about global warming presented by US politician Al Gore and became the fourth highest grossing film documentary of all-time. The film had the deliberate goal of public awareness-raising of climate change and inducing behavioural change towards lower carbon lifestyles.² Its perceived impact was undoubtedly one of the factors that led to Al Gore being awarded,

² The website for *An Inconvenient Truth* - www.climatecrisis.net - contains specific information and printable tips that are meant to foster individual efficacy, including information about how each individual can reduce his or her impact on climate change at home, in commuting, and even nationally and internationally.

jointly with the Intergovernmental Panel on Climate Change (IPCC), the 2007 Nobel Peace Prize. The citation for the Prize stated it was awarded ‘for their [Gore’s and the IPCC’s] efforts to build up and disseminate greater knowledge about man-made climate change, and to lay the foundations for the measures that are needed to counteract such change.’

In the film – and in the companion book *An Inconvenient Truth* (Gore, 2006) – Gore builds his argument that global warming is real, is largely caused by human emissions of greenhouse gases and the effects are already visible on a wide range of meteorological, geophysical and ecological indicators. His message is that humanity has the capacity and moral obligation to limit global warming and urges his audience to do so quickly through political and personal actions. Gore prefers to rely on empirical evidence of present-day climate change rather than on model-based projections, a strategy which offers some iconic and stunning visual imagery, but which may potentially be scientifically ambiguous (North, 2007).

One of a number of iconic images used to convince his audience that global warming is happening is the ice-cap on Mt Kilimanjaro. Both in the film and in the companion book Gore presents two photographs of the mountain, one from 1970 and one from 2000: ‘This is Mt Kilimanjaro in 1970 with its fabled snows and glaciers. Here it is just 30 years later – with far less snow and ice’ (Gore, 2006: 42-43). The implication is clear and is reinforced by a further photograph of an expert glaciologist standing next to a forlorn sliver of ice: ‘Here is Lonnie Thompson at the top of Kilimanjaro in 2000 with the pitiful last remnants of one of its great glaciers. He predicts that within 10 years there will be no more ‘snows of Kilimanjaro’’ (Gore, 2006: 44-45)³. The study cited here is by Thompson et al. (2002), discussed below.

The documentary made a big impact on the viewing public, especially in the United States (Haag, 2007; Quiring, 2007; Luke, 2008; Rosteck & Frentz, 2009), but also in the UK. On 2 February 2007 the British Government announced that it was to distribute the film on DVD to England’s 3,385 secondary schools as part of a climate change educational package. It was subsequent to this decision that Gore’s claim about the disappearing glaciers on Mt Kilimanjaro being caused by human-induced global warming was challenged. But the challenge to this ostensibly scientific claim came not from a scientist, a scientific association or even an educational committee. The challenge came from a member of the public, Stuart Dimmock - a lorry driver, a parent of two children and on the governing board of his local secondary school in the town of Dover in Kent.

³ The narrative in the film is very similar: “It [the CO2] just keeps going up. It is relentless. And now we’re beginning to see the impact in the real world. This is Mt Kilimanjaro more than 30 years ago ... and more recently. And a friend of mine just came back from Kilimanjaro with a picture he took just a couple of months ago. Another friend of mine, Lonnie Thompson, studies glaciers. Here’s Lonnie with the last sliver of one of the once mighty glaciers. Within the decade there will be no more Snows of Kilimanjaro.” (*An Inconvenient Truth* DVD: 15.46 to 16.12)

Gore's claim about the 'snows of Kilimanjaro' was part of the evidence Dimmock cited in a law suit which was brought against the Secretary of State for Education and Skills (David Miliband) in May 2007 complaining that the film was 'politically partisan' and did not present impartial scientific analysis of climate change: 'It should concentrate on the science and give a fair understanding of where the doubts are, and why ... Al Gore's film is too much political rhetoric rather than a proper study of the issue' (Dimmock, 2007). Through a judicial review he sought a High Court ban on the film being shown in schools because it would violate section 406(1)(b) of the 1996 Education Act. This Act requires that local education authorities, school governing bodies and head teachers 'shall forbid... the promotion of partisan political views in the teaching of any subject in the school'.

The judicial review - with four days of hearings - was presided over by Justice Sir Michael Burton. Expert written evidence was submitted by both sides: from Professor Robert Carter of James Cook University in Queensland on behalf of the plaintiff and from Dr Peter Stott of the Met Office Hadley Centre on behalf of the defence. Burton's ruling on 10 October 2007 found that although the overall message of the film that humans were altering global climate was sound, there were nine scientific 'errors' in the claims presented. Burton ruled that the film could only be shown in schools if accompanied by an amended guidance note to teachers from the Department for Education and Skills which 'pointed out where Gore's view may be inaccurate or departs from the mainstream scientific opinion' (Royal Courts of Justice, 2007: paragraph 40). Unless such amended guidance was issued the film when shown in schools, with its implicit endorsement of 'scientific errors', would breach UK education laws. Justice Burton said: 'I conclude that the claimant substantially won this case by virtue of my finding that, but for the new guidance note, the film would have been distributed in breach of sections 406 and 407 of the 1996 Education Act' (BBC, 2007).

One of the nine cited 'errors' was indeed the claim about Kilimanjaro's snows. With regard to Gore's assertion that the disappearance of snow on Mt Kilimanjaro was expressly attributable to global warming, Justice Burton ruled that 'it is common ground that the scientific consensus is that it cannot be established that the recession of snows on Mt Kilimanjaro is mainly attribute to human-induced climate change' (Royal Courts of Justice, 2007: paragraph 29). Let us briefly turn to the scientific arguments behind this judgement.

Kilimanjaro's glaciers – a résumé

No-one disputes that the glaciers on Mt Kilimanjaro have recessed markedly during the twentieth century (Figure 1). The first scientific survey of the glaciers in the late nineteenth century by geologist Hans Meyer estimated their areal extent at about 20km² and that the break-up of these ice bodies was already proceeding (Myer, 1900). Recent estimates from aerial photographs suggest between 80 and 90 per cent of this extent has subsequently been lost, the ice cover in the year 2000 amounting to about 2.6km² (Thompson et al.,

2002). In this same study Thompson used cores from the remaining ice fields to reconstruct climatic conditions over the last 12,000 years. They projected the disappearance of Kilimanjaro's ice fields by between 2015 and 2020, an outcome which would result in the absence for the first time during the entire Holocene period of the 'Snows of Kilimanjaro.'

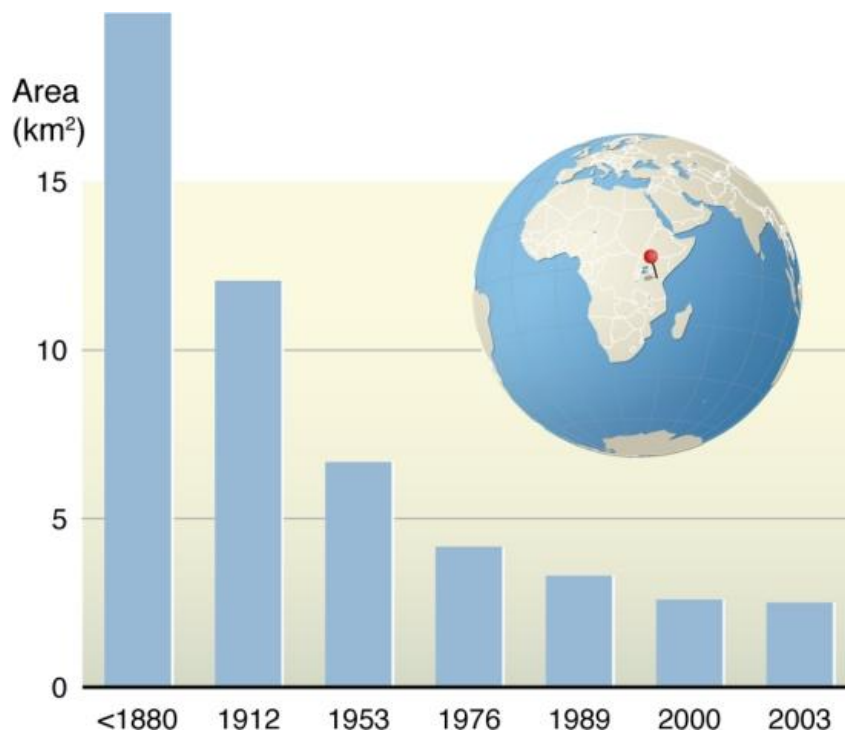


Figure 1: The reduction of the ice cover on Mount Kilimanjaro since the first observations in the 1880s, based on historical maps, aerial photographs and satellite images [Source: UNEP/GRID Arendal Maps and Graphics Library, Melting ice on Mount Kilimanjaro, East Africa, <http://maps.grida.no/go/graphic/melting-ice-on-mount-kilimanjaro-east-africa>]

Mapping and monitoring the areal extent of these tropical glaciers is much easier than understanding the physical processes leading to their retreat which, in turn, is easier than attributing these processes to specific causes. Lonnie Thompson, for example, in the study cited above merely extrapolated observed rates of decline without investigating local physical processes. More recently Mölg et al. (2003), Kaser et al. (2004) and Cullen et al. (2006) have used *in situ* measurements and regional meteorological data to try and understand the dynamics of these glaciers with a view to better attributing observed decline to specific causes. This work has suggested that surface radiation and atmospheric humidity are more much important factors than air temperature; a drier atmosphere will starve the glaciers of replenishment. There are suggestions that local deforestation or regional rainfall changes may be to blame. Cullen et al. (2006) concluded that rather than changes in twentieth century climate being responsible for their decline, the Kilimanjaro glaciers appear to be 'relics of a past [pre-twentieth century] climate that was once able to sustain

them.’ This was also the view expressed by meteorologist Stefan Hastenrath in 1975, writing well before the re-commencement of global warming around 1980 (Hastenrath, 1975).

The Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) similarly concluded that ‘complex interlinkages between various atmospheric processes ... and vegetation changes’ were at work on tropical mountain glaciers such as Kilimanjaro (Boko et al., 2007: 439) and remained ambivalent about whether or not global climate trends were responsible. If atmospheric moisture is indeed the key element in the mass balance of these glaciers, then the projected increases in East African rainfall as the world warms may even result in a reversal in their decline and future glacier growth. It was this assessment from the IPCC to which Justice Burton deferred in his October 2007 ruling.

Glaciologists Thomas Mölg and Georg Kaser conclude from these various studies:

... the commonly heard—and generally correct—statement that glaciers [worldwide] are disappearing because of warming glosses over the physical processes responsible for their disappearance. Indeed, warming fails spectacularly to explain the behavior of the glaciers and plateau ice on Africa's Kilimanjaro massif ... Rather, extensive field work on tropical glaciers over the past twenty years ... reveals a more nuanced and interesting story. Kilimanjaro ... has gained and lost ice through processes that bear only indirect connections, if any, to recent trends in global climate (Mölg & Kaser, 2007).

Meanwhile, new commentators offer their own perspective on the current health of Kilimanjaro’s glaciers. In May 2008 the Tanzanian Minister for Natural Resources and Tourism, Ms Shamsa Mwangunga, allayed fears that the ice caps could disappear permanently. Touring the region which attracts about 60,000 tourists each year she reported that the snow cover was increasing: ‘Among the signs of more snow is the decrease in temperatures in areas surrounding the mountain, heavy rainfall this year and increased spring water flow on the slopes of the mountain’ (Masanja, 2008).

Guy Callendar’s claim

Sixty-three years before Gore’s claim about the melting glaciers of Kilimanjaro was ruled ‘in error’ by Justice Burton on behalf of the British legal system, an almost identical claim had also been judged to be invalid by the journal *Nature*. On 15 April 1944, this UK-based science journal published an article by the British geologist Percy Edward Kent which remarked on the shrinking glaciers on Mt Kilimanjaro. Kent claimed that since the first European explorer climbed the mountain in 1889, ‘the amount of ice has been diminishing’ with ‘a rapid decrease in the snow cap in the period preceding 1928’ (Kent, 1944: 454). Kent argued that the primary reason for this recession was the presence of increasingly active

fumarole's – volcanic vents – in the crater which were emitting sulphurous gases and considerable heat.



Figure 2: Portrait of Guy Stewart Callendar, c.1934

The following week, on 24 April, the British engineer Guy Stewart Callendar (Figure 2) submitted a 500-word letter to the editor of *Nature* offering a contrary explanation. Although acknowledging that increasing volcanic activity might contribute to the disintegration of ice, Callendar was dubious that this was the primary cause: ‘... in fact it is quite possibly a minor [cause] for it is now known that the present is a period of general ice recession in nearly all regions where the ice movements have been closely studied (Thorarinsson, 1940)’ (Callendar, 1944). He cited as examples the neighbouring peaks of My Kenya and Mt Ruwenzori where the glaciers were also in retreat and where there was no evidence of increased volcanic activity. For Callendar, the reason for the ice recession was climatic rather than volcanic:

There is one fact, however, which gives a pointer to the immediate cause of this recession, for it has been observed at meteorological stations where very accurate records of temperature have been kept over a long series of years that the annual means tend to be slightly higher than they were half a century ago (Kincer, 1940), the amount usually being of the order of a quarter to half a degree Fahrenheit in tropical regions (Brooks, 1938) (Callendar, 1944).

Callendar’s letter to *Nature* went on to offer a reason for this world-wide warming and, hence, a reason for the glacial retreat on Mt Kilimanjaro and the other East African peaks. The use of coal and oil had added some ‘two hundred thousand million’ tons of carbon

dioxide gas to the atmosphere during the past half-century and the radiative effects of this gas on the atmosphere ‘could result in a rise of temperature.’ Callendar also exploited one further piece of supporting evidence for his contention: the simultaneous retreat of many mountain glaciers around the world – not just in East Africa - that had been noted by various commentators (see for example Thorarinsson, 1940; Matthes, 1939, 1942). He therefore attached the very visible and well documented decline in Mt Kilimanjaro’s glaciers as reported by Percy Kent to this wider global recession of ice and which, for Callendar, implied some unifying global explanation.

Callendar was here considerably more circumspect in his claim that carbon dioxide emissions were causing the world-wide warming than he had been in earlier articles he had published in the meteorological literature (Callendar, 1938; 1940). His 1938 paper – ‘The artificial production of carbon dioxide and its influence on temperature’ - was the first published account of the parallel rise in world-wide temperature and atmospheric carbon dioxide content, offering the earliest example of what we would now call a ‘detection and attribution’ study of human-induced global warming via an enhancement of the greenhouse effect. This paper remains widely cited today. For Callendar, it was a career-long mission to make the case that the fossil fuel emissions of carbon dioxide were having a detectable effect on the global climate (see Fleming, 2007).

The fate of Callendar’s letter to the journal *Nature* is instructive when we come to reflect on the ways in which truth claims about climate change are adjudicated. In an undated letter, Kent – presumably acting by invitation as an independent reviewer for the editor of *Nature*⁴ – responded to Callendar’s claim in dismissive fashion:

The view that the shrinkage of the ice cap on Kilimanjaro is primarily due to climatic change has been advanced before, but the evidence now available shows it to be untenable ... it is clear that the emission of hot [volcanic] gases ... reported by the various mountaineers cited in the article .. would be much more competent than slow climatic change in producing the rapid reduction of the ice cap which has been observed (Kent, undated).

Callendar’s attempt in 1944 to establish his claim in the pages of the world’s leading science journal that the recession of Kilimanjaro’s ice was due to human-induced climate change was unsuccessful. *Nature*’s editor, presumably weighing the views of Percy Kent and perhaps other unknown reviewers, rejected the letter for publication. Callendar continued to publish on the evidence for human-induced climate change, including a continuing interest in the behaviour of glaciers, but he never published his claim about Mt Kilimanjaro’s glaciers in the peer-reviewed scientific literature.

⁴ The handwritten letter of P E Kent in the Papers of Guy S Callendar is undated and unaddressed. It clearly is written in response to Callendar’s submission to *Nature* and because of their joint presence in the Callendar papers and the fact that Callendar’s letter was never published, it is surmised that Kent wrote his letter as an invited reviewer for the journal. Callendar’s original submission, with Kent’s response attached, was presumably returned from *Nature* to Callendar as would be normal practice.

Adjudicating on Kilimanjaro's shrinking glaciers

It is possible to suggest some similarities between the claims of Gore and Callendar and their fate. In the mid-1940s, Guy Callendar was one of the few people who believed that human emissions of greenhouse gases were leading to a discernible warming of global climate and with noticeable biogeophysical effects. He was to remain an almost solitary advocate of this position until the late 1950s. For example, following Callendar's death in October 1964 the noted climatologist Gordon Manley in a letter of condolence to his widow wrote: 'I should like to assure you how that classic [1938] paper by G S Callendar stands as an original contribution nearly twenty years before the Americans began to think along similar lines' (Manley, 1964). And Charles D Keeling, the American geochemist who established the world's longest carbon dioxide measurement series at Mauna Loa, also recognised Callendar's unique contribution: '[Callendar] was a major contributor to keeping alive interest in the CO₂ Greenhouse Effect during decades when it had almost been forgotten by the science community' (Fleming, 2007: 95). Callendar's 1944 letter to *Nature* about the cause of Kilimanjaro's retreating glaciers was therefore driven by his passionate conviction in the reality of human-induced global warming and his desire to find tangible physical evidence of this warming.

Al Gore's claim in 2006, too, was driven by a passionate belief in the reality of global warming and, in his case, in the urgency of taking political action to arrest it. 'Gore's mission ... [was] to be decisive and lead toward a goal that he believes in regardless of the uncertainties' (North, 2007: 29). Unlike Callendar, however, Gore was not alone in pursuing this mission. He was a very visible, well-endowed and self-proclaimed spokesperson for carrying these beliefs to a wider public audience. Yet like Callendar, Gore too settled on the Kilimanjaro glaciers as 'powerful symbols of a fragile earth at risk from the impacts of climate change' (Doyle, 2007: 129).

The respective adjudications of their two claims might also appear to bear a passing similarity. In each case, one individual was responsible for passing a definitive judgement on the claim: geologist Percy Kent on Callendar and Justice Michael Burton on Gore. Neither adjudicator accepted that the evidence in support of the respective claims was compelling and the two claims were rejected as being, respectively, 'untenable' and 'erroneous'. Both adjudicators were 'appointed' by the respective institutions to which the claims were brought: the editor of *Nature* in the case of Callendar and the British legal system in the case of Gore. And both their judgements were 'final' in the sense that they were accepted by the claimants: we have no evidence that Callendar contested the rejection of his letter for *Nature*; we know for sure that Al Gore and the film's promoters did not appeal against the High Court ruling.

Yet these similarities between the two cases are mostly superficial. More instructive is to reflect on the many things - in nature, science and culture - that had changed between 1944 and 2007, changes which therefore led to very different performative roles of the two adjudications. Yes, Kilimanjaro's glaciers had further shrunk in the intervening 63 years and global temperature, having first fallen slightly through the 1940s and 1970s, had subsequently warmed by a further 0.5°C to 2007. And much more evidence about the reality of human-induced climate change was available to Gore than ever was to Callendar.

But the biggest changes between 1944 and 2007 occurred in the ways scientific truth claims were adjudicated and in the cultural role of scientific knowledge in wider social discourse about climate change. These changes are revealed by contrasting the two audiences for the claims made about Kilimanjaro's glaciers and the two audiences for their adjudication. For Callendar, the initial audience for his claim was the editor of *Nature* and whichever expert peer reviewer(s) was selected to advise on publication, whilst the only audience for the adjudication was Callendar himself. In contrast, for Gore the audience for the claim were the tens of millions of citizens world-wide who saw the film either at the cinema or on DVD at home or in schools or who read the book, whilst the audience for the adjudication was the mass public - in the UK and, again, worldwide – who were given access to the Court judgement through print, broadcast and internet media.

In 1944, the claim and its adjudication were broadcast solely within the restrictive and secluded spaces of Polanyi's 'Republic of Science'. The claim was scrutinised *before* it became publicly visible. In 2007, the claim and the legal display of its adjudication were broadcast worldwide to whoever had access to the relevant forms of mass media. The claim was scrutinised *because* it had been made publicly visible. Inevitably, given these different audiences, the consequences of the two judgements differed. The consequence for Callendar was that his claim about human-induced changes in climate causing the retreat of Kilimanjaro's glaciers was not given visibility or credibility through the pages of *Nature*. It was to be many years before such a claim was to be resurrected by Al Gore. It did not, however, dampen Callendar's belief in the reality of climate change due to increases in carbon dioxide emissions, a belief for which he continued to find and publish evidence during the remaining twenty years of his working life (Fleming, 2007). The consequence for Gore was that the 'errors' in his film – including the claim about Kilimanjaro - were publicly labelled as such, even if the general thrust of the film's argument was not undermined by the Court ruling (see Nielsen-Gammon, 2007).

Kilimanjaro's glaciers and extended peer communities

These contrasts between the status, fate and consequences of two scientific claims - similar, but separated in time - about Kilimanjaro's glaciers illustrate both the nature of contemporary scientific 'truth-making' with regards to climate change and also how the new

extended peer community of post-normal science operates across the worlds of science, politics, media, public and judiciary. I explore the wider significance of this study by now addressing the three questions posed earlier relating to the operation of the extended peer community: Who participates in it? How is trust stabilised within it? Does it democratise science?

Who participates in the extended peer community?

Multiple actors were involved in the construction, mobilisation, contestation and adjudication of Gore's claim about Kilimanjaro's glaciers. Some of these actors were operating within the conventional boundaries of scientific peer-review that would have been recognised in the 1940s by Guy Callendar and Percy Kent. For example, the glaciologist Thomas Mölg took Richard Taylor and colleagues to task in the pages of an academic journal for claiming that there is a strong link between rising air temperature and recent glacier retreat in East Africa. Mölg claims that Taylor et al.'s (2006) conclusion is based on 'questionable data and wrong assumptions for the interpretation of these data ... we argue that its principal message is misleading and incorrect' (Mölg et al., 2006: 1). This is a display of what Collins and Evans (2007) call 'contributory and interactional expertise' at work in the academic peer community, but which itself now forms part of the extended peer community.

Then there is the IPCC and its assessment of scientific understanding about Kilimanjaro's glaciers. IPCC-validated knowledge is itself the result of an extended peer community at work (Edwards & Schneider, 2001; Saloranta, 2001), although one which does not embrace the media, the public or the judiciary. As noted earlier, the IPCC Fourth Assessment Report was ambivalent about the cause of the disappearing Kilimanjaro glaciers and this ambivalence was a significant part of the evidence interpreted and weighed by Justice Burton.

Al Gore – who is at the centre of our study - was a very different type of actor, but equally a member of the extended peer community. A significant American politician turned advocate for environmental policy and international action on climate change, Gore's film *An Inconvenient Truth* wraps his own life story, beliefs and values around a science-based narrative of the evidence for human-induced climate change. Where one ends and the other begins is hard to disentangle (Rosteck & Frentz, 2009). On the other hand, Gore's 'adversary' in the judicial review is a very different character, the plaintiff Stuart Dimmock. As we have seen, Dimmock is a parent and a school governor who challenged the accuracy of the film on the basis of his understanding and interpretation of the science. In cases such as this, members of the public participate in the extended peer community alongside scientific experts and politicians. Also active in this community, even if in the shadowy background, was Dimmock's primary backer Christopher Monkton, 3rd Viscount Monkton of Brenchley, a well-known and outspoken UK critic of established positions on human-induced climate change. Although not made public at the time, it later transpired that

Dimmock received considerable backing and encouragement in mounting his legal challenge from Monckton and his associates (Monckton, 2008).

The extended peer community in this case also included other sources of expertise. As is common in such legal hearings, both parties in the dispute brought forward expert witnesses in support of their position on the (in)validity of the scientific claims made by the film. The two principal witness statements were prepared by Dr Peter Stott, an atmospheric research scientist at the UK's Hadley Centre, and Professor Robert Carter, a quaternary scientist and university professor from Australia. Both parties claimed expert status for their respective witnesses, although Carter interpreted Stott's statement that he was 'not an atmospheric scientist' as a challenge to the relevance of his expertise on the matters at hand. Carter defended himself in his statement thus: 'My own expertise ... is just as relevant to making considered judgements on climate change as is Dr Stott's own expertise' (Carter, 2007). Such challenges concerning the legitimacy of expertise in judicial cases of claims adjudication is common (Jasanoff, 2008b) and the distinction between contributory and interactional expertise may again here be helpful. Finally, and completing the main actors in this extended peer community judging the causes of Kilimanjaro's shrinking glaciers, we have Justice Michael Burton. Burton was born in 1947, educated at Eton and the University of Oxford and has been a High Court Judge since 1998. He earlier had stood in elections for the Labour Party (1971 and 1974) and for the Social Democratic Party (1981) and was President of the country's Employment Appeal Tribunal from 2002 to 2005.

This case therefore offers a good example of the very different roles, expertises and statuses of participants in extended peer communities now involved with the adjudication of scientific truth claims: practising independent scientists, a major international scientific assessment, a high profile politician, a member of the public, a member of the aristocracy, scientific experts recruited by the adversaries, and a senior judge. This reflects the observation made by Funtowicz and Ravetz (1993: 332) on the nature of extended peer communities: '... the establishment of the legitimacy and competence of participants will inevitably involve broader social and cultural institutions and movements'. In 1944 it took one scientist, one peer-reviewer and one journal editor to adjudicate on Kilimanjaro's glaciers. In 2007 a similar adjudication mobilised a substantially wider range of legitimate interests and competences and required the involvement of the judiciary.

How is trust stabilised in the extended peer community?

'Facts' – such as Kilimanjaro's retreating glaciers – are now called upon to serve a wide array of political or social functions, yet the heterogenous nature of the extended peer community in post-normal science offers a serious challenge to the governance, institutions and practices of science. As Healy (1999: 660) points out, '... the taken-for granted bond of trust that decision makers still regularly assume between science and the general community can no longer be relied upon.' The politicised nature of contemporary climate change science and the mobilisation of a fluid and ever-changing extended peer community

demands new forms of knowledge governance and trust-building. The judiciary is one institution that can be used.

In the case of *Dimmock versus the Secretary of State for Education*, Justice Burton is doing two things which are essential for the stabilisation of trust in the extended peer community. He is adjudicating between the upper (the public) and lower (the institution of science) houses of Beck's parliament (cf. Demeritt, 2006) and he is stabilising the boundary between facts and values, between science and politics. The key issue here is trust. Who can be trusted in the extended peer community to 'tell the truth' about the causes of the shrinking glaciers: individual scientists, the IPCC, Al Gore or Stuart Dimmock?

In 1944, deferring to the internal and professional practices of Polanyi's republic of science was sufficient to establish 'the facts'. In 2007, in a more disputive and politically charged agora, Justice Burton was called upon to adjudicate between rival truth-tellers. What is interesting here is the way in which Burton reached his judgement. Although evidence was heard and both parties submitted expert witness statements, Burton's critical scrutiny of this evidence (cf. Jasanoff, 2008b) relied heavily on his deference to the IPCC Fourth Assessment Report (Royal Courts of Justice, 2007: pp.6-8 esp.). The IPCC report was used by Burton both to confirm that 'the central scientific theme of Al Gore's Film is now accepted by the overwhelming majority of the world's scientific community', but also that 'the scientific consensus is that it *cannot* be established that the recession of snows on Mt Kilimanjaro is mainly attributable to human-induced climate change' [emphasis added].

Justice Burton stabilised trust within the extended peer community by offering legal backing to the authoritative status of the IPCC reports. He was thus performing the task of quality-assurance called for by Funtowicz and Ravetz: 'The dynamic resolution of policy issues in post-normal science involves the inclusion of an ever-growing set of legitimate participants in the process of quality-assurance of the scientific inputs' (Funtowicz & Ravetz, 1993: 332). Although the knowledge reported by the IPCC claims universal validity, these truth-claims require further scrutiny and validation within specific cultural and national contexts, in this case by the British High Court. This case not only points to the authoritative status accorded to the IPCC as a means of stabilising trust within extended peer communities, it also asks questions about the local and cultural practices of IPCC knowledge validation.

The case of Kilimanjaro's glaciers is only one of several in recent years involving knowledge claims about climate change which have ended up being adjudicated by legal or regulatory systems. For example, in April 2007 in a case brought by the state of Massachusetts against the Environmental Protection Agency the US Supreme Court ruled that greenhouse gases are indeed air pollutants and thus covered by the Clean Air Act (Supreme Court, 2007). And in July 2008 the Office of Communications in the UK ruled that the TV documentary *The Great Global Warming Swindle* broadcast in March 2007 'did not materially mislead the audience so as to cause harm or offence' (OFCOM, 2008). Although the ruling found that certain scientific errors and misrepresentations had been made, the scientific consensus on

climate change was judged to be so strong – again deferring to the IPCC – that it was no longer a matter of political controversy. In each case, disputes in the extended peer community about the quality and status of scientific knowledge are stabilised through these legal instruments of social authority, thus ‘securing social stability and order’ (Jasanoff, 2008a: 761).

Does the extended peer community democratise science?

Funtowicz and Ravetz (1993) also argue that an extended peer community working for the establishment and deployment of scientific knowledge is part of a broader democratisation of science. Such democratisation, they claim, is ‘necessary’ if science is to be effective for the governance and management of complex issues such as climate change. Backstrand (2003) broadens the justification for the democratisation of science – or what she calls ‘civic science’ – by claiming that it also restores public trust in science and installs democratic governance of science.

I have argued above that the courts and other regulatory systems can act as a stabilising force in the governance of the extended peer community, cultivating trust between sometimes antagonistic participants. Does the case of Gore’s claim about Kilimanjaro’s glaciers also reveal the democratisation of science at work? To consider this question let us examine some of the reactions and consequences of the judicial review.

The 2007 ruling of Justice Burton was, perhaps inevitably, interpreted in a number of different ways by public commentators. There were those who argued (Daily Mail, 2007) that the ‘nine errors’ in *An Inconvenient Truth* – including the claim about Kilimanjaro’s glaciers - demonstrated that the film was indeed political propaganda rather than an evidence-based documentary, even though Burton declared that the central thesis of the film was sound. Others used the ruling about the ‘nine errors’ to educational advantage. In re-issuing the accompanying guidance material for school teachers, a requirement of the judgement, the UK Government’s Department for Children, Schools and Families stated (emphasis added):

An Inconvenient Truth is a film that has had a big impact. Its aim is to make the science and the arguments about global warming and climate change and its effects accessible to all audiences. However, in parts of the film Gore presents evidence and arguments which do not accord with mainstream scientific opinion. This guidance [note] points out ... the areas where further input will be required from teaching staff. This guidance is designed to help teaching staff encourage their pupils to assess the validity and credibility of different information sources and explore different points of view so as to form their own opinions. (DfCSF, 2007)

And there were others who interpreted the adjudication differently, simply side-stepping the erroneous claims. Gabrielle Walker and David King in their subsequent book *The Hot Topic*, for example, skate over the question of Gore’s claim about Kilimanjaro’s glaciers. ‘All

the fuss about Kilimanjaro is really just a distraction from the bigger picture' (Walker & King, 2008: 265), the bigger picture presumably being the one in which humans are altering global climate.

Yet such off-hand dismissal of the extended peer community at work may not be so wise. Removing science from its 'black-box' status by subjecting its truth-claims to different forms of public scrutiny and accountability (legal in this case) adds new social value to scientific knowledge. It also opens up possibilities for adjusting public expectations about the different levels of confidence with which science can speak. But this can cut both ways. Building public trust in the institutions of science through greater transparency and engagement are laudable goals of science practiced in an open democracy (Backstrand, 2003; Irwin, 2008; Collins 2009). On the other hand, it seems at least plausible to argue that the public visibility of the case of *An Inconvenient Truth* – and also the later public controversy about the TV documentary *The Great Global Warming Swindle* (see above) – has contributed to the public perception in the UK that scientists continue to be divided about the causes, reality and consequences of global warming. For example, an Ipsos Mori poll in May 2008 suggested that 60 per cent of the UK public believed that 'many scientific experts still question if humans are contributing to climate change' (Ipsos MORI, 2008).

'Democratising science' through the mobilisation of an extended peer community – even allowing for the stabilising role of the judiciary - carries risks as well as benefits.

Conclusion

This study of Kilimanjaro's shrinking glaciers has illuminated the changing nature of scientific truth-claims and their adjudication through the operation of an extended peer community. In 1944, Guy Callendar became the first scientist to link the diminishing glaciers with the global climatic effects of inadvertent human modification of the atmosphere. His claim was quietly refuted through a solitary expert peer review of his short letter to *Nature*, a review which judged his evidence to be 'untenable'. The claim remained in Callendar's private and unpublished papers, entirely forgotten for many years. In a later, very different and very public setting, Al Gore in his 2006 film *An Inconvenient Truth* made the same claim as Callendar, yet this time the adjudication was performed by a British High Court judge in response to a plaintiff, a private UK citizen. Although the result was the same – the claims were dismissed – the constituency of legitimate actors, the processes of adjudication and the wider cultural significance of these processes were very different.

The different origins of these comparable claims about Kilimajaro's glaciers, and the different processes by which they were adjudicated, illustrates the changing status and performative role of climate science in social discourse between the years 1944 and 2007. One consequence of this change is that the adjudication of scientific truth-claims now

involves agents far beyond the boundaries of science's republic: an extended peer community is at work in mobilising and validating scientific knowledge. The public visibility thus given to such disputation yields new social values – but also new potential social liabilities – for climate change knowledge in a way that geologist Percy Kent's private put-down of Callendar's claim in 1944 could never have done.

Moving the sites for resolving scientific 'truth' from Polanyi's republic of science to the civic agora alters the public interpretation of disputed science-policy phenomena such as climate change. New sites for the adjudication of truth claims about climate change, such as the courts, regulatory bodies or other public spaces, may achieve greater public legitimacy, acceptability and deployment of science than do some other evolving institutional practices from within science's republic. For example, it is not necessarily the case that an institution such as the IPCC, itself operating beyond the expertise of traditional peer-review but seeking consensus with non-scientific actors still only at the boundaries of the republic, will over-ride other institutional practices of truth-adjudication. Notwithstanding the universal knowledge claims about climate change made by the IPCC, these claims still need to be interpreted and validated through geographically and culturally situated practices (Jasanoff, 2005). Together with the unpredictable configurations of these validating extended peer communities, these different practices can easily lead to fragmented and contradictory interpretations of climate change knowledge.

The case of Callendar, Gore and Mt. Kilimanjaro's glaciers also illustrates the ambiguous – or at least the conditional - benefits of moving truth adjudications from the republic to the agora. Democratisation of science, in this case discursive checking of scientific claims by Beck's 'open upper chamber', may destabilise knowledge as much as it may legitimise it. The interplay between these two consequences of the democratic move in science depends crucially on notions of trust: trust in the transparency with which experts are selected and trust in the new processes of adjudication thereby established – in this case the judiciary. If the reality of climate change on the basis of evidence is to be 'owned' by the people, the people must be confident that adequate provisions are made for quality assurance of that evidence by an extended peer community. As the case of Kilimanjaro's glaciers shows, such confidence has to be earned not assumed.

Acknowledgements

I would like to thank Jim Fleming at Colby College who initiated the project to digitise all of Guy Stewart Callendar's papers and Alan Ovenden of the School of Environmental Sciences at the University of East Anglia who pointed me in the right direction. Two reviewers and the journal editors offered comments and suggestions which have benefitted the paper.

References

- Backstrand, K. (2003) Civic science for sustainability: reframing the role of experts, policy-makers and citizens in environmental governance *Global Environmental Politics* 3(4), 24-41
- BBC (2008) Climate documentary 'broke rules' *BBC News on-line*
<http://news.bbc.co.uk/1/hi/sci/tech/7517509.stm> (accessed 4 December 2008)
- Boko, M., Niang, I., Nyong, A., Vogel, C., Githeko, A., Medany, M., Osman-Elasha, B., Tabo, R. and Yanda, P. (2007) Africa pp.433-467 in: *Climate change 2007: climate change impacts, adaptation and vulnerability* (eds.) Parry, M., Canziani, O., Palutikof, J.P., van der Linden, P. and Hanson, C., WGII Contribution to the Fourth Assessment Report of the IPCC, Cambridge University Press, Cambridge, UK, 975pp.
- Brooks, C.E.P. (1938) The warming Arctic *The Meteorological Magazine* 73, 29-32.
- Callendar, G.S. (1938) The artificial production of carbon dioxide and its influence on temperature *Quarterly Journal of the Royal Meteorological Society* 64(2), 223-240
- Callendar, G.S. (1940) Variations of the amount of carbon dioxide in different air currents *Quarterly Journal of the Royal Meteorological Society* 66, 395-400
- Callendar, G.S. (1944) Volcanism or climate change? Unpublished letter to *Nature*, 24 April 1944 G S Callendar Collection Box 1, University of East Anglia
- Carter, R.M. (2007) *Second witness statement of Professor Robert Merlin Carter* Witness Statement, High Court of Justice, Claim CO/3615/2007, London
- Collins, H. (2009) We cannot live by scepticism alone *Nature* 458, 30-31
- Collins, H. and Evans, R. (2007) *Rethinking expertise* The University of Chicago Press, Chicago, 159pp.
- Cullen, N.J., Mölg, T., Kaser, G., Hussein, K., Steffen, K. and Hardy, D.R. (2006) Kilimanjaro glaciers: recent areal extent from satellite data and new interpretation of observed 20th century retreat rates *Geophysical Research Letters* 33, L16502
doi:10.1029/2006GL027084
- Daily Mail (2007) Schools must warn of Gore climate film bias *Daily Mail newspaper*, 3 October 2007 www.dailymail.co.uk/news/article-485336/Schools-warn-Gore-climate-film-bias.html [accessed 27 May 2009]
- Demeritt, D. (2006) Science studies, climate change and the prospects for constructivist critique *Economy and Society* 35(3), 453-479
- DfCSF (2007) *The climate change film pack- guidance for teaching staff* Department for Children, Schools and Families, HSMO, London, 58pp.
- Dimmock, S. (2007) Why I'm taking on the government Interview published at:
www.straightteaching.com/index.php?option=com_content&task=view&id=13&Itemid=27 (accessed 26 November 2008)
- Doyle, J. (2007) Picturing the clima(c)tic: Greenpeace and the representational politics of climate change communication *Science as Culture* 16(2), 129-150

- Edwards,P.N. and Schneider,S.H. (2001) Self-governance and peer review in science-for-policy: the case of the IPCC Second Assessment Report pp.219-246 in: *Changing the atmosphere: expert knowledge and environmental governance* Miller,C. and Edwards,P.N. (eds.) MIT Press, Cambridge MA, 385pp.
- Fischer,F. and Mandell,A. (2009) Michael Polanyi's republic of science: the tacit dimension *Science as Culture* 18(1), 23-46
- Fleming,J.R. (2007) *The Callendar Effect: the life and work of Guy Stewart Callendar (1898-1964)* American Meteorological Society, Boston, 155pp.
- Gore,A. (2006) *An inconvenient truth: the planetary emergency of global warming and what we can do about it* Bloomsbury, London or Rodale Press, New York, 328pp.
- Haag,A. (2007) AI's army *Nature* 446, 723-724
- Hastenrath,S. (1975) Glacier recession in East Africa pp.135-142 in: *Proceedings of the WMO/IAMAP Symposium on Long-Term Climatic Fluctuations, Norwich 18-23 August 1975*, WMO No.421, Geneva, 503pp.
- Healy,S. (1999) Extended peer communities and the ascendance of post-normal politics *Futures* 31, 655-669
- Hemingway,E. (1938) *The fifth column and the first forty-nine stories* P F Collier & Son, New York, 597pp.
- Hutchinson,J.A. (1965) The meaning of Kilimanjaro *Tanganyika Notes and Records* 64, 65
- Ipsos MORI (2008) *Public attitudes to climate change 2008: concerned but still not convinced* Ipsos MORI, London Published at www.ipsos-mori.com/researchspecialisms/publicaffairs/socialresearchinstitute/envfoodruraff/understanding/attitudes.ashx (accessed 26 November 2008)
- Irwin,A. (2008) STS perspectives on scientific governance pp.583-607 in, *The handbook of science and technology studies* (3rd edition) (eds.) Hackett,E.J., Amsterdamska,O., Lynch,M. and Wajcman,J., The MIT Press, Cambridge MA, 1065pp.
- Jasanoff,S. (1987) Contested boundaries in policy-relevant science *Social Studies of Science* 17(2), 195-230
- Jasanoff,S. (2003) Contested boundaries in policy-relevant science *Social Studies of Science* 17, 195-230
- Jasanoff,S. (2005) *Designs on nature: science and democracy in Europe and the United States* Princeton University Press, Princeton & Oxford, 374pp.
- Jasanoff,S. (2008a) Making order: law and science in action pp.761-786 in, *The handbook of science and technology studies* (3rd edition) (eds.) Hackett,E.J., Amsterdamska,O., Lynch,M. and Wajcman,J., The MIT Press, Cambridge MA, 1065pp.
- Jasanoff,S. (2008b) Representation and re-presentation in litigation science *Environmental Health Perspectives* 116(1), 123-129
- Jha,S.R. (2002) *Reconsidering Michael Polanyi's philosophy* University of Pittsburgh Press, Pittsburgh PA, 318pp.

- Kaser,G., Hardy,D.R., Mölg,T., Bradley,R.S. and Hyern,T.M. (2004) Modern glacier retreat on Kilimanjaro as evidence of climate change: observations and facts *International Journal of Climatology* 24, 329-339
- Kent (undated) Activity of Kilimanjaro Reply to a letter by Mr G S Callendar G S Callendar Collection Box 1, University of East Anglia
- Kent,P.E. (1944) Kilimanjaro: an active volcano *Nature* 153 454-455
- Kincer,J.B. (1940) Relation of recent glacier recessions to prevailing temperatures *Monthly Weather Review* 68, 158-160
- Kuhn,T. (1962/1970) *The structure of scientific revolutions* University of Chicago Press, Chicago IL, 168pp.
- Luke,T.W. (2008) The politics of true convenience or inconvenient truth: struggles over how to sustain capitalism, democracy, and ecology in the 21st century *Environment and Planning A* 40, 1811-1824
- Manley,G. (1964) Unpublished letter to Mrs Phyllis Callendar, dated 18 October 1964 G S Callendar Collection Box 8 Folder 1
- Masanja,E. (2008) Minister: ice won't vanish on Kili *The Citizen newspaper*, Dar-es-Salaam <http://allafrica.com/stories/200805260817.html> (accessed 3 October 2008)
- Matthes,F.E. (1939) Report of Committee on Glaciers, April 1939 *Transactions of the American Geophysical Union* 20, 518-23
- Matthes,F.E. (1942) Glaciers pp.149-219 in, *Physics of the Earth IX, Hydrology* (ed.) Meinzer,O.E., McGraw-Hill Book Co., New York NY, 712pp.
- Merton,R.K. (1973) *The sociology of science: theoretical and empirical investigations* (ed.) N.W.Storer, University of Chicago Press, Chicago IL, 605pp.
- Modie,N. (2008) Kilimanjaro: on Africa's roof still crowned with snow *The Herald Tribune* 21 January 2008 <http://www.iht.com/articles/2008/01/21/travel/explorer.php>
- Mölg,T. and Kaser,G. (2007) The shrinking glaciers of Kilimanjaro: can global warming be blamed? *American Scientist* 95, 318-325
- Mölg,T., Hardy,D.R. and Kaser,G. (2003) Solar-radiation maintained glacier recession on Kilimanjaro drawn from combined ice-radiation geometry modelling *Journal of Geophysical Research* 108(D23), 4731 doi:10.1029/2003JD003546
- Mölg,T., Rott,H., Kaser,G., Fischer,A and Culen,N.J. (2006) Comment on 'Recent glacial recession in the Rwenzori Mountains of East Africa due to rising air temperature' by Richard G Taylor, Lucinda Mileham, Callist Tindimugaya, Abushen Majugu, Andrew Muwanga and Bob Nakileza *Geophysical Research Letters* 33, L20404 doi:10.1029/2006GL027254
- Monckton,C. (2008) Glenn talks with Lord Monckton *Transcript of television interview 4 March 2008, The Glenn Beck Program* www.glennbeck.com/content/articles/article/196/6783/ - accessed 26 May 2009
- Myer,I.L. (1900) *Der Kilimandscharo* Reiner-Vohsen, Berlin

- Nielsen-Gammon, J.W. (2007) *An Inconvenient Truth: the scientific argument* *GeoJournal* 70, 21-26
- North, G.R. (2007) *An Inconvenient Truth* and the scientists *GeoJournal* 70, 27-31
- O'Neill, S.J. and Hulme, M. (2009) An iconic approach for representing climate change *Global Environmental Change* (under revision)
- OFCOM (2008) *Ofcom Broadcast Bulletin* Issue Number 114
www.ofcom.org.uk/media/news/2008/07/nr_20080721 [accessed 27 May 2009]
- Polanyi, M. (1958) *Personal knowledge: towards a post-critical philosophy* University of Chicago Press, Chicago, 429pp.
- Polanyi, M. (1962) The republic of science: its political and economic theory *Minerva* 1, 54-74
- Quiring, S.M. (2007) Science and Hollywood: a discussion of the scientific accuracy of *An Inconvenient Truth* *GeoJournal* 70, 1-3
- Ravetz, J. (1999) What is post-normal science? *Futures* 31, 647-654
- Rosteck, T. and Frenzt, T.S. (2009) Myth and multiple readings in environmental rhetoric: the case of *An Inconvenient Truth* *Quarterly Journal of Speech* 95(1), 1-19
- Royal Courts of Justice (2007) Stuart Dimmock and Secretary of State for Education and Skills *England and Wales High Court (Administrative Court) Decisions*, Case No. CO/3615/2007, London, 20pp.
- Saloranta, T. (2001) Post-normal science and the global climate change issue *Climatic Change*, 50, 395-404.
- Scott, A. (2007) Peer review and the relevance of science *Futures* 39, 827-845
- Shapin, S. (1998) Placing the view from nowhere: historical and sociological problems in the location of science *Transactions of the Institute of British Geographers* 23, 5-12
- Supreme Court (2007) Massachusetts et al versus Environmental Protection Agency et al
www.supremecourt.us/opinions/06pdf/05-1120.pdf [accessed 27 May 2009]
- Taylor, R.G., Mileham, L., Tindimugaya, C., Majugu, A., Muwanga, A. and Nakileza, B. (2006) Recent glacial recession in the Rwenzori Mountains of East Africa due to rising air temperature *Geophysical Research Letters*, 33(10), doi:10.1029/2006GL025962
- Thompson, L.G., Mosley-Thompson, E., Davis, M.E., Henderson, K.A., Brecher, H.H., Zagorodnov, V.S., Mashiotta, T.A., Lin, P.-N., Mikhailenko, V.N., Hardy, D.R. and Beer, J. (2002) Kilimanjaro ice core records: evidence of Holocene climate change in tropical Africa *Science*, 298, 589-593
- Thorarinsson, S. (1940) Present glacier shrinkage and eustatic changes of sea-level *Geografiska Annaler* 22, 131-159
- Turner, S. (2008) The social study of science before Kuhn pp.33-62 in, *The handbook of science and technology studies* (3rd edition) (eds.) Hackett, E.J., Amsterdamska, O., Lynch, M. and Wajcman, J., The MIT Press, Cambridge MA, 1065pp.

- Walker,G. and King,D. (2008) *The hot topic: how to tackle climate change and still keep the lights on* Bloomsbury Press, London, 309pp.
- Wilsdon,J. and Willis,R. (2004) *See-through science: why public engagement needs to move upstream* Demos, London, 69pp.
- Wynne,B. (1996) May the sheep safely graze? A reflexive view of the expert-lay knowledge divide pp.44-83 in: *Risk, environment and modernity: towards a new ecology* (eds.) Lash,S., Szerszynski,B. and Wynne,B., Sage, 296pp.
- Wynne,B. (2006) Public engagement as a means of restoring public trust in science - hitting the notes, but missing the music? *Public Health Genomics* 9(3), 211-220

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