BJHS Themes (2024), 1–20
doi:10.1017/bjt.2024.1

RESEARCH ARTICLE

Planetary pictures: historicizing environmental and climate sciences in the Anthropocene

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Abstract

How should historians of environmental and climate sciences respond to the Earth's move from the blank canvas to a foreground feature of 'big-picture' scholarship? This article highlights three crucial themes for histories of science in the Anthropocene: categories of scale and methods of scaling, the relationship between history of science and the disciplines it historicizes, and the entanglement of environmental damage and environmental knowledge. Critically engaging a wide range of recent literature across history of science, environmental history, and environmental humanities, alongside an array of case studies, the article puts forward an agenda for 'planetary pictures'. These are analyses that actively contribute to the vital political and ethical task to make visible, and force a reckoning with, the perpetrators and victims of Anthropocene violence.

The essays in the 1993 *BJHS* special issue on *The Big Picture* can be read as products of the late Holocene, the geological epoch marked by stable climate following the end of the last glacial period approximately 11,700 years ago. Environmentalism and environmental regulations make brief appearances in some contributions.[1] Yet it is striking that issue editor James Secord's powerful call for historians of science to go bigger than 'precise contexts of time and place' invokes categories such as 'longer time spans' and 'wider regional and global perspectives', the coherence and stability of which no longer seem self-evident.[2] The 'Goldilocks planet' frequently taken to underwrite human 'civilization' in the Holocene is being wrenched from its 'just-right' climate regime, until recently assumed tacitly by humanities scholars to be open-ended.[3] And, in Dipesh Chakrabarty's terms, 'the globe' – an analytically complex but materially neutral backdrop for the very biggest historical pictures – is being joined by an active 'planet' – increasingly dictated by, but also reactive to, human activities.[4] Although yet to be

1 Andrew Cunningham and Perry Williams, 'De-centring the "big picture": *The Origins of Modern Science* and the modern origins of science', *BJHS* (1993) 26, pp. 407–32, 415–16, 431–2; Andrew Barry, 'The history of measurement and the engineers of space', *BJHS* (1993) 26, pp. 459–68, 467.

2 James A. Secord, 'Introduction', *BJHS* (1993) 26, pp. 387–9, 387.

3 Jan Zalasiewicz and Mark Williams, *Goldilocks Planet: The Four Billion Year Story of Earth's Climate*, Oxford: Oxford University Press, 2012.

4 Dipesh Chakrabarty, *The Climate of History in a Planetary Age*, Chicago: The University of Chicago, 2021, pp. 3–4.

ratified as a geological epoch, there is a compelling case that we are no longer in the Holocene; we are now in the Anthropocene.[5]

How should historians of environmental and climate sciences respond to the Earth's move from the blank canvas to a foreground feature of 'big-picture' scholarship? I propose that historians' 'planetary pictures' should critically engage with three problematics: categories of scale and methods of scaling, the relationship between history of science and the disciplines it historicizes, and the connection between environmental damage and environmental knowledge. Before turning to these themes, I first want to substantiate the distinction between Holocene and Anthropocene histories. Holocene histories include some works that take environmental agency seriously, but tend, to quote Fernand Braudel's famous work on the Mediterranean, to treat 'man's relationship to the environment' as an 'almost timeless history ... of constant repetition, ever-recurring cycles'.[6] This changed somewhat in the later decades of the twentieth century, warranting a separate subcategory of 'late Holocene' histories. These histories, including, as mentioned above, the essays that comprise the *Big Picture* special issue, were attentive to more sudden environmental change and to human impacts on environments. Just as environmental science and, arguably, environmental history crystallized as 'crisis disciplines' in the 1960s and 1970s, so too have major contributions to the history of environmental sciences for some time been inspired by claims of anthropogenic environmental crisis.[7]

Take, for example, Peter Bowler's extensive overview of the history of environmental science, published the year before *The Big Picture* (and cited in Ludmilla Jordanova's contribution to the special issue as an example of 'big-picture literature informed by new scholarship').[8] Bowler opened with the assertion that 'the environmental sciences have now become a matter of acute concern'.[9] He went on to suggest that this concern 'provides historians with a new incentive' to study past 'efforts to understand the environment'. In turn, historians' identification of a 'unified group of environmental sciences' prior to the advent of modern environmental science in the later twentieth century aimed to inspire 'the scientists themselves to take a broader perspective', and 'revive a sense of unity that has been lost in the period of increased specialization'.[10] In Bowler's influential framing, histories of environmental sciences were prompted by scientists' and environmentalists' recognition of environmental crises, and sought to inform understandings of and responses to these crises. Bowler did *not* suggest, however, that

5 This phrasing is a version of the words reportedly used by atmospheric chemist Paul Crutzen at a meeting of the International Geosphere–Biosphere Programme in February 2000, often taken as the original declaration of the Anthropocene. See Will Steffen, 'Commentary: Paul J. Crutzen and Eugene Stoermer, "The Anthropocene" (2000)', in Libby Robin, Sverker Sörlin and Paul Warde (eds.), *The Future of Nature: Documents of Global Change*, New Haven, CT: Yale University Press, 2013, pp. 486–90, 486.

6 Fernand Braudel, *The Mediterranean and the Mediterranean World in the Age of Philip II* (tr. Sian Reynolds), 2 vols., Berkeley: University of California Press, 1972, vol. 1, p. 20. On this feature of Braudel's work see also Dipesh Chakrabarty, 'The climate of history: four theses', *Critical Inquiry* (2009) 35, pp. 197–222, 204–5.

7 The term 'crisis discipline' first appeared in Michael Soulé, 'What is conservation biology?', *Bioscience* (1985) 35, pp. 727–34. On environmental science and climate science as crisis disciplines see, for example, Michael Egan, 'Survival science: crisis disciplines and the shock of the environment in the 1970s', *Centaurus* (2018) 59, pp. 26–39; Robert Luke Naylor, 'Reid Bryson: the crisis climatologist', *WIREs Climate Change* (2022) 13, e744. Examples of the history of environmental ideas and environmental history being prompted by 'crisis' and 'cries for environmental responsibility', respectively, are Lynn White Jr, 'The historical roots of our ecologic crisis', *Science* (1967) 155, pp. 1203–7; Roderick Nash, 'American environmental history: a new teaching frontier', *Pacific Historical Review* (1972) 41, pp. 362–72, 362.

8 Peter J. Bowler, *The Fontana History of the Environmental Sciences*, London: Fontana, 1992; Ludmilla Jordanova, 'Gender and the historiography of science', *BJHS* (1993) 26, pp. 469–83.

9 Bowler, op. cit. (8), p. 1.

10 Bowler, op. cit. (8), p. 3.

https://doi.org/10.1017/bjt.2024.1 Published online by Cambridge University Press

anthropogenic entanglement with the environment required historians of science to adapt their core methods (which, I argue below, should be a key feature of Anthropocene histories). Instead, he responded to environmental crisis by reaffirming the core principle of history of science in the late twentieth century that science is a thoroughly social enterprise. 'Science's very adaptability to social influence, rather than its imagined objectivity', the final sentence of Bowler's book stated, 'will allow it to be used constructively in a world that has seen the Green light'.[11]

Late Holocene characteristics were not exclusive to histories of environmental sciences. Much environmental history around the time of Bowler's book and the *Big Picture* special issue (and indeed up to the present day[12]) shared these traits – an important point given that one of the threads running through this article is that environmental history and the history of environmental sciences should mutually inform each other. In the late 1980s and early 1990s, leading environmental historians were primarily concerned with competing theories of how, in Donald Worster's words, 'the two spheres, the natural and the cultural, confront or interact with one another'.[13] While some fellow practitioners took issue with Worster's instruction to 'first understand nature itself', arguing instead that '*nature* is itself an astonishingly complex human construction', they shared the notion that humans and environments are essentially distinct realms.[14] This disagreement hinged on the crisis of representation rather than on crises of environment and climate. Take, for example, Worster's claim in response to his critics that 'the animating purpose of environmental history ought to be an attempt to rescue us from the predicament' that the confusion of nature and culture had left people 'incapable … of seeing any order or independent force or intrinsic value anywhere outside our human realm' and thereby mired in a 'state of nihilism, relativism, and confusion'. The problem was discursive rather than planetary, and environmental history's role was not to *innovate* but to *return* to 'one of humankind's oldest intuitions … that the realm of nature has an objective, independent order and coherence'.[15] As among contemporary historians of science, many environmental historians at this juncture could recognize increasingly significant and problematic mutual interactions between humans and environments without seeing this as a prompt to new modes of intellectual inquiry.

Identifying late Holocene traits in environmental history and history of science is not meant to imply that all humanities scholarship reacted belatedly to science-led conceptions of the Anthropocene starting in the year 2000.[16] In fact, key features of what are now widely considered Anthropocene humanities emerged in the 1980s and 1990s. A far from exhaustive selection includes multiple variants of post-humanist scholarship, from Donna Haraway's 'A manifesto for cyborgs' (1985) to the development of actor-network theory during the 1980s;[17] Michel Serres's claim in 1990 that in the era of

11 Bowler, op. cit. (8), p. 553.

12 This point is made in greater detail in Emily O'Gorman and Andrea Gaynor, 'More-than-human histories', *Environmental History* (2020) 25, pp. 711–35, 714–15.

13 Donald Worster, 'Transformations of the Earth: toward an agroecological perspective in history', *Journal of American History* (1990) 76, pp. 1087–1106, 1090.

14 Worster, op. cit. (13), p. 1090, original emphasis; William Cronon, 'Modes of prophecy and prediction: placing nature in history', *Journal of American History* (1990) 76, pp. 1122–31, 1122. See also Cronon, 'The trouble with wilderness: or, getting back to the wrong nature', *Environmental History* (1996) 1, pp. 7–28.

15 Donald Worster, 'Seeing beyond culture', *Journal of American History* (1990) 76, pp. 1142–7, 1146–7.

16 Paul J. Crutzen and Eugene F. Stoermer, 'The Anthropocene', *IGBP Newsletter* (2000) 41, pp. 17–18.

17 Donna J. Haraway, 'A manifesto for cyborgs: science, technology, and socialist feminism in the 1980s', *Socialist Review* (1985) 80, pp. 65–108; Bruno Latour, *Science in Action: How to Follow Scientists and Engineers through Society*, Cambridge, MA: Harvard University Press, 1987.

https://doi.org/10.1017/bjt.2024.1 Published online by Cambridge University Press

environmental crises, 'earth, waters, climate, the mute world … burst in on our culture';[18] and two very different forms of environmental history – John McNeill's identification in 2000 of a 'Great Acceleration' in human entanglements in planetary spheres, and the 1995 argument by Richard White (one of Worster's critics) that 'the boundaries between the human and the natural have existed only to be crossed'.[19] In very different ways, these theories, themes, and methods pre-empted the Anthropocene insofar as all suggested that nature and culture are – or have become – an inseparable whole. All refuted the idea expressed by Worster that the modern commingling of humans and environments behoves humanities scholars to reassert their separability. All were sceptical about the implication of Bowler's work that established historical methodologies are adequate to the task of analysing recent ways of knowing and making environments. And all proposed that creating a 'Big Picture' is more than a matter of expanding the spatial and/or temporal frame, instead requiring picturing different things and different relationships. The scholars involved in such work were, in Bruno Latour's words, 'waiting for [the Anthropocene] like the servants in the Gospel, our lamps already lit'.[20] The remainder of this article outlines how such principles of Anthropocene disciples and disciplines have recently been, and might in future be, put to work in histories of environmental sciences.

Is the planet big?

Critical approaches to scale and attention to the methods and impacts of particular processes of scaling have become important features of environmental humanities and history in recent decades.[21] A growing array of scholars share the conviction that, as anthropologist Anna Tsing puts it, 'scale is not just a neutral frame for viewing the world; scale must be brought into being: proposed, practiced, and evaded, as well as taken for granted. Scales are claimed and contested in cultural and political projects'.[22] Scale and scaling have become focal points in the history of environmental and climate sciences thanks especially to the work of Deborah Coen. In empirically grounded analysis of climatology and climate sciences in the Habsburg Empire and in methodological interventions, Coen promotes and practises 'a history of scaling'.[23] Among the most penetrating insights of her approach is that histories of scale rarely, if ever, reveal simple progression from the small or local to the large or global; instead, multiple scales tend to emerge in relation to each other. Relatedly, each shift in scalar thinking and practice not only involves rendering more things commensurable, but also creates 'new

18 Michel Serres, *The Natural Contract* (tr. Elizabeth MacArthur and William Paulson), Ann Arbor: University of Michigan Press, 1995, p. 3.

19 J.R. McNeill, *Something New under the Sun: An Environmental History of the Twentieth-Century World*, New York: W.W. Norton, 2000; Richard White, *The Organic Machine: The Remaking of the Columbia River*, New York: Hill and Wang, 1995, p. xi.

20 Bruno Latour, 'Biography of an inquiry: on a book about modes of existence', *Social Studies of Science* (2013) 43, pp. 287–301, 294.

21 Libby Robin, 'Environmental humanities and climate change: understanding humans geologically and other life forms ethically', *WIREs Climate Change* (2017) 9, pp. 1–18, 8–12; Sebouh David Aslanian, Joyce E. Chaplin, Ann McGrath and Kristin Mann, 'AHR *conversation*. How size matters: the question of scale in history', *American Historical Review* (2013) 119, pp. 1431–72.

22 Anna Lowenhaupt Tsing, *Friction: An Ethnography of Global Connection*, Princeton, NJ: Princeton University Press, 2005, p. 58. See also Tsing, *The Mushroom at the End of the World: On the Possibility of Life in Capitalist Ruins*, Princeton, NJ: Princeton University Press, 2015, pp. 36–43.

23 Deborah R. Coen, *Climate in Motion: Science, Empire, and the Problem of Scale*, Chicago: The University of Chicago Press, 2018; Coen, 'Big is a thing of the past: climate change and methodology in the history of ideas', *Journal of the History of Ideas* (2016) 77, pp. 305–21.

https://doi.org/10.1017/bjt.2024.1 Published online by Cambridge University Press

incommensurabilities': things are lost as well as gained in every scaling project.[24] Importantly for the question of what 'big-picture' history of science means in the Anthropocene, Coen's work shows that 'big' in the sense of 'significant' is far from identical with – and in fact is often inimical to – focusing on 'big' spatial and temporal sweeps. 'Rather than framing ['going big'] as an either/or choice', she suggests, 'we might think historically about what is involved in working now between and across different scales of observation, analysis, and action'.[25] 'The big picture' means something very different when we follow Coen in considering that 'big is a thing of the past' – that is, a historical actors' category – and remembering that conventionally expansive frames are neither new, nor necessarily superior.

Whole-Earth photographs taken from space are the archetypal 'planetary pictures' and might be assumed to counteract Coen's complication of 'bigness' in history of science. The two most famous examples of the genre, *Earthrise* (taken from Apollo 8 in 1968) and *The Blue Marble* (taken from Apollo 17 in 1972), are commonly cited as icons of 'global environment'. The images inspired hopes of a 'second Copernican revolution', in which a new 'planetary consciousness' would prompt responsible recognition of human unity on a fragile common home.[26] Recent scholarship points out that such optimism proved unfounded, not because the images had a limited effect but because their impact was so enormous and multifaceted. Benjamin Lazier points out that they were an icon of 'competing globalisms … commercial and environmental globalisms above all', and asks 'whether the visions and vocabularies of the Earthrise era have inadvertently accelerated our planetary emergency as much as they have inspired us to slow it down'.[27] In addition to concerns about the effects of these images, Elizabeth DeLoughrey reminds us that they are just one instance of the broader fact that 'visualizations of an ecological globe' were products of the environmental harms and 'scopic regimes of Cold War militarism'.[28]

A further point of critique is the smooth upscaling implied in one-world pronouncements that invoked these images. To stand in for 'global humanity', a photograph not only had to absent actual people in order that differences could be elided and the contentious and laborious 'work of agreement [made to] seem unnecessary'.[29] It also had to be manipulated in order to make them shockingly new in familiar ways. By this, I mean that they could only evoke emerging forms of globality if they conformed to existing expectations of what the terrestrial globe looked like – expectations embedded by a long lineage of globe images in the Euro-Western world.[30] Furthermore, as Alison Bashford points out, envisioning 'spaceship Earth' was 'already many generations old' in geopolitical and biopolitical sciences by the time a platform had been devised for a whole-Earth

24 Coen, 'Big is a thing of the past', op. cit. (23), p. 314.

25 Coen, *Climate in Motion*, op. cit. (23), pp. 16–17.

26 Robert Poole, *Earthrise: How Man First Saw the Earth*, New Haven, CT: Yale University Press, 2008; Perrin Selcer, *The Postwar Origins of the Global Environment: How the United Nations Built Spaceship Earth*, New York: Columbia University Press, 2018, pp. 2–3.

27 Benjamin Lazier, 'Earthrise; or, the globalization of the world picture', *American Historical Review* (2011) 116, pp. 602–30, 608. On the existence of global sentiment as a necessary precursor to the reception of these images see Samuel Randalls, 'Climatic globalities: assembling the problems of global climate change', in Rens van Munster and Casper Sylvest (eds.), *The Politics of Globality since 1945: Assembling the Planet*, London: Routledge, 2016, pp. 145–63, 161.

28 Elizabeth DeLoughrey, 'Satellite planetarity and the ends of the Earth', *Public Culture* (2014) 26, pp. 257–80, 266, 274.

29 Quotation from John Tresch, 'Cosmic terrains (of the sun king, son of heaven, and sovereign of the seas)', *e-flux* (2020) 114, pp. 1–11, 1. On the absence of people and technocratic implications see Selcer, op. cit. (26), p. 3.

30 Denis Cosgrove, *Apollo's Eye: A Cartographic Genealogy of the Earth in the Western Imagination*, Baltimore: Johns Hopkins University Press, 2001.

https://doi.org/10.1017/bjt.2024.1 Published online by Cambridge University Press

Figure 1. AS-17-148-22727, from which *The Blue Marble* was cropped (1972). Image sourced from www.lpi.usra.edu/resources/apollo/images/print/AS17/148/22727.jpg (accessed 15 March 2023).

photograph.[31] Image AS-17-148-22727 (Figure 1) only became *The Blue Marble* when printed, cropped to centre planet Earth with the blackness of space as a well-proportioned mount, and flipped 180 degrees so that Antarctica appears at the bottom.[32] These adaptations made planet Earth look exactly like the globe its viewers already knew.

One feature of *The Blue Marble* little discussed in recent critical scholarship is that, as of 1972, the features of the planet that it depicted – an expanse of ocean, Africa, and Antarctica – were each already established, or becoming established as, hotspots of environmental concern and inquiry. Antarctica and the 'global ocean' were firmly embedded as crucial sites of environmental knowledge production during the International Geophysical Year of 1957–8. And climatologists were beginning to theorize the severe famine in the Sahel region of Africa during the early 1970s as a marker and outcome of worldwide climatic shifts.[33] That the whole-Earth image was not a whole-Earth's-surface image was a vital aspect of the scaling at work in *The Blue Marble*. Following Coen, we should attend

31 Alison Bashford, *Global Population: History, Geopolitics, and Life on Earth*, New York: Columbia University Press, 2014, pp. 170, 355–6.

32 On the original orientation of the image see Elizabeth Leane, *South Pole: Nature and Culture*, London: Reaktion, 2016, pp. 42–3.

33 Elena Glasberg, *Antarctica as Cultural Critique: The Gendered Politics of Scientific Exploration and Climate Change*, New York: Palgrave Macmillan, 2012; Jessica Lehman, 'Making an Anthropocene ocean: synoptic geographies of the International Geophysical Year (1957–1958)', *Annals of the American Association of Geographers* (2020) 110,

https://doi.org/10.1017/bjt.2024.1 Published online by Cambridge University Press

to how any variant of globality emerges in conjunction with other scales. In the case of *The Blue Marble* and the environmental politics and science with which it was bound up, particular features – a chunk of cryosphere, the ocean, a drought-stricken ecological region – took on outsized importance in framing a planetary picture. However, the continued salience of whole-Earth images in environmental science and politics depends on the capacity for some of these particularities to remain while others fade away. Antarctica is the key example of the former: as DeLoughrey says, we still 'turn to the ends of the earth in order to visualize both deep planetary time and climate change as an inevitable future'.[34] Instances of the latter include the immediate crises of the early 1970s, the militarized technoscience of the Cold War, and the specific part of Earth depicted in *The Blue Marble*. As Lazier puts it, the 'afterlives' of these images are in part 'a story of error, blindness, and forgetting'.[35] Indeed, these are features of any project of scaling, and accordingly should be prime concerns for historians of environmental sciences in the Anthropocene.

Histories of scaling in environmental sciences must attend to time as well as – and often in conjunction with – space. Dipesh Chakrabarty's tendency to suggest that the ways in which Earth system and human histories 'operate on different scales and at different speeds' renders them incommensurable has met with resistance from a number of historians and anthropologists of science.[36] In her work on uranium mining in Gabon, Gabrielle Hecht proposes that particular objects, such as radioactive rock formations, act as 'interscalar vehicles'. Through this term, Hecht identifies how objects are deployed – in multiple, often competing, ways – as 'means of connecting stories and scales usually kept apart'.[37] Sophia Roosth develops this theme in her analysis of fieldwork recently undertaken in Oman by geologists of the Ediacaran subcommission of the International Commission on Stratigraphy. These scientists closely engaged with Earth system histories, Roosth shows, routinely find ways to operate across the timescales of politics and planet. A key aspect of this capacity to slip between historical scales is that 'disciplinary vocabularies – whether global or historiographic – are already shot through with one another's idioms: historians reference the geological as much as geologists reference history'.[38] Historians of science might do well to follow Roosth's lead by exploring not only how, in Jim Secord's words, 'geology is always embedded in geopolitics',[39] but also how geopolitics is often embedded in and expressed through geology and other environmental sciences.[40] In particular, attempts to mark planetary time have always been entangled with expressions of sociopolitical progress. Thus Roosth suggests that the 'unevenness of modernity' in Oman 'is echoed in geologists' efforts to gather up the nonsynchronous Ediacaran period into something that they can agree to nominate as global'.[41] Multiple

pp. 606–22; Robert L. Naylor and Eleanor Shaw, 'The 200-year cycle: an early climate-based reaction to the crisis in the Sahel and its uptake in 1973', *History of Meteorology* (2022) 11, pp. 1–17.

34 DeLoughrey, op. cit. (28), p. 274.

35 Lazier, op. cit. (27), p. 626.

36 Dipesh Chakrabarty, 'Climate and capital: on conjoined histories', *Critical Inquiry* (2014) 41, pp. 1–23, 3.

37 Gabrielle Hecht, 'Interscalar vehicles for an African Anthropocene: on waste temporality, and violence', *Cultural Anthropology* (2018) 33, pp. 109–41, 115.

38 Sophia Roosth, 'The sultan and the golden spike; or, what stratigraphers can teach us about temporality', *Critical Inquiry* (2022) 48, pp. 697–720, 719–20.

39 James A. Secord, 'Global geology and the tectonics of empire', in H.A. Curry, N. Jardine, J.A. Secord and E.C. Spary (eds.), *Worlds of Natural History*, Cambridge: Cambridge University Press, 2018, pp. 401–17, 416.

40 An excellent recent example of such work is Adam Bobbette, *The Pulse of the Earth: Political Geology in Java* (Durham, NC: Duke University Press, 2023).

41 Roosth, op. cit. (38), p. 719.

https://doi.org/10.1017/bjt.2024.1 Published online by Cambridge University Press

modernities and fragmented periods of planetary history go hand in hand in locations deemed 'peripheral' by Euro-Western standards.

A comparable knot of contentious developmental and deep time can be discerned a century and a half earlier in British colonial India. In turning to this case, I want to complicate Roosth's characterization of Victorian geology as constructed around 'an imperial time in which geological periods were synchronized by reference to … metropolitan rocks'. This was certainly part of the story, but the complex knowledge politics of British imperialism also gave rise to versions of what Roosth identifies as the peculiarly post-colonial phenomenon of the production of geological periods by 'calibrating multiple peripheral places to one another'.[42] Working to facilitate the extraction of coal in the eastern India, European personnel of the Geological Survey of India gleaned evidence in the 1850s that glaciers had existed there in the Palaeozoic era, long before the (then newly hypothesized) European Ice Age of the much more recent Pleistocene epoch. Bypassing the imperial metropole and communicating with colleagues in British colonies in the southern hemisphere enabled these geologists to identify this rock formation with others in the South African Karoo and in New South Wales. Such inter-colonial work eventually led to the hypothesis that the three areas had been joined when the stratum formed, influentially expressed in Eduard Suess's 1885 label 'Gondwána-Land'.[43] According to Alison Bashford, Pratik Chakrabarti and Jarrod Hore, the term's origin in colonial ethnology and geology in the tribal uplands of southern India 'suggests a new antipodal history for the Anthropocene'.[44]

Shortly after their identification of a patch of deep time connecting colonies either side of the equator while distancing the imperial metropole, personnel of the Geological Survey of India attempted a different type of spatiotemporal scaling. Employing the language of contemporary debates on the international reform of clock time, they sought to include India on the Europe-centred map of the Pleistocene Ice Age.[45] Leading figures in the survey claimed that the effort to 'fix the date and the cause of that [Pleistocene glacial] extension' was the key to overcoming the 'great obstacle to exact speculation in geology', namely 'the utter uncertainty between local and true time'.[46] In this instance, then, scientific personnel in colonies clamoured to be included in metropolitan time frames while also asserting that they could discern their own, even deeper, planetary periods. Like those of Roosth's contemporary earth scientists in Oman, the planetary pictures of colonial geologists in nineteenth-century India were rendered in particular localities, and were framed by – and in turn framed – deeply politicized categories of developmental time.

Spiky subjects: competing Anthropocene histories

The most conspicuous way in which time matters in the Anthropocene is the issue of its start date. The Anthropocene is 'an argument wrapped up in a word',[47] and a crucial part of the polemic concerns periodization. When the Anthropocene begins strongly implies what it consists of and who is responsible. Unlike other global boundary stratotype

42 Roosth, op. cit. (38), pp. 699–701.

43 Eduard Suess, *Das Antlitz der Erde*, 5 vols., Leipzig: G. Freytag, 1885, vol. 1, p. 768.

44 Alison Bashford, Pratik Chakrabarti and Jarrod Hore, 'Towards a modern history of Gondwanaland', *Journal of the British Academy* (2021) 9(6), pp. 5–26, 6. See also Pratik Chakrabarti, 'Gondwana and the politics of the deep past', *Past & Present* (2019) 242, pp. 119–53.

45 Vanessa Ogle, *The Global Transformation of Time: 1870–1950*, Cambridge, MA: Harvard University Press, 2015.

46 H.B. Medlicott and W.T. Blanford, *A Manual of the Geology of India*, Calcutta: Government Printing, 1879, p. 668.

47 Paul Voosen quoted in Jason W. Moore, 'The Capitalocene, part I: on the nature and origins of our ecological crisis', *Journal of Peasant Studies* (2017) 44, pp. 594–630, 594.

https://doi.org/10.1017/bjt.2024.1 Published online by Cambridge University Press

sections and points (GSSPs) – the 'golden spikes' that define the lower boundary of a stage on the geologic timescale – this one comes with politics and ethics very clearly attached.[48] The stakes are such that the decision in 2019 of the Anthropocene Working Group, the body tasked with proposing a single golden spike for the Anthropocene, to locate it 'around the mid-twentieth century' has not stopped alternatives gaining traction.[49]

One of the most widely discussed of these alternatives is Simon Lewis and Mark Maslin's 1610 Orbis Spike, the minimum of the decline in CO_2 levels (as revealed in ice cores) caused by the death of approximately 50 million Native Americans and resulting extension of forests into previously cleared areas. 'In narrative terms', they propose, 'the Anthropocene began with widespread colonialism and slavery: it is a story of how people treat the environment and how people treat each other'.[50] This thoroughly historical explanation, invoking empire, labour, and human violence to establish the start of an era, is the work of two scientists – by training a plant ecologist and a palaeo-oceanographer respectively. The Orbis Spike has subsequently crossed disciplinary boundaries to be developed by, among others, sociologists, ecologists, anthropologists, geographers, Indigenous studies scholars and critical theorists.[51] Here is an upshot of what Dipesh Chakrabarty influentially identified in the first of his four theses on 'The climate of history' as 'the Collapse of the Age-old Humanist Distinction between Natural History and Human History':[52] history is no longer the preserve of humanities scholars, let alone historians.[53] And, as Lukas Verburgt and Elske de Waal put it, 'although it is perhaps true that the divide between the sciences and the humanities "melts in the heat of global warming," historians' history does not always sit well with scientists' history'.[54] Historians have begun to formulate various – and often clashing – responses to this simultaneous expansion of their potential field of study and encroachment by scientists on their traditional domain.

Two partially overlapping discussion points are especially significant for historians of science. First, what is the value of identifying precursors and alternatives to Anthropocene concepts and methods? Second, what stance should historians adopt to dominant framings of the Anthropocene, especially those of Earth system science (ESS)? As Michael Simpson suggests, the 'debate over the Anthropocene's intellectual origins mirrors the search for a "golden spike"'.[55] If understandings of human impacts on planetary processes stretch back centuries rather than decades, an arguable implication is that the Anthropocene itself should extend back at least as far. Moreover, identifying the extent of Anthropocene-type knowledge changes the politics and ethics that attach

48 For an overview of the novelty of the Anthropocene GSSP see Jamie Lorimer, 'The Anthropo-scene: a guide for the perplexed', *Social Studies of Science* (2017) 47, pp. 117–42, 119–21. See also Dipesh Chakrabarty, 'Anthropocene time', *History and Theory* (2018) 57, pp. 5–32, 5–9.

49 'Results of a binding vote by AWG. Released 21st May 2019', http://quaternary.stratigraphy.org/workinggroups/anthropocene/ (accessed 17 March 2023).

50 Simon L. Lewis and Mark A. Maslin, *The Human Planet: How We Created the Anthropocene*, London: Penguin, 2018, p. 13.

51 For example, Moore, op. cit. (47), p. 619; Janae Davis, Alex A. Moulton, Levi van Sant and Brian Williams, 'Anthropocene, Capitalocene, … Plantationocene? A manifesto for ecological justice in an age of global crises', *Geography Compass* (2019) 13, e12438, p. 3; Heather Davis and Zoe Todd, 'On the importance of a date, or decolonizing the Anthropocene', *ACME: An International Journal for Critical Geographies* (2017) 16, pp. 761–80, 764.

52 Chakrabarty, op. cit. (6), p. 201.

53 On this point see also Libby Robin and Will Steffen, 'History for the Anthropocene', *History Compass* (2007) 5, pp. 1694–1719, 1694.

54 Lukas M. Verburgt and Elske de Waal, 'Introduction: rethinking history of science in the Anthropocene', *Isis* (2022) 113, pp. 366–76, 373.

55 Michael Simpson, 'The Anthropocene as colonial discourse', *Environment and Planning D: Society and Space* (2020) 38, pp. 53–71, 54.

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to the label. This is why Simon Lewis and Mark Maslin give prominence to a conceptual history of the Anthropocene in bolstering their case for the Orbis Spike. Doing away with what they term the '"accidental Anthropocene" story' is an integral part of their account of the people and processes responsible for altering planetary systems.[56] Fabien Locher and Jean-Baptiste Fressoz are foremost among scholars who develop this mode of history-of-science-as-critique. Their work on European knowledge of anthropogenic environmental degradation through the late eighteenth century and much of the nineteenth foregrounds and politicizes the 'strange and disturbing fact' that destruction persisted in the presence of theories identifying harms and the agents responsible.[57] This perspective lends historical depth to Mike Hulme's insistence that we are mistaken if we think that more scientific knowledge of climate change (or other Anthropocene components) will automatically lead to more preventive or rectificatory action.[58]

Fressoz's work with Locher and with Christophe Bonneuil also addresses the significance of forgetting and overlooking knowledge of anthropogenic environmental damage. Drawing on the terminology of interdisciplinary work on the production of ignorance,[59] Fressoz and Bonneuil suggest that the Anthropocene is partly an 'Agnotocene' – an age of suppressing forms of knowledge of environmental destruction by 'externalizing nature [and] economizing the world'.[60] Naomi Oreskes and Erik Conway offer an important counterpart focused on the past half-century of climate science and its corporate-sponsored deniers.[61] And scholars including Kyle Powys Whyte, Candis Callison and Zoe Todd show how one of the Agnotocene's most insidious manifestations is the displacement and dismissal of Indigenous experiences of the entangled violence of settler colonialism and Anthropocene damage.[62] Yet many forms of unknowing in the environmental sciences still await engaged analysis from historians of science. For instance, a characteristic pattern of past scientists relying upon but suppressing non-Western knowledge when producing climate knowledge is only just beginning to receive sustained scholarly attention.[63] In expanding this focus, historians could productively look to work in environmental humanities identifying forms of representation and reception that have depoliticized the Anthropocene by occluding particular victims and perpetrators of harm.[64] What visual

56 Lewis and Maslin, op. cit. (50), pp. 17–41, quotation at 25.

57 Fabien Locher and Jean-Baptiste Fressoz, 'Modernity's frail climate: a climate history of environmental reflexivity', *Critical Inquiry* (2012) 38, pp. 579–98, 598.

58 Mike Hulme, *Why We Disagree about Climate Change: Understanding Controversy, Inaction and Opportunity*, Cambridge: Cambridge University Press, 2009, pp. 103–4.

59 Robert N. Proctor and Londa Schiebinger (eds.), *Agnotology: The Making and Unmaking of Ignorance*, Stanford, CA: Stanford University Press, 2008.

60 Christophe Bonneuil and Jean-Baptiste Fressoz, *The Shock of the Anthropocene: The Earth, History and Us* (tr. David Fernbach), London: Verso, 2016, pp. 198–221. See also Jean-Baptiste Fressoz and Fabien Locher, *Les révoltes du ciel: Une histoire du changement climatique XVe–XXe siècle*, Paris: Editions du Seuil, 2020, pp. 227–9.

61 Naomi Oreskes and Erik M. Conway, 'Challenging knowledge: how climate science became a victim of the Cold War', in Proctor and Schiebinger, op. cit. (59), pp. 55–89; Oreskes and Conway, *Merchants of Doubt: How a Handful of Scientists Obscured the Truth on Issues from Tobacco Smoke to Global Warming*, New York: Bloomsbury, 2010.

62 Kyle P. Whyte, 'Indigenous science (fiction) for the Anthropocene: ancestral dystopias and fantasies of climate change', *Environment and Planning E: Nature and Space* (2018) 1, pp. 224–42; Candis Callison, 'Refusing more empire: utility, colonialism, and Indigenous knowing', *Climatic Change* (2021) 167, e58; Zoe Todd, 'An indigenous feminist's take on the ontological turn: "ontology" is just another word for colonialism', *Journal of Historical Sociology* (2016) 29, pp. 4–22. See also Simpson, 'Anthropocene', pp. 65–8.

63 For example, Philipp Lehmann, *Desert Edens: Colonial Climate Engineering in the Age of Anxiety*, Princeton, NJ: Princeton University Press, 2022, pp. 1–37; Harriet Mercer, 'Atmospheric archives: gender and climate knowledge in colonial Tasmania', *Environment and History* (2021) 27, pp. 193–210; Fiona Williamson, 'Just doing their job: the hidden meteorologists of colonial Hong Kong *c.*1883–1914', *BJHS* (2021) 54, pp. 341–59.

64 For example, Rob Nixon, *Slow Violence and the Environmentalism of the Poor*, Cambridge, MA: Harvard University Press, 2011; T.J. Demos, *Against the Anthropocene: Visual Culture and Environment Today*, London:

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theorist Nicholas Mirzoeff terms the '(an)aesthetics' of certain Anthropocene representations are every bit as evident in the technologies of past environmental sciences as those of the arts.[65]

Histories of the Anthropocene concept and of environmental sciences more broadly are, however, hardly immune to charges of themselves being overly selective. Fressoz and Locher, for instance, take to task what they dub the 'official genealogy' of climate science.[66] Like equivalent genealogies of Anthropocene theorists and Earth system scientists,[67] this history was initially constructed by scientists in order to produce their own scientific authority through the citation of precursors, but has since been taken on by some historians and in the IPCC's forays into the history of climate science.[68] It reduces the history of climate change to a narrow, canonical history of individual scientists' contributions to the 'discovery' of the greenhouse effect.[69] But the alternative casts of 'Anthropocenologists' and pioneering climate change theorists that the likes of Fressoz and his co-authors propose have themselves been critiqued as consisting merely of a few 'eccentric' outliers.[70] Paul Warde, Libby Robin and Sverker Sörlin suggest that such individuals had little impact in their own times and advanced theories that are only superficially Anthropocenic.[71] There is certainly a risk that Anthropocene countercanons become as selective, unchangingly repeated, and focused on 'heroic' (and overwhelmingly pale and male) individuals as the 'official genealogy of the greenhouse effect'.[72] As such, it is vital not to forget the myriad roles of diverse actors that collectively constituted projects of 'proto-Anthropocene' knowledge making.[73] Here, the work of environmental historians such as Warde and Lydia Barnett on environmental-change theories in early modern European societies provides useful pointers for a broader conception of whose and what knowledges are Anthropocenic.[74]

Sternberg Press, 2017; Michelle Bastian, 'Whale falls, suspended ground, and extinctions never known', *Environmental Humanities* (2020) 12, pp. 454–74.

65 Nicholas Mirzoeff, 'Visualizing the Anthropocene', *Public Culture* (2014) 26, pp. 213–32.

66 Fressoz and Locher, op. cit. (60), pp. 221–2.

67 For example, Paul J. Crutzen, 'Geology of mankind', *Nature* (2002) 415, p. 23; Will Steffen, Katherine Richardson, Johan Rockström and Hans Joachim Schellnhuber, 'The emergence and evolution of Earth System Science', *Nature Reviews: Earth & Environment* (2020) 1, pp. 54–63.

68 Spencer Weart, *The Discovery of Global Warming*, Cambridge, MA: Harvard University Press, 2003; H. Le Treut et al., 'Historical overview of climate change science', in S. Solomon et al. (eds.), *Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*, Cambridge: Cambridge University Press, 2007, pp. 93–127; D. Chen et al., 'Framing, Context, and Methods', in V. Masson-Delmotte, *Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change*, Cambridge: Cambridge University Press, 2021, pp. 147–286, 174–86.

69 Fressoz and Locher, op. cit. (60), pp. 225–6. See also Deborah R. Coen, 'The advent of climate science', in Hans von Storch (ed.), *The Oxford Research Encyclopedia of Climate Science* (online 2020).

70 Bonneuil and Fressoz, op. cit. (60), pp. 47–64; Fressoz and Locher, op. cit. (60).

71 Paul Warde, Libby Robin and Sverker Sörlin, *The Environment: A History of the Idea*, Baltimore: Johns Hopkins University Press, 2018, p. 38.

72 A recent attempt to add a woman to the greenhouse canon is Joseph D. Ortiz and Roland Jackson, 'Understanding Eunice Foote's 1856 experiments: heat absorption by atmospheric gases', *Notes and Records* (2022) 76, pp. 67–84.

73 Sverker Sörlin and Erik Isberg, 'Synchronizing earthly timescales: ice, pollen, and the making of proto-Anthropocene knowledge in the North Atlantic region', *Annals of the American Association of Geographers* (2021) 111, pp. 717–28; Sverker Sörlin, 'The Anxieties of a Science Diplomat: Field Coproduction of Climate Knowledge and the Rise and Fall of Hans Ahlmann's "Polar Warming"', *Osiris* (2011) 26, pp. 66–88.

74 Paul Warde, *The Invention of Sustainability: Nature and Destiny, c.1500–1870*, Cambridge: Cambridge University Press, 2018; Lydia Barnett, *After the Flood: Imagining the Global Environment in Early Modern Europe*, Baltimore: Johns Hopkins University Press, 2018, p. 8.

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An alternative approach to the identification of Anthropocene concepts and methods before the twenty-first century is work that historicizes in order to critique these dominant concepts and methods. An important contribution in this mode is Deborah Coen and Fredrik Albritton Jonsson's analysis of the 'historical contingency' of Earth system science, through which they propose alternative ways of comprehending the Anthropocene.[75] They focus on how, during the 1980s, physical sciences came to dominate ESS's model of interdisciplinarity to the relative exclusion of life sciences and social sciences. In valorizing the Holocene as 'the "safe operating space" for the [human] species', ESS, they suggest, overlooks 'the late Holocene beliefs and ideas' – modernity, freedom and progress – 'that caused or exacerbated the crisis in the first place'.[76] Like geographer Kathryn Yusoff's critique of geology,[77] Coen and Jonsson take particular issue with the exclusion of 'questions of class, gender, race, and empire' from ESS and its concomitant reduction of 'Indigenous, enslaved, and colonized peoples [to] passive victims of the forces of nature'.[78] Highlighting some of these alternative ways of knowing the Earth and revealing the processes that occluded them from dominant science are explicit attempts to change science. Such an approach insists that science must acknowledge how ethics and politics inhere in its objects and techniques of study. For Yusoff, this means an 'insurgent geology'; for Coen and Jonsson, it means an ESS geared towards 'transformation for both sustainability and justice'.[79]

This model of how history of science should relate to sciences of the Anthropocene is highly contested – and not just by scientists. For Dipesh Chakrabarty, reducing the Anthropocene to familiar problematics of human history like race, gender and class 'blinds us to the nature of our present', understating the radical nature of the irruption of 'the geological into the everyday'.[80] On these grounds, he counts himself among the historians and humanities scholars who 'accept as foundational the basic findings of Earth system science and those of the Anthropocene Working Group'.[81] Subscribers to this perspective insist that agreement with ESS principles and findings is the basis upon which vital multidisciplinary work on the Anthropocene can proceed.[82] According to Julia Adeney Thomas, historical work that focuses on critiquing the science is marked by 'deep conservatism', especially an insidious desire to protect 'disciplinary prerogatives … from the challenge posed by the Anthropocene'.[83] 'A good Anthropocene story', she argues, fits into the 'much more restricted future' identified by Earth system science relative to the 'dizzying range of stories' possible thanks to the apparently stable Earth system of the Holocene.[84] The Anthropocene is altogether too serious a predicament to allow for pluralizing critique, or what she terms an 'Anything Goes' approach.[85]

75 Deborah R. Coen and Fredrik Albritton Jonsson, 'Between history and Earth System science', *Isis* (2022) 113, pp. 407–16, 408.

76 Coen and Jonsson, op. cit. (75), pp. 413–14.

77 Kathryn Yusoff, *A Billion Black Anthropocenes or None* (Minneapolis: University of Minnesota Press, 2018); Yusoff, 'The inhumanities', *Annals of the American Association of Geographers* (2021) 111, pp. 663–76.

78 Coen and Jonsson, op. cit. (75), pp. 415–16.

79 Yusoff, *A Billion Black Anthropocenes or None*, op. cit. (77), p. 22; Coen and Jonsson, op. cit. (75), p. 416.

80 Chakrabarty, op. cit. (36), p. 11; Chakrabarty, op. cit. (48), pp. 30–31.

81 Dipesh Chakrabarty, 'Foreword', in Julia Adeney Thomas (ed.), *Altered Earth: Getting the Anthropocene Right*, Cambridge: Cambridge University Press, 2022, pp. xi–xiii, xi.

82 Julia Adeney Thomas, Mark Williams and Jan Zalasiewicz, *The Anthropocene: A Multidisciplinary Approach*, Cambridge: Polity, 2020.

83 Julia Adeney Thomas, 'Humanities and social sciences: human stories and the anthropocene Earth system', in Thomas, op. cit. (81), pp. 51–80, 64.

84 Thomas, op. cit. (83), p. 53. See also Zoltán Boldizsár Simon and Julia Adeney Thomas, 'Earth System science, Anthropocene historiography, and three forms of human agency', *Isis* (2022) 113, pp. 396–406.

85 Thomas, op. cit. (83), pp. 57–65.

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Putting history of science and STS in tandem with ESS was a prominent feature of Bruno Latour's late work,[86] and has become a fully fledged agenda in the 'geoanthropology' of Jürgen Renn. Echoing Thomas, Renn argues that 'identifying causes and culprits does not necessarily put us into a better position for predicting which solutions are equal to the challenges of the Anthropocene'.[87] He emphasizes the significance of knowledge systems in generating and sustaining the unprecedented impacts on the Earth system of what he terms the 'ergosphere' – that is, the field of operation of 'the transformative power of human work and material culture'.[88] Renn prescribes the need for 'knowledge for the Anthropocene' – an amalgam of scientific knowledge, knowledge of 'the role of human societies as part of the Earth System', and knowledge pertaining to 'individual and collective identities and values'.[89] History of science is one key contributor to the transformative change required to 'existing modes of knowledge production and dissemination' in order for them to be equal to 'the greatest challenges of humanity'.[90]

Attempts to align ways of knowing with the practical exigencies of environmental and climate crisis also underpin more targeted projects. One example is Jo Guldi's exploratory use of 'text mining' – digital counting of key words and phrases – to routinize and update the work of holding to account those who delay responses to the climate emergency.[91] Unlike the 'far from urgent' nature of 'much climate writing in humanities and social sciences', she claims that her approach takes seriously the science that presents climate change 'as an *emergency* that requires immediate and practical adjustments to life'.[92] Such 'crisis talk' is contentious, however. Candis Callison makes the important point that by focusing on the immediate future, this framing 'fundamentally limits questions about "how we got here"' and, in particular, elides the crises already experienced by Indigenous communities.[93]

The spikiness of debates about the proper relationship between historians and the sciences they historicize or collaborate with reflects divergent framings of what exactly is the big picture for the history of science in the Anthropocene. For Julia Adeney Thomas, Jürgen Renn and others, the severity of the environmental emergency demands that scholars do away with internecine campus politics and put aside theoretical and methodological niceties to perform their practical duty in a time of crisis. Theirs is a big picture in which historians of science add details, texture and shading to science's broad-brush rendering. For Fressoz, Locher, Bonneuil, Coen and Jonsson, and others, dominant science doesn't do a good enough job of providing outlines in the big picture of the Anthropocene, not only smudging out crucial details but also trying to cram everything into a single image when multiple canvases are required.

86 Bruno Latour, *Facing Gaia: Eight Lectures of the New Climatic Regime* (tr. Catherine Porter), Cambridge: Polity, 2017; Latour, *Down to Earth: Politics in the New Climatic Regime* (tr. Catherine Porter), Cambridge: Polity, 2018; Bruno Latour and Timothy M. Lenton, 'Extending the domain of freedom, or why Gaia is so hard to understand', *Critical Inquiry* 45 (2019), pp. 659–80.

87 Jürgen Renn, *The Evolution of Knowledge: Rethinking Science for the Anthropocene*, Princeton, NJ: Princeton University Press, 2020, p. 365.

88 Renn, op. cit. (87), p. 31. See also Jürgen Renn, 'From the history of science to geoanthropology', *Isis* (2022) 113, pp. 377–85.

89 Renn, op. cit. (87), pp. 377–407.

90 Renn, op. cit. (87), pp. 394–5.

91 Jo Guldi, 'The climate emergency demands a new kind of history: pragmatic approaches from science and technology studies, text mining, and affiliated disciplines', *Isis* (2022) 113, pp. 352–65.

92 Guldi, op. cit. (91), p. 356, original emphasis. On emergency scholarship see also Andreas Malm, *How to Blow Up a Pipeline: Learning to Fight in a World on Fire*, London: Verso, 2021.

93 Candis Callison, 'The twelve-year warning', *Isis* (2020) 111, pp. 129–37, 130.

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I suggest taking forward aspects of both of these visions. Historians must work alongside rather than against scientists: as Andreas Malm writes, 'today, science is not the enemy; suppression of science – by Exxon for example – is the enemy'.[94] But, against Thomas and in keeping with Coen and Jonsson, I do not understand the condition of possibility for productive conversation being unequivocal acceptance of ESS's terms, including its disciplinary genealogy and model of interdisciplinarity. As Andrea Westermann and Sabine Höhler put it, historians' 'counter-conceptual innovations are more than mere language games. They give voice to the observation, that despite having measured and mapped the changes in the earth and climate with enormous precision … the sciences fall flat when facing societal cause and action'.[95] Renn's disconnection of Anthropocenic causes and solutions seems to me specious: identifying the processes that perpetrated and perpetuate Anthropocene harms is essential to understanding what is to be done. However, as I detail in the following section, histories of environmental and climate sciences can benefit from an intensified focus on the planetary processes – and human reshaping of these processes – that environmental and climate sciences identify. The mode of interaction between history and science most appropriate to the nested crises of the Anthropocene is one of mutual learning but also mutual challenge.

Damage and knowledge

How might historians analyse environmental and climate sciences in ways that take seriously scientific framings of the Anthropocene while retaining the prerogative to critique and reshape these framings? One approach to gain ground among a few historians of science and a wider range of environmental historians and environmental-humanities scholars is to focus on sites of anthropogenic damage as sites of knowledge production. This work suggests that places and processes of extraction, extinction, despoliation and exposure are often powerful prompts to new ways of conceiving of environments. In his US-centred analysis of environmental science and crisis from the 1960s to the present, anthropologist David Bond proposes the concept of 'negative ecologies' to capture the entanglement of damage and knowledge. Fossil-fuel and nuclear pollutants, he argues, have played a 'outsized role … in making the environment visible, factual, and politically operable'.[96] Bond also shows that the initially radical orientation of this pollutant-based 'insurgent science of survival', with the likes of Rachel Carson and Barry Commoner at the forefront, quickly gave way to 'an institutionalized science of concession'. Instead of identifying and working to dismantle the polluting processes of American global power, from the 1970s environmental science primarily sought to comprehend and manage effects through techniques like environmental impact assessments and 'safe' thresholds for individual pollutant substances.[97] Bond adds to earlier work such as Richard Grove's *Green Imperialism* that couches environmental awareness as inherently questioning dominant power structures, instead presenting a case in which knowledge was not only prompted by damage but became complicit in its perpetuation.[98]

94 Andreas Malm, *The Progress of This Storm: Nature and Society in a Warming World*, London: Verso, 2018, p. 132.

95 Andrea Westermann and Sabine Höhler, 'Writing History in the Anthropocene', *Geschichte und Gesellschaft* (2020) 46, pp. 579–605, 596.

96 David Bond, *Negative Ecologies: Fossil Fuels and the Discovery of the Environment*, Oakland: University of California Press, 2022, p. 5.

97 Bond, op. cit. (96), pp. 40–41, p. 51.

98 Richard Grove, *Green Imperialism: Colonial Expansion, Tropical Island Edens and the Origins of Environmentalism, 1600–1860*, Cambridge: Cambridge University Press, 1995.

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We might embrace the critical potential of this analysis without subscribing to Bond's suggestion that 'negative ecologies' originate with postwar US imperial power.[99] Here, work that seeks to 'provincialize' the Anthropocene, highlighting its differential causes, manifestations and effects across time and space is especially pertinent. Using the case of electrification in India, China and Japan as the basis of her characterization of an 'Asian Anthropocene',[100] Elizabeth Chatterjee 'refute[s] the notion of any simple relationship between colonialism and fossil capitalism'.[101] Instead, nation states took the lead in developing fossil energy infrastructure and 'increasingly large segments of Asia's population began to regard cheap energy as a right and a necessity'. Here, then, is an example of the blurred boundaries between the perpetrators and victims of Anthropocene bundles of damage and knowledge. Studies of 'African Anthropocenes' similarly highlight features that are concealed by a 'planetary gaze' framed solely by American power. Mineral and fossil-fuel extraction in postcolonial Africa perpetuated the power dynamics of European territorial imperialism in nationally or regionally differential forms, such as South African apartheid.[102] The case of uranium mining in Gabon suggests an even more fragmented landscape of damage and knowledge. There, the lingering effects of French imperial rule, the agnotology practised by multinational corporations, the competing priorities of earth scientists and nuclear physicists, and transnational mutual-aid networks for Gabonese workers all shaped environmental knowledge and patterns of harm.[103] In these instances and many more besides, associating 'negative ecologies' exclusively with the US risks becoming another mode of occluding Anthropocenic diversity, overlooking 'imperial durabilities' and local specificities.[104]

Just as the planetary is not an exclusively Euro-American domain, so is it not solely a late twentieth-century phenomenon. Understanding the distribution, movement, and durability of specific substances on a planetary scale was not unique to the era of hydrogen bombs and big oil. Shortages of strategically vital materials during and after the First World War driven by interrupted trade arrangements and booming military demands stimulated what Etienne Benson terms 'a new science of resources'.[105] This was a multipolar enterprise in which Russian and Soviet scientists played a major part in collaboration with colleagues in Western Europe and North America. This international and interdisciplinary endeavour was centrally concerned with 'tracking specific elements as they traveled through Earth's crust, oceans and atmosphere and [with] mathematically modeling the chemical and biological processes they participated in'.[106] Two crucial offshoots were Vladimir Vernadskii's conception of the 'biosphere' and the turn in ecology from the more static notion of 'community' to a dynamic and relation-based 'ecosystem'.[107]

Although Bruno Latour and Timothy Lenton point out that the 'critical zone' of earthly life is 'a thin biofilm, a pellicle no more than a few kilometers thick',[108] military

99 Bond, op. cit. (96), p. 42.

100 On the value of centring Asia in analyses of climate change and the Anthropocene see Amitav Ghosh, *The Great Derangement: Climate Change and the Unthinkable*, Chicago: The University of Chicago Press, 2016, p. 87.

101 Elizabeth Chatterjee, 'The Asian Anthropocene: electricity and fossil developmentalism', *Asian Studies* (2020) 79, pp. 3–24, 3.

102 Iva Peša, 'A planetary Anthropocene? Views from Africa', *Isis* (2022) 113, pp. 386–95, 387.

103 Hecht, op. cit. (37).

104 Ann Laura Stoler, *Duress: Imperial Durabilities in Our Times*, Durham, NC: Duke University Press, 2016.

105 Etienne S. Benson, *Surroundings: A History of Environments and Environmentalisms*, Chicago: The University of Chicago Press, 2020, p. 116. On war as driver of Anthropocene harms see Bonneuil and Fressoz, op. cit. (60), p. 122–47.

106 Benson, op. cit. (105), p. 117.

107 Benson, op. cit. (105), pp. 108–9, 122–6.

108 Latour and Lenton, op. cit. (86), p. 676.

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technologies and warfare exigencies enhanced attention to verticality in environmental and climate sciences.[109] This tendency developed in conjunction with the trend towards what Jason Moore terms a 'primarily vertical' geography of imperial accumulation.[110] It is telling that the 1890s and 1900s saw the advent of both kites and balloons taking self-recording meteorological instruments into the upper atmosphere, underpinning new understandings of climate as global and three-dimensional, and Euro-American geopolitics predicated on 'global closure' – that is, the exhaustion of horizontal space into which empires and capital could expand.[111] The German Navy in particular took a lead role in studies of atmospheric depth, raising balloons above far-flung points on the Atlantic, Indian, Pacific and Southern Oceans shortly after the turn of the twentieth century.[112] Military-led studies of the geophysical and biological properties of ocean depths, conducted from the 1840s by British and American vessels, were already well established by this juncture.[113] The extension of observation technologies into the deep ocean and high atmosphere, enabled by the (environmentally destructive) expansion of Euro-Western military–industrial complexes, was essential to making the planet into a more voluminous scientific object.[114]

This was not a wholly novel process, but instead a phase in the vertical extension of anthropogenic environmental violence and science. In his relocation of the origins of Alexander von Humboldt's holistic environmental understanding from the mountains of South America to the coal mines of Central Europe, Patrick Anthony provides an example of how links between extraction, exposure and science extend still deeper in spatial and temporal terms.[115] Humboldt began his systematic study of the mutual interaction of plants and their environs as a young mining official in Prussia concerned with subterranean atmospheric conditions and their effects on miners' bodies. He established that cryptogams (such as lichens, mosses and fungi) were afforded new habitats by man-made mine shafts and rendered the air poisonous to humans by decomposing water and absorbing oxygen. Humboldt's way of knowing vertically variable interrelations of air, earth, bodies and plants derived from his concern to 'facilitate the extraction of one natural resource by eradicating another'.[116] Long before Bond's 'negative ecologies', then, perceptions of human-made and substance-specific crises were powerful impulses to

109 On verticality in history of science see Wilko Graf von Hardenberg and Martin Mahony, 'Introduction. Up, down, round and round: verticalities in the history of science', *Centaurus* (2020) 62, pp. 595–611.

110 Jason W. Moore, *Capitalism in the Web of Life: Ecology and the Accumulation of Capital* (London: Verso, 2015); Bond, op. cit. (96), p. 44.

111 Gerry Kearns, 'Prologue. *Fin de siècle* geopolitics: Mackinder, Hobson and theories of global closure', in Peter J. Taylor, *Political Geography of the Twentieth Century: A Global Analysis*, London: Belhaven Press, 1993, pp. 9–30.

112 H. Hergesell, 'Report of the president of the International Commission on Scientific Aeronautics', in *Report of the Eighth Meeting of the International Meteorological Committee, Paris, September, 1907* (London: His Majesty's Stationery Office, 1908), pp. 30–1; *Report of the Ninth Meeting of the International Meteorological Committee, Berlin, 1910* (London: His Majesty's Stationery Office, 1912), p. 58. See also Robert-Jan Wille, 'Colonizing the free atmosphere: Wladimir Köppen's "aerology", the German maritime observatory, and the emergence of a trans-imperial network of weather balloons and kites, 1873–1906', *History of Meteorology* (2017) 8, pp. 95–123; Dania Achermann, 'Vertical glaciology: the second discovery of the third dimension in climate research', *Centaurus* (2020) 62, pp. 720–43, 721.

113 Helen M. Rozwadowski, *Fathoming the Ocean: The Discovery and Exploration of the Deep Sea*, Cambridge, MA: Harvard University Press, 2005.

114 Franck Billé (ed.), *Voluminous States: Sovereignty, Materiality, and the Territorial Imagination*, Durham, NC: Duke University Press, 2020.

115 Patrick Anthony, 'Mining as the working world of Alexander von Humboldt's plant geography and vertical cartography', *Isis* (2019) 109, pp. 28–55.

116 Anthony, op. cit. (115), p. 40.

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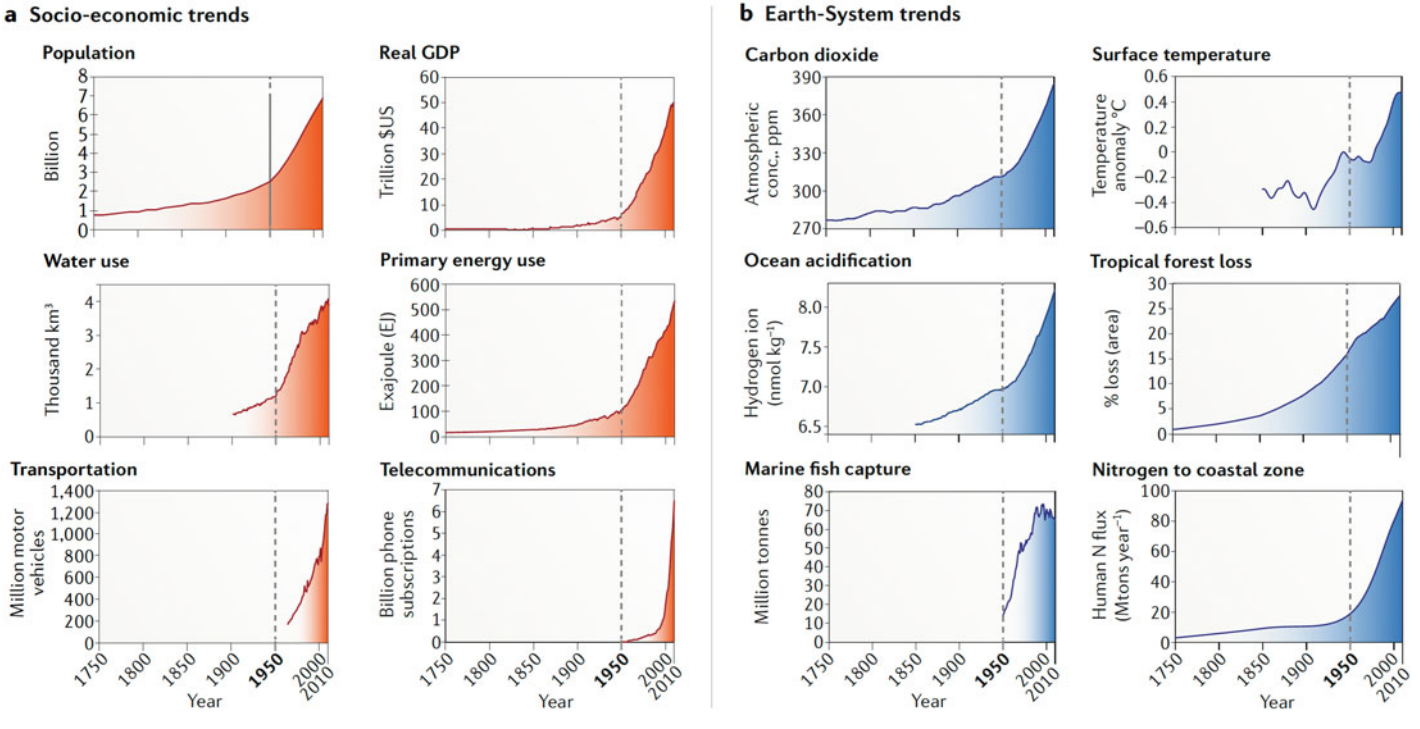

Figure 2. 'The Anthropocene', in Will Steffen, Katherine Richardson, Johan Rockström and Hans Joachim Schellnhuber, 'The emergence and evolution of Earth System Science', *Nature Reviews: Earth & Environment* (2020) 1, pp. 54–63, 60.

environmental visions and methods that foregrounded depth. With this insight, we can critically engage geologist Jan Zalasiewicz's suggestion that, 'as a first approximation, the Holocene is horizontal, and the Anthropocene is vertical'.[117] Zalasiewicz's claim specifically refers to the trend line on graphs that collectively illustrate the 'Great Acceleration' interpretation of the Anthropocene (Figure 2). Turning away from graphs and towards the measurement infrastructures and theoretical visions that undergirded sciences of the human-influenced planet illuminates a more venerable connection between verticality and the Anthropocene.

If vertical geographies of fossil-fuel extraction, use and pollution provide greater depth of focus to the picture of the co-production of environmental damage and knowledge, bringing in a broader array of resource frontiers gives this picture a longer exposure. Raj Patel and Jason Moore make the important claim that throughout its early modern and modern incarnations, capitalism has operated through expansion into new frontiers. Each moment of expansion is an attempt to fix an existing crisis caused by the despoliation of the various 'cheap things' – forms of human labour and more-than-human nature – that enable profitmaking.[118] In turn, each new frontier becomes a despoiled site that prompts further expansion. Historians of science might productively follow Patel and Moore (respectively an economist and a sociologist), along with other scholars such as anthropologist Anna Tsing,[119] to consider how projects to 'cheapen' labour and nature through violent undervaluation rely upon, and generate, new forms of science. Such a focus also entails attention to what Tsing and her colleagues term the 'patchy Anthropocene'. This spatial quality describes the highly differential local impacts of 'frenzied, accelerated' global capital,[120] defying a neat dichotomy of 'local' and 'global' that is, as I outlined earlier, a foundation of much late Holocene scholarship. Environmental historians and historical geographers have undertaken more work than historians of science on the knowledge regimes of 'patchy' resource frontiers. Grove's *Green Imperialism* is among the earliest and perhaps the most influential of an extensive literature on deforestation, desiccation and theories of environment and climate. It relates how 'the destructive social and ecological conditions of colonial rule' – especially the appetite for timber, first on small island colonies and later across substantial continental swathes – led to new notions of (anthropogenic) climatic change and environmental holism, and new schemes for managing 'nature'.[121] A similarly well-established (and overlapping) literature considers knowledge relating to irrigation and its crises.[122]

More recently, environmental historians have considered damage and knowledge across a wider array of ecological and extractive niches. One work in this vein that warrants attention from historians of environmental sciences is Debjani Bhattacharyya's analysis of troubled yet impactful colonial attempts to impose legal and technological fixity in the morphing land- and waterscape of the Bengal Delta.[123] The braiding of human and ecological agencies in this region, Bhattacharyya suggests, 'enabled multiple legal

117 Jan Zalasiewicz, 'Science: old and new patterns of the Anthropocene', in Thomas, op. cit. (81), pp. 21–50, 23–5.

118 Raj Patel and Jason W. Moore, *A History of the World in Seven Cheap Things: A Guide to Capitalism, Nature, and the Future of the Planet*, London: Verso, 2018.

119 Tsing, *Friction*, op. cit. (22), pp. 27–50.

120 Anna Lowenhaupt Tsing, Andrew S. Mathews and Nils Bubandt, 'Patchy Anthropocene: landscape structure, multispecies history, and the retooling of anthropology', *Current Anthropology* (2019) 60, pp. S186–S197, S187.

121 Grove, op. cit. (98), p. 486.

122 An important recent work in this field is Jennifer Keating, *On Arid Ground: Political Ecologies of Empire in Russian Central Asia*, Oxford: Oxford University Press, 2022.

123 Debjani Bhattacharyya, *Empire and Ecology in the Bengal Delta: The Making of Calcutta*, Cambridge: Cambridge University Press, 2018.

https://doi.org/10.1017/bjt.2024.1 Published online by Cambridge University Press

experiments, visionary ideas, and scientific theories'.[124] Here, then, human interventions and their limits involved what Sverker Sörlin and Nina Wormbs term 'environing technologies' – that is, tools for simultaneously knowing and (re)making environments.[125] What work by environmental historians like Bhattacharyya reminds historians of science of is the importance of attending to how planetary processes – such as climate dynamics, crust movements, biogeochemical cycles – are active components in human knowledge systems. This is not, however, a call for historians of science to become environmental historians. There remain plenty of cases in which environmental historians privilege the *making* element of 'environing technologies', leaving a conspicuous opening for historians of science to attend to the *knowing* aspect. One instance is Bathsheba Demuth's brilliant environmental history of the Bering Strait, which foregrounds how 'the ways that energy moved over the land and through the sea' were remade by, and in turn remade, capitalism and socialism.[126] What environmental sciences made of these divergent, destructive projects of harnessing animals, humans, earth, ocean and ice to economic ends – and what these projects did to the sciences – are problematics largely beyond the scope of Demuth's study, and surely ripe for investigation.

Conclusion

> I wanted to explore [photography] not as a question (as a theme) but as a wound: I see, I feel, hence I notice, I observe, I think.
>
> Roland Barthes, *Camera Lucida*.[127]

Being in the Anthropocene demands new forms of knowledge. 'Big pictures' born of the Holocene are no longer enough; we need 'planetary pictures' – pictures that represent the entanglement of human and planetary agencies without suppressing the heterogeneity of the 'planetary' and, especially, the 'human'. In this article, I have suggested three aspects to which historians of science might attend when they render planetary pictures: processes of scaling; the relationship between histories and the sciences they historicize; and the co-constitution of environmental violence and environmental science. The point of planetary pictures is not simply to go bigger, nor to adhere rigidly to terms set out by Earth system science, nor to assume that climate denialism and other forms of anti-science sentiment preclude historians from identifying the entanglement of damage and knowledge. Instead, Anthropocene histories of science pay attention to complexities and elisions of scaling, meaningfully engage with but also challenge environmental sciences, and focus on the ways in which anthropogenically altered environments emerge in tandem with new forms of environmental knowledge.

The planetary predicament of the Anthropocene entails more than just doing good scholarship, however; it demands doing good *with* scholarship. As studies of Anthropocene visuals – including whole-Earth images – demonstrate, it is perfectly possible for planetary pictures to have destructive effects. Some of the most outwardly successful and ubiquitous images have provoked 'terrific alienation', 'cynicism, irritability,

124 Debjani Bhattacharyya, 'A river is not a pendulum: sediments of science in the world of tides', *Isis* (2021) 112, pp. 141–9, 142.

125 Sverker Sörlin and Nina Wormbs, 'Environing technologies: a theory of making environment', *History and Technology* (2018) 34, pp. 101–25.

126 Bathsheba Demuth, *Floating Coast: An Environmental History of the Bering Strait*, New York: W.W. Norton, 2019, p. 4.

127 Roland Barthes, *Camera Lucida: Reflections on Photography* (tr. Richard Howard), London: Vintage, 2000, p. 21.

https://doi.org/10.1017/bjt.2024.1 Published online by Cambridge University Press

and issue fatigue'.[128] Certain framings of planetary pictures, as Nicholas Mirzoeff puts it, 'allow us to move on, to see nothing'.[129] Historians of environmental science should aspire to be part of an effort that crosses disciplines and extends well beyond ivory towers to make visible, and force a reckoning with, the perpetrators and victims of Anthropocene violence. What makes an Anthropocene discipline, above all, is not a specific question or methodology, but the aim of producing planetary pictures that, in Roland Barthes's terms, *wound*. This entails seeking to disclose harms while remaining sensitive to the twin dangers that such representations risk either recapitulating the damage or, at the opposite extreme, reiterating that 'no "we" should be taken for granted when the subject is looking at other people's pain'.[130] The infinitely demanding task of Anthropocene histories, then, is to make readers see, feel and, hence, notice, observe, think – and, we should add, act.[131]

Acknowledgements. Thanks to Jahnavi Phalkey, James Poskett and the anonymous reviewers for their comments and suggestions. I am especially grateful to the students I taught on the MPhil in Anthropocene Studies at Cambridge for discussing many of the ideas that appear in this article.

128 Lazier, op. cit. (27), p. 630; Saffron O'Neill, 'Defining a visual metonym: a hauntological study of polar bear imagery in climate communication', *Transactions of the Institute of British Geographers* (2022) 47, pp. 1104–19, 1117.

129 Mirzoeff, op. cit. (65), p. 217.

130 Susan Sontag, *Regarding the Pain of Others*, London: Hamish Hamilton, 2003, p. 6.

131 Simon Critchley, *Infinitely Demanding: Ethics of Commitment, Politics of Resistance*, London: Verso, 2007.

Cite this article: Simpson T (2024). Planetary pictures: historicizing environmental and climate sciences in the Anthropocene. *BJHS Themes* 1–20. https://doi.org/10.1017/bjt.2024.1