Author's preface to the third edition

The entire focus in all previous editions of the *Chemistry of the Climate System* was on a chemical understanding of the climate system in the light of *changes*, from early times to the present and even into the future. Hence, insights into the evolution (or history) of the Earth and the atmosphere became key for understanding processes under changing conditions. It was the idea of De Gruyter to issue a third edition. Unfortunately, we are living in a time when the infinitesimal period between today and tomorrow is is virtually the only thing that interests people. Holding onto the past seems to be a hobby for only a few passionate individuals and looking far into the future is of interest only to a few solitary individuals. Students ask for textbooks that are no older than 2 years, not knowing that (good) textbooks, being decades old, already contain 90% of basic knowledge for understanding natural processes (in chemistry, physics, and biology) today. Nevertheless, books always get better with each new edition, even if only mistakes are corrected. It goes without saying that mistakes have been corrected in the present text as well. My deep gratitude goes to the publishers, who granted me an extension and allowed me to fully restructure the second edition of *Chemistry of the Climate System* into two volumes, now in the present third edition. Volume 1 now comprises the physical-chemical basics (fundamentals and principles) of the chemistry of the climate system. Volume 2 treats the system with respect to its evolution (or history) and how it has changed, as well as its sustainability.

Volume 1 contains carefully corrected, fully restructured, and partly enlarged chapters from the second edition concerning the fundamentals of physics (kinetic gas theory and radiation budget), physicochemistry (thermodynamics, equilibrium, properties of water and solutions, multiphase processes), chemistry (substances and reactions, enlarged by metalloids and metals that are environmentally important), and global cycling in the climate system. All historical remarks are now – more systematically – integrated in Volume 2.

The transport and transformation of chemical species are continuous, ongoing processes in the atmosphere. Air constituents (gases, solid and liquid particles) change perpetually through chemical reactions, transfers among physical states, and transfers to (deposition) and from (emissions) the Earth's surface. Direct solar radiation and scattered and reemitted radiation interacts with air constituents, resulting in changes to energetic states and photochemical conversions. This volume mainly focuses on the physicochemical fundamentals of the climate system. As I will often mention in this book, we cannot separate chemical and physical processes. Hence, it is inevitable to outline briefly the physical fundamentals in this regard. However, there are many excellent books on atmospheric physics and meteorology on the market, and the reader is referred to them in connection with the following topics: atmospheric physics and thermodynamics (Peixoto and Oort 1992, Andrews 2000, Zdunkowski and Bott 2004, Hewitt and Jackson 2003, Tsonis 2007), atmospheric dynamics (Gill 1982,

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Holton 2004, Vallis 2006, Marshall and Plumb 2007), meteorology (Garratt 1992, Kraus 2004, Wallace and Hobbs 2006, Ackerman and Knox 2006, Ahrens 2007, Lutgens et al. 2009), and radiation (Kyle 1991, Zdunkowski et al. 2007, Wendisch and Yang 2012).

Great scientific progress was made in the nineteenth century. The twentieth century saw explosive scientific growth. What do we expect in the present century? The growth of science or "growth of knowledge," a term coined by *Karl Popper* (1902–1994), was shown to have "an exponential curve" by the sociologist *William Fielding Ogburn* (1886–1959) in 1922[1] (Popper 1962, Ogburn 1922), based on data compiled by Darmstaedter (1908) on discoveries and inventions. *Basil Bernstein* (1924–2000) said, "the theory, however primitive, has always come before the research. Thus by the time a piece of research was initiated the theory has already been subject to conceptual clarification as it engages with the empirical problem. And by the time it has finished there were further conceptual developments." (Bernstein 2000, p. 93).

By the evolution of the Earth and the climate system we will simply understand their historical development from earliest times until the present. Theories on how the atmosphere and ocean formed must begin with an idea of how the Earth itself originated (Kasting 1993). An understanding of our atmosphere and the climate system is incomplete without going into the past. "The farther backward you can look the farther forward you can see" (*Winston Churchill*). "Evolution is God's, or Nature's, method of creation. Creation is not an event that happened in 4004 BC; it is a process that began some ten billion years ago and is still under way" (*Theodosius Grygorovych Dobzhansky*). "Progress is not an objective fact of nature and cannot therefore be used to justify a normative ethic" (Ruse 1999, p. 221).

Despite important achievements in our understanding of key aspects of aerosols, clouds, and precipitation chemistry and physics, clouds and aerosols remain the largest source of uncertainty in the two most important climate change metrics: radiative forcing and climate sensitivity (IPPC 2007, 2013). This uncertainty is the "manifestation of the lack of our understanding of how aerosol–cloud–precipitation processes act in the climate system" (Heintzenberg and Charlson 2009). An understanding of this complex matter requires an interdisciplinary and integrated approach. Contemporary science has had to adopt a new way of thinking because of the emergence of a rapid accumulation of knowledge at different levels. It seems, however, that progress in understanding nature is slow and infinite. Wise adages illustrate this predicament: "Nature is simple, but scientists are complicated," said Spanish cardiologist *Francisco Torrent-Guasp* (1931–2005), and *Jean-Jacques Rousseau* asserted, "Nature never deceives us; it is we who deceive ourselves" (references from Buckberg 2005). *Albert Einstein* said that "everything should be made as simple as possible, but not simpler."

1 *Ogburn* wrote, "When the material culture was small inventions were few, and now when the material culture is large the inventions are many" or in other words, the greater the number of inventions, the greater the number of new inventions generated. *Ogburn*'s exponential curve was criticized regularly throughout history; see for example Schmookler (1966).

Stewart and Cohen (1994) also stated: "The role of science is to seek simplicity in a complex world. This is a comfortable picture, which encourages a view of the relation between laws and their consequences – between cause and effect –that might be characterized as 'conservation of complexity'. That is, simple rules imply simple behaviour, therefore complicated behaviour must arise from complicated rules."

Today, an innumerable sites devoted to the study of air chemistry exist that are often only active for short periods, with sometimes barely more than a dozen samples collected and analyzed for whatever purpose. *Josiah Charles Stamp* (1880–1941) wrote: "We are so obsessed with the delight and advantage of discovery of new things that we have no proportionate regard for the problems of arrangement and absorption of the things discovered" (Stamp 1937, p. 60).

I hope that this *history*, at least since the systematic monitoring in the second half of the nineteenth century – which is certainly unknown to most modern air chemists – will not only encourage respect for our scientific predecessors but will help to avoid many scientifically meaningless studies of the kind that have appeared over the last few decades. The endeavor remains to learn from previous studies to ask the appropriate open questions and draw the right conclusions for further studies. We learn from history that all kinds of people have been interested in our subject from a philosophical perspective or with respect to the application of techniques (engineering) but always motivated by specific problems (e.g., pollution) of their era. We also hold deep respect for our scientific forebears for the brilliant conclusions they drew based on experiments using very simple techniques and limited quantitative measurements. The great interest in historical data from the era before fossil fuel combustion lies also in the deduction of background concentrations, in other words, the natural reference concentrations for assessing human-influenced changes in chemical air composition. On the other hand, recognition of pervasive urban air pollution in the past would also provide a scale for a more realistic assessment of present air pollution, often still referred to as serious by politicians and administrators.

English chemist *Colin Archibald Russell* (1928–2013) wrote, "Science without its history is like a man without a memory. The results of such collective amnesia are dire" [In: Whigs and professionals. *Nature* (1984) 308, 777–778].

A chemist who has spent 40 years studying atmospheric chemistry and air pollution wrote this book. When I began learning what air chemistry was about, it was the era of sulfur dioxide pollution, the 1970s. It was soon clear to me – and first shown by Junge and Ryan (1958) – that aqueous-phase chemistry dominates in the overall conversion of SO_2 to sulfuric acid, i.e., chemical reactions in clouds, fog, and raindrops (Möller 1980). Being fascinated from the first publication on complex chemistry in raindrops (Graedel and Weschler 1981), we began to study acid deposition (Marquardt et al. 1984) and to develop the first extensive model on aqueous-phase chemistry for raindrops and rain events in Europe (Mauersberger and Möller 1990). Soon after, we learned that chemical conversion in rain is negligible compared to chemistry in clouds in the development of a cloud chemistry model (Möller and Mauersberger 1992). Following the motto of *Gottfried Wilhelm Leibniz* (1646–1716) "*theoria cum praxis*" we constructed a mountain cloud chemistry station at Mount Brocken of the Harz mountain range (Möller et al. 1993), in continuous operation until 2010.

Now, more than 5 years after my retirement and at the end of my scientific career, I would like to thank more people than just my former staff members (see preface to the second edition). First, I thank history (very special East German circumstances) that I had the freedom to decide in late 1974 to become an atmospheric chemist. It was the time of the so-called cold war, dividing the world into East (former "socialist" countries) and West ("capitalistic" countries), antagonized at all fronts. However, air pollution knows no borders, nor does science. Before the fall of the Wall in late 1989, despite some invitations from Western countries (my special thanks go to Henning Rodhe and Hans-Walter Georgii), my "area of distribution" remained the East before 1990. I am very happy to know *all* those individuals in the Eastern bloc (the number was limited) who worked at the same time as I did in the field of atmospheric chemistry and air pollution. It also makes me happy that I became one of the very few specialists in the field in the former Eastern bloc in the 1980s. The most renowned scientists from the East at that time, who were also of international repute, I name here: Ernö Mészáros (Budapest), Alexey Ryaboshapko (Moscow), Mark Evseevič Berljand (†), and Rimma Lavrinenko and Valerij Isidirov (Leningrad and St. Petersburg, respectively), and in addition Bedřich Binek (Prague), Dušan Závodský (Bratislava), Lászlo Hórvath, Lászlo Bózo, Lászlo Haszpra and Gabriella Várhelyi (Budapest), Stefan Godzik (Katowice), Dalia Shopauskine (Vilnius), Zhao Dianwu (Beijing), and a few more with whom I was in constant contact and was engaged in very fruitful discussions. Unfortunately, I never met the great Olga Petrovna Petrenchuk (Leningrad), a pioneer in aerosol and cloud research. Another person I never met owing to his untimely death but whom I hold in the highest regard is Hans Cauer (1899–1962), the German pioneer of chemical climatology – my intellectual father.

The dream, however, of establishing a research station at Mount Brocken became a reality only after the fall of the Berlin Wall in early spring 1990. Hence, I would also like to thank many leading West German scientists for supporting me and my project ideas in the early 1990s: Paul Crutzen, Meinrath Andreae, Adolf Ebel, Hans-Walther Georgii (†), Hans Pruppacher, Dieter Kley, Dieter Ehhalt, Ruprecht Jaenicke, Reinhard Zellner, Dieter Klockow (†), Wolfgang Jaeschke, Wolfgang Seiler, Ullrich Schurath, Peter Warneck, Gode Gravenhorst, Peter Winkler, Karl-Heinz Becker, Ulrich Platt, Jürgen Kesselmeier, and many others. I am very happy to have met Christian Junge in 1992.

My special thanks go again to Volker Mohnen, who flew me in his Cessna airplane in 1991 from Albany to Lake Placid, New York, visiting the Whiteface Mountain Field Station, which served as the inspiration for my Brocken station. Without the extensive international cooperation or idea exchange in the 1990s, the Brocken station and our large mobile measuring equipment (we participated in 12 international field campaigns at many sites throughout Europe between 1990 and 2008 and 13 joint national and 17 institutional field campaigns) would not have been developed to such a sophisticated degree. I would like to thank (in alphabetical order) Hajime Akimoto, Helen ApSimon, Greg Ayers, Len Barrie, Axel Berner, Peter Brimblecombe, Peter Builtjes, Robert Charlson, Nadine Chaumerliac, Tom Choularton, Jeff Collett, Tony Cox, Robert Delmas, Bob Duce, Sandro Fuzzi, Ian Galbally, Hiroshi Hara, Manabu Igawa, Peter Liss, Tony Marsh, John Miller, Stuart Penkett, Pascal Perros, Hans Puxbaum, Robert Rosset, Steve Schwartz, Jack Slanina, Chris Walcek, and many others.

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Detlev Möller
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