Perspectives of Earth and Space Scientists

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The acronym CAESAR stands for Cambridge Atmospheric, Environmental and Space Activities and Research.

Key Points:

- Highlights of my career in Earth and space science
- The importance of interdisciplinary and international aspects
- The significant roles played by chance and by variety, the spice of life

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A Personal Voyage Among Earth and Space Physics Disciplines

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Abstract I have organized my thoughts in an autobiographical way in relation to the several distinct phases of my career encompassing Earth and space physics. I discuss atmospheric and space physics topics of interest to me in an international context, and I emphasize the value of community activities and international conferences for the interchange of ideas between colleagues. The uniting theme is solar-terrestrial physics, which includes both observational and theoretical studies of the Earth's atmosphere, geospace, the ionosphere, magnetosphere and interplanetary space. This theme is a part of two broader topics, namely geophysics and Earth system science. To be in a position to make observations at a station which has a unique identifying feature and/or at a special time is especially advantageous. A major aspect of a career in Earth and space science is the requirement to publish papers describing the results of one's research in the refereed literature, to organize national and international conferences, to carry out committee work and organizational activities, and to write books and edit journals; here I discuss some highlights of my experiences. My main overall experience is that serendipity—and variety—play a large part in an interesting career in Earth and space science.

Plain Language Summary Here I present some features of my career of 65 years in the Earth and space sciences, with an emphasis on solar-terrestrial physics, global scale geophysics and Earth system science. I point out the value of attending national and international conferences, of making international contacts and of being involved in organizational activities, for meeting colleagues and for making new ones. It is important to write readable papers describing the results of one's researches; I also value editorial work for scientific journals and books. I conclude that chance—and variety—play crucial roles in one's career.

1. Introduction—The First 25 Years

Born on 15 July 1938, I was fortunate to receive a broad education at Merchant Taylors' School, some 20 miles North West of London, where my favorite subjects were physics, geography and Latin. From 1957 to 1960 I studied for a Bachelor's degree in Physics, with Ancillary Mathematics, at Imperial College, London. I was then lucky to gain admission to Cambridge University, and to the new Churchill College, to carry out postgraduate work toward a Ph.D. degree in the Cavendish Laboratory under the supervision of T.W. Wormell, head of the Meteorological Physics Group. (Will Wormell's Ph.D. supervisor had been C.T.R. Wilson, the Nobel prize winner in Physics, whose supervisor was J.J. Thomson, discoverer of the electron.) He suggested that I should investigate "slow tails," radio signals generated by lightning discharges occurring between ~0.1 and 1 kHz, within the extremely low frequency (ELF, 3 Hz to 3 kHz) part of the spectrum.

On a visit to the Napier Shaw Library in Cambridge one Saturday morning, I read the current issue of Nature in which Balser and Wagner (1960) reported their experimental discovery of resonances of the Earth-ionosphere cavity at 8, 14, 20 Hz excited by lightning discharges; the subject had been considered theoretically by Schumann (1952). I then focused my research on trying to confirm, or refute, their results. Analyzing many records of the ELF vertical electric field on windless days, each some 20 s long, on punched paper tape using the EDSAC computer of Cambridge University led me to confirm their omnipresence (Rycroft, 1965). Since then, this research area has been transformed by the phenomenal power of small computers such that all six field components can be studied simultaneously. A recent paper (Pizzuti et al., 2022) has considered what can be learned from a full 5 years of observations. The topic nowadays is known as the AC Global Electric Circuit. The excitation of the cavity by distant lightning is now studied in relation to climate change, El Nino/La Nina phenomena and transient luminous events such as elves, sprites and gigantic jets (Fullekrug et al., 2006).

In 1962 I was privileged to attend the Summer School at Les Houches in the French Alps, on Geophysics: The Earth's Environment (DeWitt et al., 1963). There I listened to such luminaries as Kenneth Budden, Joe Chamberlain, Sydney Chapman, Jim Dungey, Roger Gallet, Gordon MacDonald, Marcel Nicolet, and John Spreiter. John Spreiter spoke to me about the possibility of post-doctoral work at the NASA Ames Research Center funded by the National Academy of Science/National Research Council. I attended my first international conference, the sixth meeting of COSPAR, held in Warsaw, Poland, in June 1963.

2. Post-Doc Experiences With NASA in 1964 and 1965

I was fortunate to gain one of these NAS/NRC positions. My first stop in California was at the Scripps Institution in San Diego to meet Ted Madden who was studying Schumann resonances theoretically. In mid-January 1964 I started work at the NASA Ames Research Center, famous for its giant wind tunnels. I joined the Space Sciences Division headed by Charles (Chuck) Sonett, renowned for his satellite-borne and lunar magnetometers, where the deputy head was the Welshman John Thomas. I studied Alouette 1 ionograms of the topside ionosphere with him, and computed the electron density at the orbit of the satellite (altitude ∼ 1,000 km) and down to the peak of the F-layer. We published several thick books showing latitudinal variations of the electron density at different heights and of the derived scale height of the plasma distribution.

John Spreiter, with Alberta Alksne and Audrey Summers (magnetopause theory), Joan Feynman (solar wind investigator), John Wolfe (solar wind instrumentation for IMP1), Larry Colin (topside ionosphere), and Al Lieber (semi-conductor instrumentation) were friendly research active members of the Division at that time. Barbara Abraham and Richard Hartle, both of whom worked on the theory of the solar wind, were other NAS/NRC post-docs and friends of mine, as was H. Razdan (cosmic rays). I attended lectures on FORTRAN programming, and soon decided that programming was not for me.

I met Bob Helliwell, Don Carpenter, John Katsufrakis, Tim Bell, Jacinto Angerami and Neil Brice at the nearby Stanford University. I found out much more about very low frequency (VLF, 3–30 kHz) whistler-mode waves from lightning propagating through the ionosphere and magnetospheric plasma, and the “knee” in the distribution of thermal plasma in the magnetosphere, now termed the plasmapause. I was then, and still am, particularly impressed by Neil Brice's paper on the fundamental physics of wave-particle interactions in the magnetosphere via a Doppler-shifted cyclotron resonance mechanism (Brice, 1964), and also the pioneering work of Kennel and Petschek (1966).

On a few evenings I drove from Mountain View to the University of California at Berkeley to attend a course delivered during the spring semester of 1964 on Space Physics (LeGalley & Rosen, 1964). I have found this book on my bookshelf, and I am most impressed with it. It covers, in 18 chapters, experimental techniques for space physics, solar and planetary physics, fields and plasmas in interplanetary space, and high energy radiation in space. Some key authors are Alastair Cameron on planetary atmospheres and interiors, Thomas van Zandt and Robert Knecht on the Earth's upper atmosphere, Sydney Chapman on the aurora and geomagnetic storms, Laurence Cahill on the geomagnetic field, Edward Smith on interplanetary magnetic fields (“frozen in” magnetic fields), Frederick Scarf on the solar wind and its interaction with magnetic fields, Brian O’Brien on the Earth's trapped radiation zones (the inner and outer Van Allen belts, and adiabatic invariants), Wilmot Hess on the effects of high-altitude nuclear explosions, and Kinsey Anderson on energetic solar particles. I had marked certain key sentences with double pencil lines in the margins. And I recall my first ever attempt at multiple choice questions in the exam paper which tested our understanding of all this basic material.

With Jack Paddock I used a Develco very low frequency (VLF, 3–30 kHz) receiver to observe natural radio signals at a remote site to the east of NASA Ames. Later we devised a route going north to carry out a primitive study of the latitudinal variation of VLF signals due to lightning (atmospherics, or sferics for short, and the so-called “tweeks” by night) and whistlers. Unfortunately, my post-doc position was exhausted before these observations could be studied in any detail.

I gained an appetite for traveling to conferences, such as those held in Boulder, Colorado, and Washington, DC, meetings organized by URSI and the American Geophysical Union (AGU), respectively. There I was fortunate to meet Norman Ness (NASA Goddard), a pioneer of magnetopause studies, Don Gurnett and Stan Shawhan from the University of Iowa, satellite experimenters exploring whistler-mode signals, and Sidney Bowhill (University of Illinois at Urbana-Champaign), Bob Carovillano of Boston College, and Tom Potemra (Applied Physics

Laboratory at Johns Hopkins University) amongst other prominent researchers. Such discussions broadened my appreciation of related space physics disciplines, and of the interaction between observational and theoretical studies. Being able to bridge these two fields is, I believe, a great advantage; Ian Axford was a great exemplar.

A vivid recollection of mine was the showing, in the Ames auditorium, of the film of the first spacewalk made by a US astronaut, Ed White, from the Gemini 4 mission on 3 June 1965. I recall being very concerned by the cutting down of apricot orchards in the Bay area on a large scale, to make room for apartment blocks, with swimming pools.

3. Post-Doc Experiences at Imperial College, London, 1965–1966

In the autumn of 1965, John Thomas moved to Imperial College, and so did I, becoming a post-doc in Jim Dungey's group in the Physics Department. David Southwood (working on the plasmapause and geomagnetic field line resonances in the magnetosphere) and David Nunn (studying the generation mechanism of whistler-mode emissions) were two of the Ph.D. students at the time, and David Beard, a magnetospheric theorist, was there on sabbatical leave. It was great to interact with all of them. In the summer of 1966, together with Don Gurnett and Stan Shawhan, I went to Belgrade, Yugoslavia, to attend an international meeting on solar-terrestrial physics. The paper by Rycroft and Thomas (1970) showing that the magnetospheric knee and the trough in the topside ionosphere were located on the same geomagnetic field line was started. Work on the global distribution of scale heights of the exospheric plasma (Angerami & Thomas, 1964) began; this culminated in the paper by Thomas and Rycroft (1970). Work on the global distribution of the ionospheric plasma—and its irregularities—is very important today in relation to GNSS signal transmissions from satellites to ground stations, and even to smart phones (Smith et al., 2024).

4. Career at Southampton University, 1966–1979

My first attempt to gain an academic position was successful, as Lecturer in the Physics Department at Southampton University. I established the Space Radio Physics group, and set up a ground-based radio receiver to investigate whistler-mode signals on South Uist, an island in the Outer Hebrides to the west of Scotland, at $L \sim 3.4$. At the time that Duncan Bryant and Martin Courtier (of the Radio and Space Research Station at Slough) launched a small Petrel rocket from there with a Geiger counter aboard, I was recording very low frequency (VLF) signals nearby; a single burst (a few seconds long) of X-rays produced by precipitating electrons was simultaneous with a weak two hop whistler. I interpreted this as indicating that a Doppler-shifted cyclotron resonance interaction on the $L \sim 3.4$ flux tube had taken place close to the geomagnetic equator between energetic electrons and a half hop whistler, pushing the electrons into the loss cone and amplifying the whistler (Rycroft, 1973). I consider this to be my most important paper (see also Rycroft, 2011). Such wave-particle studies were pursued with the University of Maryland and Stanford University groups and collaborators at Siple Station, Antarctica. Linzmayer et al. (2025) have presented a valuable review of DEMETER satellite observations of the phenomenon of lightning-induced electron precipitation. I also had the opportunity to develop a VLF radio receiver for use aboard the Petrel rocket (Rycroft et al., 1972) and the larger Skylark rocket launched from Kiruna in Sweden. I organized two campaigns to observe VLF radio waves on the ground in Newfoundland and eastern Canada during the solar eclipses of 7 March 1970 and 10 July 1972. I prepared my first review paper, on VLF emissions in the magnetosphere (Rycroft, 1972).

Tony Hewish, a Nobel prize winner in Physics, Fellow of Churchill College in Cambridge and Professor at the Cavendish Laboratory, recommended that his Ph.D. student, Jocelyn Bell Burnell, should broaden her field of expertise after graduating. For 1 year, she worked with me on the topside ionosphere trough and plasmapause. This resulted in a paper published in the Journal of Geophysical Research (Rycroft & Bell Burnell, 1970).

In 1972, the British Council supported my first visit to Finland, at the invitation of Jussi Oksman. I gave talks in Helsinki, Oulu and Sodankyla, north of the Arctic Circle. I especially remember my visit to that Observatory because, midway through my seminar, a reindeer appeared just outside the window.

I supervised the Ph.D. studies of several students. Phil Alexander performed whistler-mode VLF ray tracing studies through a model plasmasphere which were extended by Hal Strangeways. Mathur et al. (1972) investigated experimentally the effect of the ring current on whistlers that had been studied theoretically by Spreiter and Briggs (1962). Rycroft and Mathur (1973) extrapolated the frequency-time (f-t) trace of a whistler to determine

the minimum group delay of a whistler which does not exhibit a nose, that is the frequency at which the travel time of the whistler is a minimum. Sam Adjepong studied chorus and its relationship with trapped and precipitating >40 keV electrons observed on a satellite (Adjepong et al., 1976). Reeve and Rycroft (1972) investigated tweeks observed during a solar eclipse and Reeve and Rycroft (1976) proposed a theory for the generation of whistler precursors.

Martin Jarvis, Neil Murdoch and Paul Cannon, President of URSI from 2014 to 2017, were Ph.D. students who were especially active in high latitude ELF and VLF radio observations. An interesting by-product of these was hearing a distorted version of the tune "Midnight in Moscow" on the hour when aurorae were active. Turunen et al. (1980) suggested that this was due to the ionospheric demodulation of amplitude modulated signals from LF/MF Soviet radio transmitters by the strong auroral electrojet and their re-radiation. Such studies were later extended by the HAARP (High-frequency Active Auroral Research Program) program in Alaska (Hysell et al., 2014).

With two other Ph.D. students, Alan Theobald and Gareth Williams, I modeled the effects of changing fluxes of ultraviolet radiation from the Sun and of solar cosmic rays on the temperature and the distribution of ozone in the stratosphere and mesosphere (Theobald et al., 1977). Rycroft and Theobald (1978) considered the stratospheric temperature response to a sinusoidal wave, with a period of 14 days, of the flux of solar UV radiation. The maximum effect was found to have an amplitude of almost 1 degree Centigrade at an altitude just below 40 km. This field of science has developed greatly since then.

For the 1974 to 1975 academic year, I was a Visiting Professor at the University of Houston, to replace Bob Sheldon who was carrying out small rocket experiments on Kerguelen Island in the remote Indian Ocean; I had met Bob Sheldon at a COSPAR meeting. In Houston I worked with Jim Benbrook and Gar Bering who broadened my research interests still further. Whilst in the USA, I gave seminars at Los Alamos, at the Universities of Kansas and Iowa, and at the NOAA/ERL/Space Environment Laboratory in Boulder, Colorado.

After returning to Southampton, I applied to be a Payload Specialist for the ESA Spacelab program aboard the NASA Space Shuttle. I was fortunate to be one of the five British candidates put forward to ESA in 1977 to join five candidates proposed by 11 other European countries. However, I was eliminated when the number of budding astronauts was reduced to 11, of whom four eventually became Payload Specialists. A popular science book on Spacelab: research in Earth orbit was published by Shapland and Rycroft (1984).

I arranged a seminar series for a few years for my Space Radio Physics group and the research groups of Pamela Rothwell and Geoff Daniell. I especially remember two sabbatical visitors to Pamela's group, Kinsey Anderson and Carl McIlwain, as well as some of her research students, particularly Harry Collin, Geoff Jenkins, and Betty Lanchester.

In 1973 I was invited to deliver a seminar in Brussels by Baron Marcel Nicolet; he introduced me to Joseph Lemaire, Marcel Kockarts and Guy Brasseur. Joseph Lemaire and I organized three symposia on important magnetospheric boundaries, on the plasmapause (in Trieste in 1974), the magnetopause (in Amsterdam in 1976) and the bow shock (in Strasbourg in 1978) at annual meetings of the fledgling European Geophysical Society (EGS) which—including me—first met in Reading in 1973. Attendance at a solar-terrestrial physics meeting in Madrid, Spain, in 1972 was especially memorable as was, four years later, a meeting in Boulder, USA. There I organized, on a Sunday, the very first meeting on active experiments in space. I visited South Africa in 1978, delivering lectures at Witwatersrand, Durban, Grahamstown, and Hermanus, and going down into a gold mine.

My first invitation to act as an external examiner was from Jim Sayers, at Birmingham, to examine the Ph.D. thesis of Nur Tulunay from Turkey on Ariel 3 observations of the topside ionosphere; this was followed by several examinations at Sheffield University for VLF/whistler projects by Ph.D. students supervised by Tom Kaiser and Ken Bullough, including Mark Lester and Mark Clilverd.

With colleagues in the Geology and Oceanography Departments, I organized an interdisciplinary course of modules in Geophysical Sciences, to complement an Environmental Sciences course, for undergraduates. Although this was most successful it has now been discontinued.

During the 1970s, I had the privilege to edit, sometimes jointly with one or two eminent colleagues, the Proceedings of the annual meetings of COSPAR; most of these large volumes were published by Springer-Verlag. COSPAR Proceedings are now published as the Elsevier journal Advances in Space Research. I was a member of

national (Royal Society) committees for Solar-Terrestrial Physics, Geomagnetism and Aeronomy, Space Research and Radio Science, and of the Science and Engineering Research Council Solar System Committee, a grant giving body. I particularly appreciated the opportunity to carry out such community activities.

5. Career at the British Antarctic Survey, 1979–1990

In the middle of 1979, I moved to Cambridge, to join the British Antarctic Survey as Head of the Atmospheric Sciences Division. Some details of my time at Southampton University and at BAS are given in a paper to mark my eightieth birthday, prepared by Aplin et al. (2020). The position was an administrative one, being responsible for the meteorological, ozone, ionospheric and magnetospheric research programmes at Halley and Faraday. I had the privilege of visiting these stations on three memorable visits to the Antarctic, memorable in terms of seeing albatrosses, penguins and seals, majestic icebergs, and appreciating, the clarity of the clean atmosphere.

The scientific highlight was the discovery of the "ozone hole" by Farman et al. (1985)—see Brasseur (2020) and, on its fortieth anniversary, Editorial (2025). The moral of that momentous result is to persevere with making careful observations, and not to ignore, as NASA scientists at the time are said to have done, observations which disagreed with their preconceptions. I particularly remember discussing the ozone hole with Susan Solomon and also with David Attenborough on a journey by ship from the Falkland Islands to South Georgia. I was invited by the Royal Geographical Society to deliver an evening lecture in 1988 on the Antarctic atmosphere; this resulted in a paper (Rycroft, 1990a).

With the expansion of BAS activities after the Falklands conflict, I introduced theoretical studies of magnetospheric plasma physics, and appointed Dyfrig Jones and Richard Horne in that field; since that time this field of activity has broadened further to encompass space weather. Together with Ching Meng and Lou Frank, I organized a successful international conference on Auroral Physics at St John's College, Cambridge, resulting in a book (Meng et al., 1991).

A joint Working Group of IAGA (International Association of Geomagnetism and Aeronomy, a science-oriented organisation) Divisions II and III and URSI (Union Radio Scientifique Internationale, a radio technique-oriented organisation) Commissions G and H was established in 1975. I was IAGA Co-chairman and Don Carpenter (Stanford University) was URSI Co-chairman, until 1981; meetings of this VLF/ELF Remote Sensing of Ionospheres and Magnetospheres (VERSIM) Working Group were held at IAGA and URSI General Assemblies. Since 2004, meetings have been organized independently and successfully.

In 1982, I was elected to the Council of the Royal Astronomical Society for three years. Because of this position I received an invitation to attend a garden party in July 1982 at Buckingham Palace at which my wife, Mary, and I had a conversation with Her Majesty Queen Elizabeth the Second. In 1985 I became a Member of the International Academy of Astronautics.

Also in 1982 I was invited to visit Sri Lanka to deliver a lecture on the occasion of the inauguration of the Institute of Fundamental Sciences in Colombo; this resulted in a publication (Rycroft, 1984). At the invitation of Hermann Bondi, Chairman of the Natural Environment Research Council, I joined the committee of his fledgling Environmental Physics Group of the Institute of Physics.

6. Career at College of Aeronautics, Cranfield University, 1990–1995

Highlights were two visits to Taiwan, to recruit postgraduate students, and one to the People's Republic of China for an international conference on mathematics and its applications, in Xi'an. As Professor of Aerospace, I had the opportunity to encourage in its early days the Master's course in Astronautics and Space Engineering, which is now tremendously successful. Nigel Marsh was one bright student, as also was Paul Craven who later became a Ph.D. student of mine, working on the damage to the DNA in biological cells caused by cosmic rays (Craven & Rycroft, 1996). Radiation damage to humans, whether on the ground or in space, especially on long duration missions, for example, to Mars, is a research topic of continuing importance. I worked with colleagues in the School of Mechanical Engineering on the effects on nitric oxide emissions from jet engines on atmospheric ozone. The Cambridge Encyclopedia of Space, which I edited, was published (Rycroft, 1990b).

In 1992, I arranged a meeting in Cranfield between Victor Trakhtengerts, a plasma theorist from Nizhny Novgorod in Russia, Tauno Turunen, Director of the Sodankyla Observatory in Finland who observed naturally

occurring VLF radio emissions at a very quiet site, and David Nunn, a VLF theoretician from Southampton University. This led to a long-lived research collaboration on the generation and propagation of such signals, supported by NATO and INTAS, with productive meetings being held in Nizhny Novgorod and Prague, and to the book Cyclotron and Alfven mode cyclotron masers in space (Trakhtengerts & Rycroft, 2008).

Discussions over a glass of beer in Prague triggered the series of workshops arranged by the VERSIM group, the first of which was held in Sodankyla in September 2004—unfortunately I could not attend in person due to a recent hip operation, but Tauno Turunen spoke to my viewgraphs. I gave an invited talk at the VERSIM meeting held in Brazil in September 2012 and, the following week, another at the Brazilian Symposium on Space Geophysics and Aeronomy. I attended the next VERSIM meeting in Dunedin, New Zealand, organized by Craig Rodger. The tenth VERSIM workshop took place in Sodankyla in November 2022, with me giving the opening paper by Zoom. Collaborations with Tauno Turunen and Jyrki Manninen there have been fruitful, and my quite frequent visits to Sodankyla to make and analyze VLF recordings have given me opportunities to observe directly many different auroral features.

From 1989 to 1999, I was Editor in Chief of the Journal of Atmospheric and Terrestrial Physics, which transmogrified into the Journal of Atmospheric and Solar-Terrestrial Physics. One day I had the unusual opportunity of meeting the founder of its publisher Pergamon Press, Robert Maxwell, at his Headquarters in the City of London. It was a particular pleasure to work with Tim Killeen on this journal. At this time, I was also an active member of the Council of the Institute of Mathematics and its Applications and Chairman of its Environmental Mathematics Group from 1989 to 1991. I was a Member of the SCOSTEP bureau for eight years from 1989.

7. Career at International Space University, Strasbourg, France, 1995–2000

My appointment as one of three senior faculty positions to devise a new Master of Space Studies course (Rycroft, 1997) was a significant challenge, and a book, Keys to Space: An Interdisciplinary Approach to Space Studies (Houston & Rycroft, 1999) was the major outcome of that enterprise. I found that the breadth of my experience was of real value here. An annual highlight was the Symposium on a particular theme, with papers being published in book form by Springer. One such was devoted to the commercialization of the International Space Station (Haskell and Rycroft, 2000), and another on the future of human spaceflight, beyond the ISS (Rycroft, 2002).

I also had the title of Director of Research, and I published two papers on a mechanism for sprite generation with the Teaching Associate, Mengu Cho (Cho & Rycroft, 1998, 2001). Since then, transient luminous events (TLEs) have become a real research interest of mine (Fullekrug et al., 2006).

During this period, I received an honorary D.Sc. degree from De Montfort University in Leicester in 1998 and was elected to Membership of Academia Europaea in 2000.

8. Experiences Since Retirement, 2000–Present

From 1996 to 2003 I was the General Secretary of the European Geophysical Society (now the European Geosciences Union, EGU); its main annual meeting was then held in Nice, France, and now in Vienna, Austria. My main task was to record the Minutes of the Council Meetings. And through this position I came to know Fred Spilhaus, Executive Director of the AGU.

At a memorable dinner in an informal restaurant in Nice, Torsten Neubert asked several of us to write our ideas for research on sprites and related matters on a paper table napkin. He returned home with these and prepared a proposal which led to the Coupling of Atmospheric Layers (CAL) program and to work with colleagues in Hungary (Satori et al., 2013). And it led, eventually, to the successful Atmosphere-Space Interactions Monitor (ASIM), presently observing TLEs aboard the International Space Station.

With colleagues in Europe I initiated, through funding provided by the European Science Foundation, the SPECIAL program - Space Processes and Electrical Changes Influencing Atmospheric Layers, which ran from 1999 to 2004. As presented by Rycroft and Fullekrug (2004), this describes how the program came into being, and how the initial ideas evolved via discussions in the network. Both the organizational structure and some scientific themes are covered. SPECIAL led to my position as Senior Visiting Fellow at the University of Bath, from 2006 to 2017, and to continuing studies of the DC Global Electric Circuit (Rycroft et al., 2008). This evolved into joint

research with colleagues including Anna Odzimek, Karen Aplin, Giles Harrison, Colin Price, Sasha Nickolaenko, Christos Haldoupis, Evgeny Mareev and Valery Denisenko. It broadened even more to investigate coupling processes from ground level, vertically up through the atmosphere to the ionosphere. In July 2022, I attended my last international meeting, the eighth IAGA/ICMA meeting on Vertical Coupling in the Atmosphere-Ionosphere System which took place in Sopron, Hungary. My current research is now focussed on the DC Global Electric Circuit (Rycroft, 2025b; Rycroft et al., 2024, 2025), attending international meetings via Zoom.

On the research front, I have also worked with Chandra Wickramasinghe on aspects of astrobiology, for example, on whether life carrying molecules found on the external windows of the International Space Station could have come up from the Earth's surface or whether they came from outer space (Wickramasinghe et al., 2018).

A major—and challenging—task from 2001 to 2025 was associated with my position as Editor in Chief of the Springer Nature journal Surveys in Geophysics, which publishes review papers on all aspects of the Earth and space sciences. An Editorial on my retirement summarizes my various tasks as an Editor (Rycroft, 2025a). An especially rewarding experience has been its increasing Impact Factor; papers are submitted from many countries, in particular now from China, and many are on topics of direct relevance to human society.

For a second time I joined the Council of the Royal Astronomical Society, the prime body in the UK for studies in astronomy and geophysics. I was a member of a panel appointed by the Czech Academy of Sciences to evaluate the research programmes of Earth Sciences Institutes on three occasions.

9. Concluding Remarks

The breadth of my research interests, and the value of that breadth, must surely be the main message to readers of this paper. My research has centered on large scale geophysics, even global scale geophysics. In Earth system science, the relationships of one topic to another are explored from an interdisciplinary perspective (Bloschl et al., 2015); as examples of this, see Rycroft et al. (2008), Borovsky and Valdivia (2018) and Lockwood (2022). Tsurutani et al. (2023) have prepared a valuable and comprehensive review of space plasma physics and space weather. National and international meetings provide the necessary conduit for the advancement of research in all these fields.

Research should seek the truth, leading to new results, new information, new knowledge and new understanding. It is especially desirable to test hypotheses. My advice to young researchers is to think creatively, innovatively and "outside the box." To be able to make observations at a place (e.g., a station with a high geomagnetic latitude and an even higher geographic latitude, such as Halley) and time (e.g., during a solar eclipse) with unique features is especially advantageous. I believe that experimentalists should also study the appropriate theory, and vice versa. The research should also be important and relevant to human society; this is particularly so today for climate change, and its associated feedback processes (see, e.g., Gettelman & Sherwood, 2016). And, of course, one's research should be enjoyable and fun (see Mozer, 2022; Tsurutani, 2024), as well as being intellectually satisfying and worthwhile. Finally, I advise young researchers in the Earth and space sciences to take advantage of serendipity, and of all the unexpected and unplanned opportunities for new collaborations and for using new techniques that can present themselves when they are least expected.

Conflict of Interest

The author declares no conflicts of interest relevant to this study.

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Data were not used, nor created, for this study. Software (other than for typesetting) was not used for this study.

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