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A Perfectly Nebulous Experiment: C.T.R. Wilson's Cloud Chamber

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The Romantic poet John Keats describes in a letter to his brother how drifting clouds on the mountaintop of Ben Nevis seemed to open and close like 'dome curtains'.[1] Inspired with awe, he wrote a sonnet, 'Read Me a Lesson Muse, and Speak It Loud' (1818), while sitting on the stony edge of a Ben Nevis cliff with the valley below him. A wondrous and sombre reflection on human limits marks his last three lines: 'all my eye doth meet is mist and crag, not only on this height, But in the world of thought and mental might!'[2] The desire for revelation is readily apparent in Keats's evocation that mist hides secrets to be illuminated. That clouds would elicit the imagination resonates with a long history of myths. In the Renaissance the shapes of clouds were feared to be the work of demons finding embodiment in fog and mist and transmuting themselves into ominous appearances in the sky.[3] Half a millennium later, the nineteenth-century writer and art critic John Ruskin described a billowing storm cloud as the hundred-headed dragon of the Hesperides and another as 'a black monster cloud – half dolphin, half tiger' that 'rolled and rose, and finally toppled and tumbled' like an avalanche.[4] In like manner, during the filming of *The Avenging Conscience* (1914), the director D.W. Griffith requested a series of cloud studies in a sequence featuring the apparitions of angels and demons.[5] The late nineteenth and early twentieth centuries seem to inherit an early modern fascination with creatures and spirits continuously saturating the air with clouds. Yet, it was also in the late nineteenth century that meteorology was transformed into a science proper. The weather was increasingly explained using science, thus progressively pushing aside the role of mythology and other less-than-materialist accounts. One of the significant contributors to the scientific understanding of cloud formation was the Scotsman Charles Thomson Rees Wilson (1869–1959), a meteorologist who discovered a means to render the path of electrons visible, thereby visually proving their material existence. He received the Nobel Prize in physics in 1927 for this work, which entailed photographing the tracks of

charged particles in his so-called cloud chamber soon designated 'the most original and wonderful instrument in scientific history'.[6] The visualization of subatomic matter that this instrument promised initiated several generations of research into microphysics.

C.T.R. Wilson famously began his Nobel Prize lecture by attributing his success with the cloud chamber to his visual experience at the meteorological observatory on the Scottish mountaintop of Ben Nevis. Sounding more like an artist than a scientist, Wilson sought to recreate his experiences and so made a miniature world using a small laboratory chamber. Wilson's aesthetic interest in the cloud chamber is examined in detail by the historian of science Peter Galison.[7] When Galison questions why Wilson eventually purified the air in his chamber when dust is naturally present in the atmosphere, he concludes that Wilson's goal had turned from imitating to dissecting nature. But despite Galison's admirable cultural-historical analysis of the invention, it remains too safely rooted in the realm of present-day science. From its very beginning, the achievements of Wilson's cloud chamber reveal no clear distinction between what we might conceive as 'matters of fact' and 'matters of concern',[8] or between the realms of science, art and metaphysics. This essay argues that Wilson's earliest cloud chamber project sought to idealize the place he identified as home and recreate an exemplary nature from his experience on Ben Nevis. By reproducing local nature as perfectly pure, however, his early cloud chamber experiments relied on a metaphysically oriented scientific practice dominant before the mid-nineteenth century, one that had turned quite outmoded by the end of the century when Wilson was thinking through his project. As a result, in the 1890s, Wilson shared more artistic and environmental concerns with John Ruskin – including his lecture 'The Storm-Cloud of the Nineteenth Century' (1884) – than with John Constable and his cloud studies (1821–22). This paper's proposed shift in viewpoint for Wilson's cloud chamber highlights, then, how the seeds of a progressive science of meteorology and, later, particle physics were set in motion by one man's at times scientifically regressive ideas about art, science and nature. Thus, the scientific research on meteorology of the late 1880s and 1890s and his own metaphysical worldview confirmed the possibility of dust-free air on the mountaintop. Ben Nevis represented his pride in his local region and, with a geocentric picture of the world, Wilson imagined a purer realm above the earth and closer to heaven. It is this perfectly pure experience that Wilson wished to reproduce in his early cloud chamber through the recreation of optical phenomena.

Producing Clouds and Optical Phenomena in the Laboratory

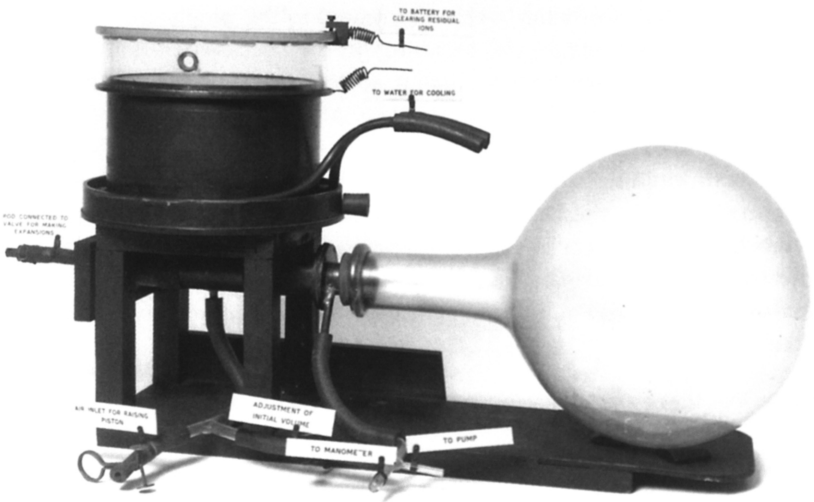
Wilson's earliest predecessor for the cloud chamber was Robert Boyle's experiments with an air pump in the late 1650s in London, which spurred the idea of artificial experiments existing as matters of fact; that an experiment

as human artifice could be just like nature. Wilson's desire to produce a second, mediated world was related to one already theorized in the realm of philosophy and aesthetics on the Continent in the nineteenth century. In the 1820s and 1830s, Hegel was lecturing on the necessity of understanding artistic activity as an act of reproduction, seeing art as an 'offspring' in which one planted one's own thought and nature. Alien nature was made familiar, inviting one to see an aspect of one's self in one's own doing: 'This human need runs through the most varied phenomena up to that particular form of self-reproduction in the external fact which is presented us in human art'.[9] The fabrication of Wilson's early cloud chamber in 1895 served the purpose of orchestrating and realizing an event as a matter of fact by means of an artificial, visual and tangible object that mimicked the object of nature sufficiently well to stand in for it:

> In September 1894 I spent a few weeks in the Observatory which then existed on the summit of Ben Nevis, the highest of the Scottish hills. The wonderful optical phenomena shown when the sun shone on the clouds surrounding the hill-top, and especially the coloured rings surrounding the sun (coronas) or surrounding the shadow cast by the hill-top or observer on mist or cloud (glories), greatly excited my interest and made me wish to imitate them in the laboratory.[10]

Though Wilson's initial trip to Ben Nevis made him 'fall in love with clouds'[11] and inspired him to create his first cloud chamber, he made many versions of it, each time modifying the apparatus according to its newly given purpose. While recreating fogs, mists and optical phenomena in 1895, for example, he also used his cloud chamber to measure levels of expansion at which vapour condensed or to observe moments at which colours were most brilliant. Soon after his creation of optical effects, his focus turned to an investigation of the possibilities for condensation. It is through his investigation with purified air in the cloud chamber that Wilson demonstrates his attitudes towards and pride in local nature. Examining a 1911 version of Wilson's cloud chamber, however, will aid in designating the various parts of the cloud chamber and how they operate (Figure 10.1). The top, flat glass chamber of Wilson's apparatus is where he would observe his experiments. The chamber sits on a brass cylinder inside of which a movable piston floats in a shallow trough of water keeping the air moist inside the cylinder. The large glass ball on the right is attached to a valve underneath the cylinder. The air in the glass ball is then evacuated using a pump. When the valve under the cylinder is opened, the piston inside the cylinder drops quickly, causing filtered (dust-free) air from the chamber to rush into the glass ball. The drop of pressure in the chamber makes the air expand, cooling the temperature and causing supersaturation in the glass chamber. Wilson would observe the top, flat glass chamber in darkness with a direct light source and make notes of the optical phenomena and cloud condensation created.

The introduction of photography into Wilson's later experiments changed the course of the project towards an investigation of subatomic matter not seen



10.1 Wilson's Cloud Chamber (1911). Courtesy Cavendish Laboratory, Physics Department, University of Cambridge

by the naked eye. Thus, after approximately 10 years (1900–10) of focusing on thunderstorms and atmospheric electricity, Wilson returned to the cloud chamber with the intent of photographing rather than merely observing falling drops of liquid in the chamber. Once Wilson noticed cloud tracks in the chamber that looked like tiny, barely visible trails, presumably left behind by invisible subatomic particles, he managed to visually document the tracks through photographs showing 'little wisps and threads of clouds' excited by radiation. This new finding relied not only on the authoritative role of the photographic technology as an equivalent to sight, but, more importantly, on an image (almost) making possible an 'extension of vision' into the submicroscopic world.[12] As one physicist writes about the photographs of clouds tracks, '[b]ecause of the immediacy of the pictures obtained, the existence of the elementary particles is forced upon even the most skeptical'.[13] While Wilson's documentation of the tracks of charged particles is an exciting turn for his cloud chamber project, it is his early experiments, prior to his use of photography, at a time when he focused on the imitation of optical phenomena, that is of primary concern here. One of Wilson's notebook entries in 1895 poses the question, 'When [are the optical effects] best formed (In dusty or tolerably pure air ...) [?]' The notebook entries that followed show that he proceeded by completely purifying the air.[14] The question of the inclusion or exclusion of dust in his cloud chamber foregrounds the extraordinary puzzle of Wilson's intentions with his initial experiments.

Wilson's colleague, the meteorologist John Aitken, had observed and measured dust particles in nature and in artificially created, supersaturated environments.[15] Aitken had also spent time at the observatory at Ben Nevis

during the years 1889–93 and constructed a miniature dust chamber so as to count the dust particles in the atmosphere at the meteorological observatory.[16] Aitken found that the resulting condensation in his chamber was due to the presence of dust and concluded, as a result, that no clouds formed when dust particles had been filtered from the air. But Wilson knew that it was in fact possible to produce clouds through condensation of purified air *if* a specific 'expansion limit' was reached.[17] In fact, the environment created in the cloud chamber caused condensation in the chamber if one or all of the following circumstances were met: if dust particles were present in the chamber; if the expansion rate was sufficiently high (that is, if the drop in pressure in the chamber was sufficiently sudden and rapid); or, as he later discovered, and some had already theorized in the 1890s, if ions were present.[18] Through his experiments with the creation of optical effects – such as coronae (coloured concentric rings caused by light from the sun or moon hitting water droplets in clouds or fogs) and glories (coloured rings around the observer's shadow cast on a fogbank) (Colour plate 13) – Wilson had found limits at which expanded, moist and filtered air would indeed produce fog, mist or rain-like condensation. As he stated in his Nobel lecture several years later, '[w]ith expansions exceeding this limit, dense clouds were formed in dust-free air, the number of drops in the cloud increasing with great rapidity as the expansion was increased beyond it and giving rise on account of their small and uniform size to very beautiful colour phenomena'.[19] Wilson was clearly seeking to recreate magnificent optical phenomena, yet it seems less obvious why he chose to artificially filter all the dust from his chamber to reproduce optical effects when dust is naturally present in the atmosphere.

Peter Galison interprets Wilson's attempt to purify the air as a divergence from his previous intentions to make a mimetic experiment. 'This artificial aspect of his experiments', says Galison, 'signals a significant departure from the mimetic tradition in which his work was initially embedded'. According to this hypothesis, Wilson was no longer working with a matter of fact that was just like nature. Consequently, Galison concludes that, unlike Aitken who had wanted to recreate nature, 'Wilson created artificial laboratory conditions in order to "dissect nature"'.[20] But there are several problems with Galison's conclusion that Wilson was knowingly diverting from a mimetic experiment when he purified the air in the chamber. First of all, between the years 1904–10, Wilson put aside his cloud chamber, and did so because he worried that his use of X-rays, and the resulting condensation, was an artifice of his laboratory.[21] Considering this later and abrupt rejection of his project at a moment of marked doubt regarding its link with reality, it seems only plausible that Wilson's faith in his creation of a mimetic experiment was still intact during the time preceding his use of X-rays. Secondly, Galison seems to rely too comfortably on contemporary science when he draws his conclusion that Wilson was creating an artificial laboratory environment. For at the time of Wilson's experimentations, it was generally understood among meteorologists and laymen alike that the summit of Ben Nevis and

the surrounding highlands provided the purest air, at times even exhibiting completely dust-free air. William Thomas Kilgour, a long-time staff member at the Ben Nevis Observatory, states that

> the summit of Ben Nevis ... enjoys the unique distinction of being the only station of the many at which observations have been taken where, at times, it has been found impossible to detect the presence of any dust. Sometimes, of course (particularly when the wind is from the direction of dense population), Ben Nevis air shows a large number of dust particles per cubic centimeter; but, on the mean, the West Highlands of Scotland, whether at a low or a high level, furnish the purest air as yet discovered in Europe.[22]

John Aitken was the authority on the measurement of dust, and in a 1902 retrospective paper on his work at Ben Nevis, he states that 'on a few occasions' he had observed no dust on the Ben. Meteorological observations reveal, adds Aitken, that the 'Western Highlands of Scotland is by far the least dusty in the world', noting soon again that 'the air of the Highlands is purer than at any other stations tested'.[23] Wilson's laboratory experiment with pure air cannot be divorced from a turn-of-the-century science of meteorology that conceived of the actuality of dust-free air under exceptional conditions.[24] Wilson was not only still working in the mimetic tradition, he had a specific experience and place in mind. Though rare but feasible according to Aitken's calculations, the atmosphere and upper air surrounding Ben Nevis could exhibit dust-free air.

Ben Nevis and Local Pride

Galison's account places insufficient emphasis on the locale that Wilson had in mind. That local meteorology mattered is evident in the descriptions by Kilgour and Aitken quoted above representing the quality of the air at the summit of Ben Nevis as well above the norm. This focus on locale seems more indicative of an eighteenth-century meteorology that sought to link the weather to the pride and identity of a region, a practice especially popular in the British provinces. Provincial weather phenomena were understood as part of the regional natural history and consequentially managed to signify the cultural importance of a local community.[25] Wilson's personal investment in the region near the Scottish hills appears in his propensity to describe his climbs on Ben Nevis and the surrounding hills alongside his laboratory notes. He was born and raised in the 'pastoral countryside', as he says, near Glencourse in the Pentland Hills and, upon retirement, returned to this place where his forebears had been farmers for generations. He acknowledged his debt to the locale in his Nobel Prize banquet speech when he declared, 'To those few weeks spent on the highest point of my native land I owe many happy years of work in the laboratory'.[26] And the constant emphasis on 'home' in his 'Reminiscences' (1960) confirms the extent to which he not only identified with the region but also understood his scientific work as bound

to those experiences.[27] Wilson's meteorological practice was domestically centred and fundamentally a remnant of a bygone era.

The emphasis on personal experiences on the summit of Ben Nevis raises the question of Wilson's preferred imitation of the atmosphere at the mountaintop. For when Wilson purified the air in his cloud chamber, he was imitating what he believed to be a very specific and favourable condition right after condensation resulting in the purest experience possible on the summit. Dust-free air was not the norm; it was the exception, according to scientific research at the time. It was an extraordinary condition happening only rarely, as per Aitken's observations. The glories and coronae that Wilson sought to recreate were singular, specific to high altitudes and barely understood at the time.[28] Why was Wilson seeking to mimic the purest and most perfect experience possible, rather than what would have been conceived as an ordinary atmospheric condition on the top of Ben Nevis?

Constable or Ruskin as Artistic Source?

Late nineteenth-century meteorologists had laboured hard to dispel metaphysical and mythological speculations about the weather still lingering in the cultural mainstream.[29] In fact, meteorology as a science had long suffered from its own regressive theories, based as they were on Aristotle's *Meteorologica* as late as the 1600s. Even Luke Howard's 'Modifications of Clouds' (1803) was in principle merely descriptive of the various kinds of visual shapes formed by clouds. By the mid-1800s, meteorology was finally drawing on physics and chemistry for its practice, relying on experimental science rather than description or conjecture.[30] To now propose the possibility that Wilson's intentions might extend beyond scientific fact, beyond aesthetics and into the realm of metaphysics would be to suggest a major setback for the science of meteorology and, by extension, for particle physics. Perhaps it is for this reason that Galison chooses to omit the great Victorian writer, art critic, social critic, artist, scientist, poet and environmentalist John Ruskin from his cultural history of Wilson's cloud chamber, and this despite Ruskin's extensive writings on clouds. As a result, Galison provides a markedly different historical take on the Victorian imagination by including John Constable's cloud studies (1821–22), for example, while omitting John Ruskin's lecture 'The Storm-Cloud of the Nineteenth Century' (1884). These two Victorian men illustrate two very different, but contemporaneous ways of perceiving nature and truth. To Constable the idea of a 'truth of nature' would be nature itself made manifest, whereas to Ruskin 'truth of nature' would mean the revelation of a spiritual presence.[31]

In his lecture on the storm cloud, Ruskin described the existence of an unusual white cloud appearing in pure air, the cloud's 'prismatic colours' being 'impossible to paint'. He contrasted the pure, white cloud with the 'sulphurous chimney-pot vomit' of a 'diabolic' cloud.[32] In *Modern Painters*

(1888), Ruskin drew directly on biblical references when he claimed that clouds were God's chariot and His dwelling place, stating that it was precisely the colourful phenomena of light on the firmament of clouds that showed the divine most immediately.[33] Ruskin's emphasis on purity brings to mind an earlier scientific and artistic endeavour exemplified by Goethe's idea of the pure phenomenon (1798). He argued for a scientific experiment of a higher kind seen by the soul more than the eyes. After observing nature and subtracting the 'impure' and accidental, the pure phenomenon would emerge in the union of 'all experiences and experiments' combined.[34] In Goethe's mimetic science, man placed himself in nature (rather than against it), and through science and art he perfected it with the creation of an archetypal phenomenon. Wilson's early cloud chamber comprised a personal collection of thoughts externalized in a chamber placed in and beside nature. It served as an 'offspring', both like nature and more perfectly human. 'The nearest cloud maker is one's own self. All men are created cloud builders', says one meteorologist reflecting on the nature of clouds and the possibility of producing and controlling them. '[W]hen we cease cloud making we cease to live'.[35] In his cloud chamber Wilson planted his wonder and concerns, the experiences and experiments that for him truly mattered.

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Notes

1 Gary Hawkins, notes to *The 64 Sonnets* by John Keats, ed. Edward Hirsch (Philadelphia: Paul Dry Books, 2004), p. 108 n.

2 Ibid. Charles Brown copied Keats's poem, probably the same year that Keats wrote it, and gives this account in his *Life of John Keats* (London: Oxford University Press, 1987).

3 Michael Cole, 'The Demonic Arts and the Origin of the Medium', *Art Bulletin* 84 (December 2002): p. 623; Hubert Damisch, *A Theory of /Cloud/: Toward a History of Painting*, trans. Janet Lloyd (Stanford: Stanford University Press, 2002), p. 23; Carlo Ginzburg, *The Night Battles: Witchcraft and Agrarian Cults in the Sixteenth and Seventeenth Centuries*, trans. Anne Tedeschi and John Tedeschi (London: Routledge and Kegan Paul, 1983).

4 John Ruskin, 'The Storm-Cloud of the Nineteenth Century' (1884), in *The Works of John Ruskin*, ed. E.T. Cook and Alexander Wedderburn (London: George Allen, 1908), p. 24, n. 3.

5 L.R. Phillips, *D.W. Griffith: Titan of the Film Art* (New York: Gordon Press, 1976), p. 109.

6 Lord Rutherford, 'C.T.R. Wilson – Bibliography', *Nobel Lectures, Physics 1922–1941* (Amsterdam: Elsevier Publishing, 1965), http://nobelprize.org/nobel_prizes/physics/laureates/1927/wilson-bio.html.

7 Peter Galison, 'Cloud Chambers: The Peculiar Genius of British Physics', in Galison, *Image and Logic: A Material Culture of Microphysics* (Chicago: University of Chicago Press, 1997).

8 Bruno Latour, 'Why Has Critique Run Out of Steam? From Matters of Fact to Matters of Concern', *Critical Inquiry* 30 (Winter 2004): p. 232.

9 G.W.F. Hegel, introduction to 'The Philosophy of Fine Art', in *Philosophies of Art and Beauty: Selected Readings in Aesthetics from Plato to Heidegger*, ed. Albert Hofstadter and Richard Kuhns (Chicago: University of Chicago Press, 1964), pp. 400–401.

10 C.T.R. Wilson, 'On the Cloud Method of Making Visible Ions and the Tracks of Ionizing Particles', Nobel Lecture (December 12, 1927), p. 194, in *Nobel Lectures, Physics 1922–1941*, http://www.nobel.se/physics/laureates/1927/wilson-lecture.pdf.

11 C.T.R. Wilson, 'Banquet Speech', Nobel Banquet in Stockholm (December 10, 1927), in *Les Prix Nobel en 1927*, ed. Carl Gustaf Santesson (Stockholm: Nobel Foundation, 1928), http://nobelprize.org/nobel_prizes/physics/laureates/1927/wilson-speech.html.

12 For a discussion of the problems inherent in the idea of an extension of vision through the use of instruments, see Joel Snyder, 'Visualization and Visibility', in *Picturing Science, Producing Art*, ed. Caroline A. Jones and Peter Galison (New York: Routledge, 1998), pp. 379–97.

13 Cyril Henderson, *Cloud and Bubble Chambers* (London: Methuen, 1970), p. vii.

14 C.T.R. Wilson's laboratory notes, A1 (March 26–August 15, 1895), Library of the Royal Society of London, quoted in Galison, *Image and Logic*, p. 96.

15 Boyle's air pump was made by his assistant Robert Hooke, who was to become the father of modern meteorology for inventions like the thermometer. Howard Frisinger, *The History of Meteorology to 1800* (New York: Science History Publications, 1977). Other important forerunners to Wilson's earliest work with the cloud chamber are Robert von Helmholtz, Carl Barus, Karl Kiessling and Jean Paul Coulier. See C.T.R. Wilson, 'Condensation of Water Vapour in the Presence of Dust-Free Air and Other Gases', *Philosophical Transactions of the Royal Society of London, A* 189 (1897).

16 John Aitken, 'Report on Atmospheric Dust', Meteorology of the Ben Nevis Observatory, *Transactions of the Royal Society of Edinburgh* 42/2 (1902): pp. 479–89; John Aitken, 'On the Formation of Small Clear Spaces in Dusty Air' (1883–84), *Transactions of the Royal Society of Edinburgh* 32/2 (1887): pp. 239–72.

17 Wilson, 'Condensation of Water Vapour', p. 266.

18 Galison, *Image and Logic*, pp. 94–96.

19 Wilson, Nobel Lecture, p. 195.

20 Galison, *Image and Logic*, pp. 95–96.

21 P.M.S. Blackett, 'Charles Thomson Rees Wilson', *Biographical Memoirs of Fellows of the Royal Society* 6 (November 1960): p. 287; Galison, *Image and Logic*, pp. 106–7.

22 William Thomas Kilgour, *Twenty Years on Ben Nevis* (London: Alexander Gardner, 1906), pp. 166–67.

23 Aitken, 'Report on Atmospheric Dust', p. 482.

24 Wilson himself justifies his use of dust-free air in his laboratory experiments by noting the difference in pressure between the air at the lower cloud layer and the air that rises above it where condensation becomes again possible. He adds, however, that any increasing, rapid expansion in his chamber beyond this re-emerging condensation would have little meteorological significance, as it would be unlikely to occur in nature. Wilson, 'Condensation of Water Vapour', p. 286.

25 See Vladimir Janković, *Reading the Skies: A Cultural History of English Weather, 1650–1820* (Chicago: University of Chicago Press, 2000), p. 166.

26 Wilson, Nobel Banquet Speech.

27 C.T.R. Wilson, 'Reminiscences of My Early Years', *Notes and Records of the Royal Society of London* 14/2 (1960): pp. 163–73.

28 Alexander Buchan, 'The Meteorology of Ben Nevis', *Transactions of the Royal Society of Edinburgh* 34 (1890): p. xlix.

29 Thunderstorms, for example, were thought to cause living organisms to rot. John Aitken, 'On the Number of Dust Particles in the Atmosphere of Certain Places in Great Britain and on the Continent with Remarks on the Relation between the Amount of Dust and Meteorological Phenomena' (1892), *Transactions of the Royal Society of Edinburgh* 37 (1892–95): p. 21.

30 Aristotle, *Meteorologica*, trans. H.D.P. Lee (Cambridge: Harvard University Press, 1952); Luke Howard, 'On the Modifications of Clouds, and on the Principles of their Production, Suspension, and Destruction: Being the Substance of an Essay Read before the Askesian Society in the Session 1802–1803', pts 1 and 2, *Philosophical Magazine* 16 (1803): pp. 97–107; 344–57; 17 (1803): pp. 5–11.

31 Ann Bermingham, *Landscape and Ideology: The English Rustic Tradition, 1740–1860* (Berkeley: University of California Press, 1986), p. 178.

32 Ruskin 'The Storm-Cloud', pp. 38–40.

33 Wilson was married to a reverend's daughter. John Ruskin, *Modern Painters*, vol. 4, *Of Mountain Beauty* (Orpington, Kent: George Allen, 1888), pp. 85–89.

34 Johann Wolfgang Goethe, 'The Pure Phenomenon' ('Das Reine Phänomen') (January 15, 1798), in *Goethe's Color Theory*, American edition, trans. and ed. Herb Aach (New York: Van Nostrand Reinhold, 1971), pp. 65–66.

35 Alexander McAdie, *A Cloud Atlas* (Chicago: Rand McNally, 1923), p. 27.