BIOGRAPHICAL MEMOIRS

Sir (Basil) John Mason CB. 18 August 1923 — 6 January 2015

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Elected FRS 1965

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Sir John Mason will be remembered for establishing cloud microphysics as a coherent discipline and for building the Meteorological Office into a leading centre of excellence on the international stage. A charismatic man, he possessed scientific vision, enthusiasm and an inspiring style of lecturing and advocacy that enabled him to recruit good scientists and raise the funds needed to achieve these ends, although his manifest self-belief and forthright manner upset some. He was highly influential within international institutions such as the World Meteorological Organization and nationally as president of many scientific bodies and Senior Vice-President and Treasurer of the Royal Society from 1976 to 1986.

EARLY LIFE

John Mason was born on 18 August 1923 in Docking, Norfolk, east of Hunstanton. His father was a farmer who died in 1936, and so his mother—a school teacher—would have been a major influence in his upbringing. When he spoke of them he tended to give the impression that his parents were simple folk who would not have understood his work or his eminence. He could already read and recite his arithmetic tables by the time he was four years old, when he started at the local village primary school. At the age of 11 years he went to the nearby Fakenham Grammar School. World War II began when he was in the sixth form, and many of his teachers were called up. As a result he had no formal teaching in mathematics or physics for his Higher School Certificate, the then equivalent of today’s A-levels. A school from London was evacuated to Fakenham and its headmaster taught him mathematics in odd moments, but he more or less taught himself physics. There was, however, a very good biology teacher and so Mason concentrated on biology; in 1941 he won a scholarship to what was then University College Nottingham on the strength of his performance in biology. Once in university, however, he took up physics and mathematics. He had toyed with the idea of studying the arts but decided

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on physics instead because of the need for people in radar and signals during the war. He easily came to grips with physics; indeed, because many lecturers had been called up, he was given the responsibility in his second year of lecturing to first-year students. But then, in 1944, he himself was called up before he could enter the third and final year of his degree course.

He went into the Royal Air Force (RAF) and was appointed immediately as a radar officer. He had the usual six-week short-service training and was then commissioned and unusually quickly promoted to Flight Lieutenant. His first job was as Chief Instructor at the Fighter Command Radar School. He found the teaching experience very valuable. New radar-sets, mainly from the USA, were becoming available at that time and because there were virtually no manuals he had to determine how the sets worked, sometimes the previous night, before teaching people how to use and service them the next day. The work was extraordinarily demanding but he thrived on the challenge.

In early 1944 he was posted to India and Burma before being made Officer-in-charge of Signals and Telecommunications in Batavia (now Jakarta, Indonesia) in what was then the Netherlands East Indies. He was still only 21 years old but the early responsibility provided him with further remarkable experience, which stood him in good stead later. So young was he that he recalls his nonplussed Warrant Officer peevishly saying that he ‘had seven children, five of whom are older than you, sir’ (Royal Meteorological Society 1985). He was in the job for about 14 months before being demobilized. During that period he had had to learn quickly how to manage people.

After leaving the RAF he went back to Nottingham University. Because he returned part way through an academic year, he had only six or seven months before sitting his final examinations. During this period he had to assimilate not only the third-year material, some of which he had missed, but also revise all the things he had been taught in his first two years. Accordingly he decided that there was insufficient time for him to attend lectures or laboratory sessions and, much to his professor’s annoyance, he instead read through the textbooks by himself. At this stage he was, of course, much older than most of the other students who had not been called up and he was determined not to let them beat him. He graduated in 1947 with a first-class honours degree: it was an external degree of London University because at that time Nottingham did not grant its own degrees. He was then awarded a Shirley Research Fellowship and worked on surface physics at Nottingham for a year in anticipation of going on to complete a PhD in this field. However, an attractive job opportunity arose elsewhere and he left after one year with an MSc and two research papers on surface tension to his name.

His next job was the result of a successful interview with Professor David (later Sir David) Brunt FRS, who was then head of the Department of Meteorology at Imperial College, London. Although Mason had no background in meteorology, he had been attracted by the advertisement for an assistant lecturer or lecturer in experimental physics in the department. Brunt explained that he wanted to build up the department after the war and that, apart from P. A. (‘Peter’) Sheppard (FRS 1964), who was then a Reader but later became Professor and Head of Department, they had nobody on the staff who did much experimental work. Mason subsequently remarked that he was very impressed by Brunt’s approach, which was in stark contrast to today’s tendency towards micromanagement. Indeed, Brunt’s approach to management may well have influenced the style of management that Mason himself later adopted. He recalled (Royal Meteorological Society 1985) Brunt telling him at his interview:

It doesn’t matter if you don’t know any meteorology. I’m told you are a very strong-minded young man who has got plenty of energy, drive and enthusiasm, and you know where you are going … so you can do anything you like. Come here and you can start from scratch; you can build up and
Basil John Mason

take any branch of atmospheric physics and just get on with it. And if I offer you an appointment and you take it, I’ll tell you just one thing: I am now Physical Secretary of the Royal Society and am getting on … so I don’t have much time to supervise you but if you make a good job of it and you show promise, I will back you to the hilt. If you don’t, I shall kick you out!

The idea of working on his own and having a free hand captured Mason’s imagination and he accepted the offer. Commenting on this later, he said:

I’ve often reflected whether [working on one’s own] is necessarily a good thing. … That has some pros and cons: I would no doubt have learnt a great deal and would have been influenced a great deal if I had been under some great man or been in … one of the major schools of physics. On the other hand I may have grown up in their shadow and may not have developed my own independence and [gone] my own way.

The present writer, however, finds it hard to imagine Mason remaining in anyone’s shadow.

**Imperial College, 1947–65**

*Department of Meteorology*

One might have thought that Mason’s interest in cloud physics would have been sparked by his wartime work with radar and its ability to detect rain; however, although he was in contact with meteorologists in the RAF, he has said that this was not the case and that the main reason was Professor Brunt’s personality and the opportunity he provided at Imperial College for him to do experimental work in a new field. Anyway, he started work in the Department of Meteorology in 1947 as an Assistant Lecturer at an annual salary of £400. A year later he was promoted to Lecturer and his salary increased, but only to £600. During his time in the department, it was a very lively place, with several other able and ambitious lecturers such as Richard Scorer, Eric Eady and Frank Ludlam, all eventually professors, and all prima donnas in their own way.

At the start of his new job, Mason looked around for a topic in which he could exploit his interest in experimental physics, preferably one that did not require him to have a significant background in meteorology. He found out about work under Professor G. M. B. Dobson FRS going on at Oxford University using cloud-chamber experiments, pioneered by the Nobel prize-winning physicist C. T. R. Wilson FRS, to investigate the freezing of water drops. He and Frank Ludlam also came across captured German documents describing some remarkable work on clouds carried out before and during the war by Walter Findeisen, who had a laboratory in Prague. Findeisen had not only built a big cloud chamber to try to simulate clouds but also had his own aircraft for making measurements within clouds. In addition, Mason came across the work of the American Nobel laureate, Irving Langmuir ForMemRS, who had been studying aircraft icing during the war and went on to discover, with Vincent Shaefer, that clouds can be seeded by dry ice or silver iodide to create precipitation. Against this backdrop Mason saw several threads that could be brought together in what seemed to be an area of research ripe for development.

He started by studying the nucleation of ice crystals and the supercooling of water, initially with just one or two students. His first paper was a review, published in 1950, that tried to paint a coherent picture of the nucleation of the ice phase in the atmosphere (1)*. In the same year he was invited to give one of the main lectures, on ice-crystal growth, at a meeting in

* Numbers in this form refer to the bibliography at the end of the text.
Oxford to mark the centenary of the Royal Meteorological Society. Here he came to the notice of international luminaries such as Carl-Gustaf Rossby, Eric Palmen and Sverre Petterssen. This was soon followed by an invitation from Brunt, then president of the Physics Section of the British Association for the Advancement of Science (BAAS), to help organize a session on cloud physics in the 1951 annual meeting of the BAAS, held in Edinburgh. What is more, still only 27 years old, he was asked to give the first talk in this session. It was on the natural and artificial production of rain. The Duke of Edinburgh was in the chair and so it was a big event nationally, which provided Mason with a very prominent platform. The success of his lecture effectively launched his public lecturing career. Another bonus from that lecture was that it inspired a young man to become Mason’s first PhD student: John Monteith (FRS 1971), later Professor of Agricultural Science at Nottingham University.

While in the Department of Meteorology, Mason augmented his meagre salary by appearing frequently on radio and television programmes such as the Brains Trust, answering questions and sometimes performing experiments. He also gave public lectures around the UK and travelled abroad, often to the USA, to give lectures. However, Meteorology was a postgraduate department and so he did not have to give many formal lectures within the department. As the distinguished Swedish meteorologist Tor Bergeron had observed (and Mason himself liked to recall): ‘so you’re a lecturer in meteorology and you give no lectures and you know no meteorology. You’ll go a long way, young man!’ (Royal Meteorological Society 1985). Of course, during this time he did learn a lot of meteorology, aided especially by his friendship with fellow-lecturer Frank Ludlam, who had joined the department as a Leverhulme Research Fellow from the Meteorological (Met) Office and was one of the world’s most insightful observers of the atmosphere, and of clouds in particular.

In 1951 the 28-year-old Mason was on a Rockefeller Travelling Fellowship in the USA when he was invited, together with Dr E. G. (Taffy) Bowen (FRS 1975) from Australia, to review a rain-making experiment proposed by the University of Arizona. Distinguished scientists such as Irving Langmuir were involved, but this experiment also involved commercial operators whom Mason regarded as charlatans. Although microphysics was his speciality, Mason was convinced even then that the amount and intensity of rainfall would be determined largely by the dynamics rather than the microphysics, which the would-be rain-makers were targeting. He presented his views very forcefully and argued not only for better experimental and statistical design in the experiments but, as always, also stressed the overriding need for better physical understanding. From then on, his critical attitude and emphasis on the importance of understanding the underlying physics and dynamics continued to have a moderating effect on the more exaggerated claims, and stimulated a major expansion of basic research.

In 1954 Professor Carl-Gustaf Rossby invited Mason to give a series of lectures at the University of Stockholm. As he later recalled in an interview (Taba 1995), Mason regarded Rossby as a role model who gave him a deep insight into how to manage a group of research students. By the mid-1950s Mason had built up his group to become one of the leading cloud-physics groups in the world. All the time, he and his students were producing a regular stream of research publications so that, by 1956, he was able to submit a compilation of his papers for a DSc, with Professor J. D. Bernal FRS as one of the examiners.

When Brunt retired in 1952, Peter Sheppard took over as Head of Department. John Mason had admired Brunt and owed a lot to him: not only had Brunt recruited him and given him freedom to pursue his own research agenda, but he had also engineered the platform that launched his public lecturing career. The same cannot be said of his relationship with Sheppard.
Sheppard was a very forbidding person who used to submit staff and students alike to incisive criticism when, as was the tradition, they shared their daily tea breaks with him. However, Mason stood up to him: Mason’s early opportunity for leadership in the RAF had stiffened his backbone. Although Sheppard was supportive later in Mason’s career, a situation of rivalry persisted for as long as Mason remained on the staff of the Meteorology Department. So it was probably a relief all round when, in 1956, he was awarded the Royal Society’s Warren Research Fellowship: this independent appointment at readership level effectively gave him unfettered freedom to pursue his research with his group at Imperial College. Mason retained this Fellowship for about five years, although it was interrupted in 1959/60 when he accepted an invitation by Professor Jack Bjerknes to spend a year as a visiting professor of meteorology at the University of California in Los Angeles in the company of the renowned meteorologists Jorgen Holmboe and Zdenek Sekera. While he was there he temporarily took over both the lecturing responsibilities of Professor Morris Neiburger and the supervision of his students, one of whom was Hans Pruppacher, who later became a full professor of cloud physics.

Mason was very conscious of the general lack of knowledge regarding the basic physics of water and ice and, when he resumed his Warren Fellowship and while still located in the Meteorology Department, he set up and directed an interdepartmental research programme on the subject, funded by the Rockefeller Foundation. His idea was to break down some of the barriers that existed between departments at Imperial College: such interdisciplinary activity is common nowadays but was rather novel at the time.

Department of Physics

After discussions in 1961 with Nobel laureate and Head of the Physics Department, Lord Blackett FRS (PRS 1965–70), and with Sir Patrick Linstead FRS, Rector of Imperial College, Mason was appointed to a personal chair in the Physics Department. This was during the so-called brain drain, and Mason suspected that Blackett was concerned that Americans might have induced him to remain in the USA had he not made such an attractive offer. Thus he became the first professor in the world of the (by then) rapidly growing field of cloud physics. His entire group moved from the Meteorology Department to become an independent subdepartment of the Physics Department, where he was able to give lectures in cloud physics to undergraduates, as well as taking on other lecturing responsibilities in classical physics from Blackett. This led to an increasing number of good home-grown students joining his group, which by then was close to 20 strong. The group enjoyed smart new premises in a converted townhouse in Prince’s Gardens, Kensington. Productivity was high because of the newness of the subject and the quality of students. He was a superb PhD advisor. Perhaps his greatest gift was his ability to present his students with topics to examine that were both important and tractable, a rare combination. His own enthusiasm for the research helped his students immensely through their inevitably difficult patches. Interestingly, the teatime discussions that were such a feature of life in the Meteorology Department were retained in Prince’s Gardens, although generally there was less violent criticism—they were an early example of brain-storming in which half-baked ideas were put forward to be either developed further or quietly forgotten.

Personal contributions to cloud physics research

Mason’s first paper on a cloud physics topic, in 1950, was on the nature of ice-forming nuclei in the atmosphere (1), but he was already showing a broad interest across the field.
of cloud physics and wrote a landmark review with Frank Ludlam in 1951 entitled ‘The microphysics of clouds’ (2), which helped him scope his ensuing research. A few years later he published a further review with Ludlam (5). Before the time of Mason’s work at Imperial College, research into aspects of cloud physics had been dispersed among small groups, but Mason became the first to perform laboratory research systematically on a great number of interrelated cloud physics problems, which he later brought together in his highly acclaimed book *The physics of clouds*, published in 1957 (6) and updated in 1971. A feature of this book is the interweaving of individual facets of cloud physics into clear and authoritative descriptions of cloud properties. A version of the book more suitable for a layman audience and undergraduate students was published in 1962 (10) and helped spread interest beyond the physics and meteorology communities; a second edition was published in 1975.

Mason published about 70 papers and books on cloud physics between 1950 and 1965, and his output continued even after he left Imperial College. I shall identify just a few pioneering findings to give a flavour of their scope. Particularly well known is his equation for droplet growth, sometimes referred to as the Mason equation, which takes into account both the effects of the curvature of the droplets and of soluble or insoluble material within them. Calculations based on the Mason equation have led to the development of simplified representations of the processes in weather prediction and climate models. His equation, published in *The physics of clouds* (6), provided the basis for work on the growth of a broad spectrum of cloud and rain droplets in clouds in which ice particles are not present—so-called warm clouds. At that time, cloud condensation nuclei were believed to be primarily produced by the explosive break-up of seawater bubbles. These tiny particles, on entering the bases of warm clouds, would grow to produce cloud droplets that would increase in size and could then grow large enough to engage in coalescence and produce drizzle droplets and ultimately rain. Calculations based on the Mason equation suggested that growth by condensation alone could not lead to the formation of precipitation-sized droplets within the time and spatial scales implied by observations of real clouds. Later work by Mason and Chien (9) demonstrated the importance of entrainment of fresh nuclei to maintain a broad droplet spectrum against the narrowing effects of condensation while also needing a few large nuclei on which to grow the largest drops. There is now evidence that low concentrations of large nuclei probably do play a role in the formation of a broad spectrum of droplet sizes, leading to rapid precipitation development; however, such low concentrations were below the threshold of early observations. Mason and Chien’s paper was written in the context of sea-salt nuclei, but the question of the numbers and chemistry of the most effective nuclei remains an unsolved problem for theories of droplet growth in clouds.

The above work related to the so-called warm clouds without ice, but the production of ice particles in colder clouds was also a theme of much of Mason’s work. The ice particles grow by vapour deposition because the clouds are supersaturated with respect to ice; the particles then possibly collide, adhere and fall faster than their neighbours, collecting them to form snowflakes or, in related but different circumstances, producing hail or smaller graupel-pellets. In 1956/57 Mason wrote two major papers (3, 4) with his student John Hallett, who went on to become a full professor of cloud physics in the USA. These papers showed the importance of impurities in poisoning ice nuclei, explained inconsistencies in previous studies, and at the same time clarified the mechanism for direct nucleation of sublimation. They led the way for work on other methods of nucleation such as contact nucleation.
Other significant scientific contributions in cloud physics were in the field of cloud electrification. Laboratory studies in the early 1960s led by Mason, and separately by Professor Marx Brook of the New Mexico Institute of Science and Technology, established that almost all the most promising mechanisms for cloud charging and lightning initiation were too weak to promote the required electrical breakdown. Effectively Mason whittled down the number of candidate mechanisms of charging until only one survived. In 1961 a well-known paper (8) was published by Mason together with his student John Latham, who went on to found the Atmospheric Physics Research Group at the University of Manchester Institute of Technology. The mechanism, also described in Mason’s Bakerian Lecture (12), entailed rebounding in-cloud collisions between ice crystals and growing graupel-pellets. In attempting to provide a quantitative explanation of this mechanism, it was suggested that regions of opposing charge were formed within the ice crystals where a temperature gradient existed. The laboratory experiments, although difficult to conduct at the time owing to instrument limitations, supported this hypothesis. Charge separation was believed to be due to dissociation and differential ionic mobility. Collisions between ice particles of different sizes falling under gravity could then lead to charge separation within the storms. Of course, the presence of a vertical electric field within the storm has a significant effect on the charge separation process, and a complete theory should really include dissipation as well as generation mechanisms. Nevertheless, the many modelling and field studies conducted over more recent years have continued to support the hypothesis that a non-inductive process (that is, one not requiring the presence of an electric field) is the most powerful one, although the precise charge transfer mechanism still remains to be established. Today there are more extensive observations of the distribution of electric charge within thunderstorms and these suggest that initial charge separation may occur through collisions between particles of ice and supercooled water. Although the Latham–Mason mechanism has not stood the test of time as being the major charge separation mechanism in clouds, there is no doubt that the thermoelectric effect, which they were the first to identify, is real.

Mason’s work on thunderstorm electrification illustrates well his ability to carefully isolate one aspect of a complex physical problem and then design a laboratory experiment to test a specific theory. Two of his papers (7, 11) dealing with ice-crystal habit again demonstrate the need for careful laboratory experiments if spurious results are to be avoided. These papers nicely demonstrate how the great variety of ice crystal forms found in the atmosphere can be consistently explained simply in terms of the migration of molecules across the surface during sublimation. The capability of Mason and his group to test theories through critical laboratory studies is something that is not available in many other areas of atmospheric science. Such work is becoming almost extinct in today’s financial climate. The question might be asked as to whether there was anything novel about Mason’s experimental equipment: probably there was not—even his thermal-gradient diffusion chamber for growing ice crystals was not new. Rather, it was the experimental design and the careful examination of the results that delivered results. He stressed the need to look for and rule out alternative explanations: he was very critical of those who published as soon as they got a result consistent with their theory. Mason’s ability to communicate ideas clearly and forcefully was usually beneficial but of course he was not always right. For example, Peter Jonas, professor of cloud physics at the University of Manchester, and Mason’s former student, recalls that Mason was always dismissive of a role for turbulence in the development of raindrops in clouds. The point at issue was the relative role of cloud droplets falling and colliding versus being thrown together by small turbulent eddies (Jonas 1996).
Arguably, Mason’s greatest contribution to cloud physics was in helping to build a strong international research activity in the subject, as so many of his students and research fellows moved on to form their own groups, 17 becoming full professors. Indeed, it is still true that there are few outstanding cloud physics groups that have not been influenced by involvement with scientists from his Imperial College group. Ahead of his time, Mason saw that cloud physics was crucial to the resolution of many outstanding problems in atmospheric physics. Although partly driven in the early days by interest in the possibility of weather modification, cloud microphysics remains important for the development of climate models through the microphysical properties of clouds as well as for the processing of various chemical species in the atmosphere. However, this is a difficult field of research so that, despite the huge expansion in research activity stimulated by Mason, these problems are still far from being fully resolved.

Mason’s time at the Met Office is discussed in the next section but, before leaving the topic of his specific contributions to cloud physics, it is appropriate to anticipate some of his later contributions. Soon after leaving Imperial College, he initiated experiments to understand the interaction between cloud microphysics and the dynamics of cloud systems. The dynamics are responsible not only for providing the growth environment for cloud particles but also for imposing severe constraints on their subsequent development. Three observational investigations that Mason promoted in this area were Project Scillonia (Hardman et al. 1972), the radar studies of frontal precipitation systems by the Met Office group at the Royal Radar Establishment (RRE), Malvern (13) and, as I discuss later, the GATE project in the tropical Atlantic (WMO 1972): these all led to a better understanding of precipitation systems that was subsequently incorporated into numerical weather-prediction models. The development of these models and their use for basic atmospheric research as well as for weather prediction were areas that Mason strongly supported after he left Imperial College.

**Biographical Memoirs**

**Meteorological Office, 1965–83**

It became increasingly clear during the early 1960s that Mason was destined for greater things. In 1964 Sir Graham Sutton FRS, then Director-General of the Met Office, recommended him as a possible Director of the Royal Institution. The President of the RI, Lord Fleck FRS, was also keen on Mason as a candidate, describing him as ‘very nearly … a “spellbinder”’ in his lecturing ability (Cole 2015). In the event, George (later Lord) Porter FRS (PRS 1985–1990), was selected. However, in 1965, when Sutton was due to retire from the Met Office, Mason was invited to apply for his position. Buoyed by the fact that he had just been elected a Fellow of the Royal Society, Mason attended the selection board. He told the board that he wanted to build up the Met Office to be the best meteorological service in the world. This degree of ambition was apparently welcomed, for this was the 1960s—an era of scientific and technological optimism spurred on by Prime Minister Harold (later Lord) Wilson (FRS 1969). Mason recalls that, after his successful interview, he overheard a board member remarking, ‘he’ll shake ’em up a bit … but this is just what the Met Office needs’ (Royal Meteorological Society 1985). Running an organization with some 3800 staff after being a research professor with fewer than 20 people would be a major step. Moreover, many of his academic colleagues regarded weather forecasting as a rather inferior occupation and the Met Office as being overly bureaucratic. But Mason had a more positive view, believing that the Office was undervalued
and had made great strides since the war, with the establishment of a significant programme of research: it now had some distinguished scientists, including the turbulence expert Frank Pasquill (FRS 1977) and the dynamical meteorologist John Sawyer FRS (Director of Research 1965–76), for whom he had great respect. Figure 1 shows Mason on his first day in the Met Office, on 1 October 1965.

Widely referred to by his initials, ‘BJ’, by his erstwhile students, he was now referred to almost reverentially as ‘DG’. At 42 years of age he was unusually young to be appointed Director-General. An apocryphal story he often told later in life concerned the parking spaces for senior Met Office staff at the Bracknell headquarters: on his first day Mason swept into the car park and parked in the appropriate slot. On entering the building he was stopped by the guard who said ‘Young man, you cannot park there. It is reserved for the Director-General.’ His response ‘I am the Director-General!’ would have been accompanied by his usual wide smile and laughter.

One month after becoming DG, Mason made a bold decision and, in the process, established the blueprint for his approach to creating a thrusting forward-looking organization. At that time, operational weather forecasts were being generated entirely subjectively. Mason was, however, impressed by the quality of the Office’s numerical weather forecasts, which were still undergoing trials. So he overruled the caution of the staff and decreed that they should go operational without delay, together with a major publicity drive. He argued that ‘if we go operational then we shall have to perform at concert pitch as opposed to a rehearsal and everyone will tighten up and the whole timescale will collapse’ (Royal Meteorological Society 1985). His gamble paid off and the publicity put the Met Office in a good light: 2 November 1965 was a landmark day for Numerical Weather Prediction (NWP), and although forecasters still had to exercise judgement in the application of NWP products, this did indeed set the tone for an increasingly progressive Met Office.

Although Mason initially grew to prominence with his work on cloud physics at Imperial College and through his book *The physics of clouds*, his greatest contributions to meteorology
were to come while he was in charge of the Met Office. Unlike many great scientists whose research groups are relatively narrow in their area of expertise, Mason built a research group at the Met Office that covered a huge range of expertise and in which specialists benefited from close contact with specialists in other fields—all within the same organization. Such interaction led to the development of ideas in a way that would be difficult to achieve in a much smaller, university, group. At the same time it also made for the rapid transfer of new discoveries into operational weather forecasting, which also served to identify areas where knowledge was lacking. That such a strong research activity could be built up and maintained is a testimony to Mason’s abilities and foresight.

His first step towards establishing centres of excellence was to move his entire cloud physics research group into the Met Office. However, a problem that was in danger of thwarting Mason’s aspiration for the Office to become a world leading institution more broadly was the ageing staff profile and lack of new blood. His response was to recruit first-rate new graduates, which he attracted by giving inspirational lectures at leading universities (24 of them in his first year as DG). He also contributed to the ‘reverse brain drain’ of the time by attracting leading researchers, such as Massachusetts Institute of Technology professor Raymond Hide (FRS 1971), who established a new group in the Met Office dealing with fundamental issues in geophysical fluid dynamics. Many young recruits passed through Hide’s group and honed their skills to the benefit of other areas of the Office to which they were subsequently posted. He also attracted the author of this biography back from the USA to build up the Met Office group at the Royal Radar Establishment.

Against the prevailing mood of scepticism in the Met Office about the value of radar in meteorology, he promoted two new radar programmes involving the Met Office working together with the hydrological community. One of the new radar programmes, which developed over a 10-year period starting in 1966, was the Dee Weather Radar Project. This demonstrated the capability of a single radar to measure rainfall over an area as accurately as that achievable by a dense network of raingauges, and to provide the data in real time for hydrological forecasting. The evolution of this and related programmes is recounted by Collinge (1987). The other programme, which took much longer to implement in full, began in 1971 with Mason commissioning a proposal (Bulman & Browning 1971) to establish a National Weather Radar Network in which rainfall data from a distributed network of unmanned radars would be combined for use in the detailed monitoring and forecasting of the weather. The eventual outcome was the now familiar radar rainfall display covering Britain. At the same time he secured new research aircraft for the Office’s Meteorological Research Flight and set up a satellite meteorology group to capitalize on the new satellite temperature soundings and cloud imagery. Other scientific areas that he was keen to support during his time in charge of the Met Office included the newly emerging atmospheric general circulation models. In particular, he foresaw their value in studying linkages between the atmosphere and oceans and in evaluating potential impacts on climate. One application was the simulation of the Milankovitch cycles leading to past ice ages. Another was the simulation of the impacts of increasing greenhouse gas concentrations in the atmosphere. Although he was cautious at first about accepting that man-made changes would dominate over naturally occurring variability, this work can be seen as a forerunner of the work of the Intergovernmental Panel on Climate Change that in due course demonstrated this beyond reasonable doubt.

A major opportunity arose when Mason, as the Permanent Representative of the UK with the World Meteorological Organization (WMO), attended the fifth session of the WMO
Executive Committee (EC) in 1967. The WMO at the time was planning a major programme, the World Weather Watch (WWW), to improve the world-wide observing network and to develop facilities for exploiting the new data in operational weather forecasting. Ahead of the EC meeting, Mason successfully lobbied the UK government for funding to support the Met Office at Bracknell becoming a Regional Telecommunications Hub and a Regional Meteorological Centre as part of WWW, together with a substantial training programme. The WMO EC backed the resulting proposal and a major expansion followed at Bracknell, notably a new telecommunications centre and a powerful new computer, under the charge of a new Deputy Directorate for communications and computing, all housed in a new building named after the early pioneer of Numerical Weather Prediction, L. F. Richardson FRS. Figure 2 shows Prime Minister Edward Heath with John Mason, formally opening the Richardson Wing in 1972.

Mason was proud of his ability to deliver speeches and was fond of telling the story that when the Prime Minister came to Bracknell to open the Richardson Wing, Heath told him that only once before had anyone sent him the text of his speech and then had afterwards given it word-for-word as Mason had done—without notes and seemingly spontaneously. That other person had been General de Gaulle.

At about the same time as the Met Office facilities were expanding rapidly at Bracknell, Mason persuaded the Ministry of Defence to transfer the RAF Flying Training Command Headquarters facility at nearby Shinfield Park to the Met Office for use as its new residential
college. Stan Cornford, then principal of the college, recalls that Mason was justifiably proud of achieving this: not only was a residential college just what was needed in view of the dispersed nature of the many Met Office outstations but it was also close to the Department of Meteorology at Reading University, with which there was eventually an agreement to exchange students. Another of Mason’s initiatives impacted the Met Office College soon after the college was established at Shinfield Park. Prime Minister Heath’s government had continued to be very supportive and it was not long before Mason, bolstered by the greatly improved capabilities of the Met Office and a promise of further funding from the UK government, was able to persuade a reluctant European Community to set up the new European Centre for Medium-Range Weather Forecasts (ECMWF) in new premises adjacent to the Met Office College. The work of Mason and his staff that led to the ECMWF’s being located at Shinfield Park, including Mason’s discussion with Prime Minister Heath persuading him of the benefits of having the ECMWF in the UK, are mentioned in a book on the Centre’s history (Woods 2006). The distinctive voice of Mason welcoming the ECMWF to the UK during the Centre’s first council session in November 1975 can be heard on the website at http://www.ecmwf.int/en/about/who-we-are/history. Initially two-thirds of the scientists at ECMWF were recruited from the Met Office: along with modelling and other software from the USA, this influx of Met Office staff gave the ECMWF a flying start on its trajectory towards becoming a world leader in its own right.

Mason retired from the Met Office in 1983 at the then compulsory retirement age of 60 years. He had transformed not only the Office’s facilities but also its intellectual capital. The downside of his success was that there was a touch of Fortress Bracknell and, to some extent, a downplaying of the role of outstanding meteorologists and oceanographers in the universities. However, there can be no disputing the fact that the reputation of the Office had grown enormously, to the extent that, in his last year as DG, there were about 860 applicants for 15 posts, allowing the opportunity to recruit only the brightest young mathematicians and physicists. Indeed, there was one year in which the Met Office had more applicants than the whole of the rest of the Scientific Civil Service put together. Mason justifiably claimed that his ability to attract good people was one of his greatest achievements. At the same time he also increased the reputation of the Met Office through the publicity he gained from his many awards, honorary degrees and special lectures, and through being Senior Vice-President of the Royal Society and president of many other scientific societies during (and after) his time as Director-General (listed at the end of this memoir). Mason was President of the Royal Meteorological Society at the time it moved its headquarters from Cromwell Road, near Imperial College, to Bracknell. This was financially an unfortunate move because of subsequent property inflation in London, which would have been difficult to foresee at the time; however, the move was consistent with his determination to build a meteorological powerhouse at Bracknell.

Mason’s own account of his time in the Met Office has been published by the Royal Meteorological Society (17).

**The Royal Society**

Mason was Senior Vice-President and Treasurer of the Royal Society from 1976 to 1986. Dr Peter Warren was Deputy Executive Secretary of the Royal Society during much of this time, and the following paragraphs are adapted from a eulogy that he delivered in February 2015.
Mason took up office at a challenging time for the Society: there were growing financial pressures on universities and on science, yet the Society’s influence with government was at a low ebb. However, Mason, benefiting from his managerial experience as Director-General of the Met Office, and sharing a common vision with Lord Todd, the President, set about rectifying that situation. By the end of his tenure the Society was proffering advice to government and parliament, had published some 17 reports, had a fledgling Policy Studies Unit, and had re-established itself as a force to be listened to and consulted.

As a former Royal Society Research Fellow, Mason was keen for the Society to increase research appointments for outstanding young scientists. However, cuts in university budgets in the early 1980s were seriously reducing opportunities for even the best postgraduates to remain in research so as to be able to fill tenured posts as they arose. This threatened the quality of future university staff and risked a resurgence of the brain drain. Research Councils sought ‘new blood’ schemes, and Mason was in the forefront in seeking support for an equivalent scheme for the Society—the University Research Fellowships (URFs)—to be paid for through its Parliamentary Grant-in-Aid. With no new money forthcoming at first, he had to oversee a radical shift in the use of the existing grant from research grants to research fellowships, including the demise of the sizeable Scientific Investigations Grants scheme begun in 1849. Thirty URFs were created in 1983 and, although there were setbacks, Mason ensured that the Society could retain the then target of a steady state of 100 and, with subsequent additions to that grant, achieve that target and more. The ultimate scale of success was in no small measure the result of Mason’s annual presentation of the Society’s bid for its whole Grant-in-Aid, which rose from £1.7 million in 1975–76 to some £6 million in 1986 to cover International Exchanges and Research Grants, etc., as well as research appointments. Success breeds success: there are now more than 300 URFs in post and past URFs are spread far and wide across the scientific community.

The Finance Officer at the time, Nigel Parfitt, recalls that Mason also considered himself quite ‘investment savvy’ and at Investment Advisory Committee meetings he would come up with several proposals for changing the Society’s investments: apparently the committee would always agree to one of his proposals ‘to keep him happy’. Mason’s energies were not restricted to higher matters: he also took a keen interest in reforming the Society’s catering arrangements.

INTERNATIONAL ACTIVITIES

The World Meteorological Organization

As Permanent Representative of the UK with the WMO, Mason was voted onto its 24-member EC in 1965. According to Professor John Zillman of Australia, a fellow member of the EC from 1979 onwards, it was very clear to those involved, even from first impressions, that Mason was the towering intellect and dominant personality, and everyone took notice of his interventions in debates. He recalls that Mason worked closely with WMO President Alf Nyberg of Sweden, Bob White of the USA, E. K. Federov of the USSR, Bill Gibbs of Australia, Eric Sussenberger of West Germany and Jean Bessemoulin of France. He was enthusiastically supportive and involved in the planning of WMO’s WWW and of the Global Atmospheric Research Programme (GARP), a 15-year international research programme, crucially bringing together WMO (representing the operational community) and the International Council of
Scientific Unions (representing the academic community). GARP played a vital role with its pioneering influence in the use of computers for modelling the global atmospheric circulation, and in the use of satellites for continuous global observation of the Earth. Mason pushed the EC hard for it to lead the way in the exploitation of satellites. Weather modification issues also came up in the WMO and, not surprisingly, he had strong views on these. He successfully coerced the WMO into a scientifically tough line in the design of the WMO Precipitation Enhancement Project (PEP).

The Met Office funded equipment for the meteorological services of developing countries, and for fellowships for staff from these services, mostly to study at its college at Shinfield Park: Mason insisted on approving each fellowship personally. He was mostly liked by EC members from the developing countries but he could be quite contemptuous of their scientific knowledge and often caused offence. Once he remarked, ‘If knowledge of the First Law of Thermodynamics were the criterion for EC election, this room would be almost empty!’ Also, the day before the election of EC members at the 1975 Congress, he made an intervention along the lines of ‘I don’t support scientific prizes like this for [some] little countries and, next week in EC, I will make sure we change the rules to get them excluded.’ Members of about 100 delegations muttered under their breaths ‘provided you get elected’, and sure enough, the next day, the unheard-of happened and, for the first time ever, the UK Permanent Representative did not get enough votes for election onto the new EC. Mason was devastated by the vote but he was back on the EC, only slightly chastened, two years later. It is widely believed that this incident and his generally forthright style are why he, as the leading meteorologist of his age, was never given the WMO’s top award: the IMO (International Meteorological Organization) Prize. Although he was close to winning it several times, his prospects were not helped by the arcane system for choosing the award winner and his antipathy towards WMO’s Secretary-General, Patrick Obasi.

Mason’s contribution was not restricted to his work on the EC itself; he also made a major contribution to the WMO at a more detailed level scientifically. After the sixth World Meteorological Congress in 1971, the EC agreed to mount one of the biggest ever international scientific expeditions: GATE, the GARP Atlantic Tropical Experiment (WMO 1972). Mason was the chairman of the planning board for that experiment. The purpose of GATE was to study the exchange of heat and moisture between the tropical oceans and the atmosphere, and the interaction between the meteorology of the tropics and the rest of the globe. It was the first major experiment of GARP, whose wider goal was to understand the predictability of the atmosphere and extend the time range of weather forecasts from days to more than two weeks. The experiment took place in the summer of 1974 in an area that covered the tropical Atlantic Ocean from Africa to South America. The work was truly international in scope and involved 39 research ships, 13 research aircraft and numerous buoys from 20 countries, all equipped to obtain the observations specified in the scientific plan. The long-term impact of GATE was considerable: its vast database contributed to studies that led to the first World Climate Conference in 1979 and it can be seen as one of the forerunners of the work of the Intergovernmental Panel on Climate Change.

The Surface Waters Acidification Project

In June 1983, the Royal Swedish Academy of Sciences and the Norwegian Academy of Science and Letters were asked by the Royal Society to join in a cooperative scientific project aimed at acquiring a better understanding of the causes of surface water acidification and
Basil John Mason

fishery decline in southern Scandinavia. The project was the Surface Waters Acidification Programme (SWAP). It was hoped that this effort would make it possible to evaluate the role of acid deposition from anthropogenic emissions and to assess the improvement in the aquatic environment that might be gained from a decrease in such emissions, particularly those emanating from the UK. The SWAP project was an unusual policy project for the Royal Society to undertake because it involved doing new research rather than merely synthesizing existing knowledge. Having recently retired from his Met Office position, Mason was able to take on the task of SWAP Programme Director, with a secretariat based at Imperial College. Between the times of the first two meetings of the management group, Mason prepared a joint background document with SWAP’s Scandinavian consultant, Professor H. M. Seip (14). The report contained proposals for research and represented a consensus of the scientists involved in the management of the project.

The SWAP project had 300 scientists from 30 institutions in the three participating countries. Its management committee was chaired by Sir Richard Southwood FRS, who until 1985 was chairman of the Royal Commission on Environmental Pollution. The committee travelled extensively as a social group; Professor Jack Talling FRS, another member of the committee, recalls that the official workings between Mason and Southwood were cordial and efficient, although they had very different characters. Mason’s meteorological experience and overall scientific vision were valuable, but Southwood’s tact in the face of local feelings was helpful. Their decisions were of course politically sensitive. There was some feeling that grants should be given to those working in Sweden and Norway, and not to those in Britain, but Mason held strongly to the view that all three countries were eligible to benefit. There was also sensitivity to the fact that the Central Electricity Generating Board (CEGB) burnt coal that was thought to produce much of the acidification of natural waters, so that their research opinions were liable to be questioned by those overseas. A representative of CEGB, which provided funding for SWAP, was initially a member of the management committee but eventually resigned. Despite these difficulties, the project did much to remove earlier suspicion and dissension between the nations involved, and cordiality prevailed in its meetings.

After the project was over, Mason edited the project report (15) and, although having no formal qualifications in chemistry, wrote a book on the chemical processes involved in acidification and its biological impact on freshwater life (16). The book demonstrates Mason’s wide grasp of issues and contains chapters on emissions, transport and deposition of acid pollution; hydrochemical studies in catchments; catchment process studies; catchment manipulation experiments; the role of hydrology and soil chemistry; palaeolimnological studies; the toxic effects of acidification on fish and other aquatic life; and catchment modelling studies.

An important factor was that Prime Minister Margaret Thatcher FRS had great faith in Mason’s scientific judgement and independence. As he was guarantor of the independence, quality and authority of its conclusions, the final report in 1990 provided a sound basis for subsequent public policy-making in all three countries. Because Mrs Thatcher trusted his judgement she agreed to fund a £700 million programme to clean up UK emissions. No less important were the overall lessons learned from the way in which Mason ran this collaborative project: above all, he ensured that only the best scientists were engaged, and that measurements were taken with standardized techniques and with an agreed protocol for their use before conclusions were drawn. The project was thus able to provide the collaborating academies, and the governments they advised, with broad-based collective and independent scientific evidence.
Mason had a strong, dominating personality: he rather took over any social group he was in. His duties required him to fraternize with royalty, prime ministers and many other notable people with whom, being self-assured and verbally adept, he could readily hold his own. He was always happy to recount, very fluently, stories of these encounters. In his later years he became very aware that he had become the most senior Grade 2 Civil Servant, not just in the Ministry of Defence but in the UK Civil Service as a whole. So when he visited Geneva on business he would, unabashed, requisition the Ambassador’s official limousine for both himself and his personal assistant. Most regarded these practices as part of his natural exuberance, but it made him unpopular with some who felt that modesty should prevail.

Mason did not suffer fools gladly. He was a formidable presence at conferences: he always sat in the front row and, almost without exception, would ask the first question. He would rise to deliver it, facing the audience, a very tall imposing man, closer to the audience than the lecturer, who became a diminutive figure. If he disagreed with the speaker, he made that very clear. If he considered the speaker was talking nonsense or being devious, he said so very plainly. He insisted that his sole objective in doing so was to establish the truth. He got on well with Prime Minister Margaret Thatcher: they were two of a type. She, too, was an admirer of those who knew what they wanted and ‘told it as it was’.

Mason worked phenomenally hard. As he rapidly moved up in the scientific world he did not change his work ethic or how he managed his staff. He expected a lot from his staff, or in the early days his students, but once they had earned his confidence he was very supportive. David Axford, one of Mason’s deputies at the Met Office and later Deputy Secretary-General at the WMO, recalls that a feature of Mason’s time as Director-General was to have regular lunches with staff down to Principal Scientific Officer grade. They brought their own sandwiches to his office, sat around his conference table and discussed whatever was of topical interest in an almost rank-free manner. This was a management style that Mason had developed during his time at Imperial College.

Although the ‘world’ was apt to see an aggressive exterior, Mason’s overt self-esteem was just a personal quirk that was overlaid by other desirable qualities: not only was he exceptionally able to make decisions quickly and clearly, but on a more human level he had a great sense of humour: for example, when in charge of the Met Office he delighted in showing visiting politicians his set of African rain-making stones. More importantly, there was a kind and caring man underneath. When he was invited to the homes of staff or ex-students, he loved watching their children play and holding them on his lap. If colleagues were ill he would visit them, however distinguished or lowly. One of his former PhD students relates that, although their paths had seldom crossed over the course of 20 years, when he subsequently had complex surgery Mason had phoned him in hospital every day to ask about his progress and wish him a safe recovery. This was not an isolated occurrence: he was always concerned—genuinely so—when he heard of a student or member of staff being sick or receiving bad news. The death of Frank Ludlam, his closest colleague during his time at Imperial College, affected him immensely. Although Mason may not have said much in public, he was proud of his students’ work and was pleased when they got good positions, as they so often did, after they received their PhDs. He was very supportive of his students and staff, and for the most part they were correspondingly loyal to him.
Although his work was central to his life—it was a hobby as well as a job—he had a rich and happy domestic life. His wife, Doreen (whom he predeceased), was his first love: they married in 1948 when he was a few days short of his 25th birthday and she just 20 years old. Doreen was a home-loving person who provided the stability and support that underpinned his home life. She brought up their two sons, Barry and Nigel, and seldom travelled with her husband after the children were born. However, she enjoyed the social events that went with his being Vice-President of the Royal Society and was the perfect hostess for his many visitors and friends, not least because she was an excellent cook and he was known to enjoy good food and wine.

As a family man, Mason adored his two sons and was proud of them, although he admitted he did not spend as much time with them as he would have liked while they were growing up. The elder son, Barry, became a leading economist in the Civil Service, and the younger son, Nigel, followed his father into science to become a professor of physics (currently at The Open University). Mason was very pleased to have been able to co-author a paper in his later years with Nigel. The award of the OBE to Nigel in 2007 gave him immense pleasure, and attending Buckingham Palace to see Nigel presented with this award was a lovely counterpoint to when Nigel had attended Sir John’s investiture. He was a kind father-in-law to Jane, Nigel’s wife, challenging her culinary skills at times: happily he lived to see them adopt their daughter Megan and enjoyed being a ‘grandad’.

Outside science he did have hobbies. He greatly enjoyed classical music and often went to concerts at the Royal Albert Hall, a habit begun when he worked nearby at Imperial College. Family holidays were nearly always based in the UK and involved visits to many historical houses (he was a long-time member of National Trust). Although not religious, he particularly liked church architecture, stating he believed he had visited all the cathedrals in the UK; Durham and Salisbury were his favourites. Though he did not pursue sport after his student days, he was a passionate supporter of Arsenal and could name the 1930 Championship teams. He was a keen follower of cricket and shared this passion with two close friends, Sir Bernard Lovell FRS and Sir George Edwards FRS. In his later years he looked after Doreen wonderfully well throughout a long period of illness until he himself suffered the first of two strokes. He recovered from the first stroke well enough to write his own account of his time in the Met Office (17). His second stroke left him housebound but he remained at home with Doreen, cared for by Barry.

A proud but also humane man, he leaves behind a large cohort of scientists whose careers blossomed in different ways because of him: something of which he was most proud. His portrait resides in the National Portrait Gallery.

**Honours, posts and awards**

**Appointments**

<table>
<thead>
<tr>
<th>Year</th>
<th>Position</th>
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<tbody>
<tr>
<td>1944–46</td>
<td>Commission in Radar Branch, Royal Air Force</td>
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<tr>
<td>1947–48</td>
<td>Shirley Research Fellow, University of Nottingham</td>
</tr>
<tr>
<td>1948–57</td>
<td>Lecturer in Meteorology, Imperial College, London</td>
</tr>
<tr>
<td>1957–61</td>
<td>Warren Research Fellow, the Royal Society</td>
</tr>
<tr>
<td>1959–60</td>
<td>Visiting Professor, University of California</td>
</tr>
<tr>
<td>1961–65</td>
<td>Professor of Cloud Physics, Imperial College, London</td>
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</tbody>
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Biographical Memoirs

1965–75 Member, Executive Committee of the WMO
1965–83 Director-General, Meteorological Office
1965–83 Permanent Representative of the UK with the WMO
1968–70 President, Royal Meteorological Society
1970–75 Chairman of Council, University of Surrey
1971–76 Chairman, International Tropical Experiment Board
1976–78 President, Institute of Physics
1976–86 Treasurer and Senior Vice-President, the Royal Society
1977–83 Member, Executive Committee of the WMO
1979–85 Pro-Chancellor, University of Surrey
1982–83 President, British Association for the Advancement of Science
1983–87 Member, Advisory Board of the Research Councils
1983–90 Director, Anglo-Scandinavian Research Programme on Acidification of Surface Waters
1985–89 Chairman, International Scientific Committee, World Climate Research Programme
1986–96 President, then Chancellor, University of Manchester Institute of Science and Technology
1987–91 Chairman, Co-ordinating Committee on Marine Science and Technology
1989–91 President, National Society for Clean Air and Environmental Protection
1992–93 President, Association for Science Education
1990–2000 Senior adviser to the Global Environment Research Centre, Imperial College

Honours

1965 Fellow of the Royal Society
1973 Companion of the Order of the Bath
1979 Knight Bachelor
1988 Member, Academia Europaea
Honorary Member, Royal Meteorological Society
1989 Honorary Member, American Meteorological Society
2004 Mason Centre for Environmental Flows opened at University of Manchester
2006 Mason Gold Medal established by Royal Meteorological Society (endowed by Mason)
2007 Honorary Fellow, Institute of Physics

Honorary degrees (DSc)

1966 Nottingham
1970 Durham
1975 Strathclyde
1980 City of London
1983 Sussex
1988 East Anglia
1990 Plymouth Polytechnic
Heriot-Watt
Edinburgh
1998 Reading
Honorary fellowships

1974  Imperial College
1979  University of Manchester Institute of Science and Technology (UMIST)

Awards

1959  Hugh Robert Mill Medal, Royal Meteorological Society
1965  Charles Chree Medal and Prize, Institute of Physics
1972  Bakerian Lecture and Prize, the Royal Society
      Rumford Medal, the Royal Society
      Glazebrook Medal, Institute of Physics
1975  Symons Memorial Gold Medal, Royal Meteorological Society
1979  Naylor Prize, London Mathematical Society
1988  Plymouth Marine Science Medal
1990  British Coal Science Gold Medal
      Royal Medal, the Royal Society

Special lectureships

1967  James Forest, Institute of Civil Engineers
1968  Kelvin, Institute of Electrical Engineers
      Dalton, Royal Institute of Chemistry
1975  Hugh MacMillan Memorial, Institute of Engineers & Shipbuilders in Scotland
1976  Symons, Royal Meteorological Society
1977  Halley, Oxford University
1978  Oliver Dodge, Birmingham University
1979  Larmor, Queen’s University, Belfast
1985  Macaulay, Macaulay Land Use Research Institute, Aberdeen
1987  Jesse Boot, Nottingham University
      Ramanathan Memorial, India
      Bhattacharya Memorial, India
1989  Larmor, Cambridge University
      Rayleigh, Harrow School
      Bowden, UMIST
1990  Cockcroft, UMIST
      Linacre, Oxford University
      Rutherford Memorial, Royal Society, in Canada
      H. L. Welch Memorial, University of Toronto
      British Coal Science

Acknowledgements

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REFERENCES TO OTHER AUTHORS


BIBLIOGRAPHY

The following articles and books are those referred to directly in the text and constitute a small subset of more than 250 papers by John Mason, published mainly in meteorological and physics journals.

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(13) 1981 (With K. A. Browning) Air motion and precipitation growth in frontal systems. PAGEOPH (Bergeron Memorial Volume) 119, 577–593.
(15) 1990 (Editor) Results of the Anglo-Scandinavian Acid Rain Research Programme. Cambridge University Press.