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The shaping of climate science: half a century in personal perspective

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Abstract. The paper traces my career as a climatologist from the 1950s and that of most of my graduate students from the late 1960s. These decades were the formative ones in the evolution of climate science. Following a brief account of the history of climatology, a summary of my early training, my initial teaching and research in the UK is discussed. This is followed by new directions at the University of Colorado, Boulder from October 1968. The history of the World Data Center for Glaciology/National Snow and Ice Data Center in Boulder from 1977 is described and climate-cryosphere initiatives at the Cooperative Institute for Research in Environmental Sciences (CIRES). International activities and links are then reported, followed by a section on national and international committees. I then describe my activities during sabbaticals and research leaves. The paper concludes with discussion of my "retirement" activities and an epilogue.

The paper is based on a lecture given at the Roger Barry Symposium: A Chronicle of Distinction: From the Arctic to the Andes, at the University of Colorado, 10 August 2004 and updated to 2014.

1 Introduction

Climatology is a young science, spanning barely half a century, and I have indeed been fortunate to be part of most of it. While some true pioneers – J. von Hann, W. Köppen, R. Geiger and C. E. P. Brooks – were before my time, I did know personally almost all of the players identified by Peter Lamb (2002) in his account of the "climate revolution": Ken Hare (my advisor), Reid Bryson, Hubert Lamb, Hermann Flohn, Murray Mitchell Jr., and Jerry Namias. I also met M. I. Budyko, E. B. Kraus, and H. E. Landsberg, as well as others not mentioned by Lamb – André Berger, Arnold Court, Kirill Kondratyev, Friedrich Lauscher, Gordon Manley, Tony Chandler, Russ Mather, Steve Schneider, and Carl Troll. For this reason, tracing my personal path and its determinants is a key to understanding the histories of my graduate students at University of Colorado, and my links with climate and other scientists around the world.

A career is a mixture of serendipity and being in the right place at the right time, but also requires patiently working in your areas of interest or pursuing unplanned developments at a particular point in time, without expectation that they will necessarily lead anywhere. Years later, some of these pursuits may unexpectedly bear fruit. My international links and research leaves were important in this regard.

2 The evolution of climate science

From the 1880s through the 1940s climatology was regarded by the meteorological profession as "bookkeeping" – the calculation of averages of the climatic elements at stations over long time intervals. The Russian-born climatologist Wladimir Köppen had related climate to vegetation and in 1884 devised a classification of global climates that has withstood the test of time. Local, regional and continental climates were described over subsequent decades, but the first major advance was Rudolf Geiger's book *Climate near the ground*, published in German (Geiger, 1927). The Second World War focused attention on improving weather forecasting and understanding weather and climate around the globe, especially in the tropics and the Arctic. These trends con-

tinued during the subsequent Cold War era. World War II also entrained new scientists into meteorology such as Jerry Namias (long-range forecasting and large-scale air–sea interactions), Reid Bryson (founder of the Meteorology Department at the University of Wisconsin in 1948 and researcher on climate change), and Helmut Landsberg (author of *Physical Climatology* in 1941). In the 1950s efforts began to analyze the general circulation and the energy balance of the earth that has continued for 50 years.

The 1960s–1970s saw numerous developments. William Sellers (1965) published *Physical Climatology*. Paleoclimatology focused on the timing and causes of ice ages and became strongly interdisciplinary. Ice core research, palynology, and dendroclimatology provided a wealth of paleoclimatic information. There was recognition from Keeling's measurements at Mauna Loa that atmospheric concentrations of carbon dioxide were increasing. The climate of the last millennium emerged as an important aspect of climate change studies. Hubert Lamb was a leader in this field from the 1960s (also in classifying weather types) and later published a major survey of past climate (Lamb, 1977). The 1970s also saw the introduction of general circulation models (GCMs) and model studies of CO_2 impacts on the climate system. The International Biological Program (IBP) and its successors led to international collaboration on ecoclimatological research in many different biomes. From the 1990s on, the recognition of global warming, its two–threefold amplification in the Arctic, partly linked to shrinking sea ice and snow cover, and global impacts, have been the focus of much attention using coupled global climate models and satellite observations of the cryosphere.

My contributions were made in papers and textbooks and the 65 graduate theses and dissertations that I supervised. Many of these students went on to have illustrious careers (see Appendix A).

3 Early background and training

Following an early teenage interest in weather observations, my meteorological training began when I joined the UK Meteorological Office as a scientific assistant in 1952. The eight-week basic training at Stanmore Meteorological Training School in north London included an introduction to meteorology, synoptic observations, pilot balloons, coding and decoding weather reports, and plotting chart data and tephigrams from Global Telecommunication System (GTS) teletype reports. I performed these tasks on shift work at the Royal Air Force (RAF) Station Worksop in Nottinghamshire, England, from 1952 to 1954. During this time, I also served two brief stints at a station in East Yorkshire, where I was whisked at short notice in the back seat of a Meteor jet fighter to fill in for an employee on leave. In the evenings I took correspondence courses in advanced-level mathematics and ordinary level physics on the recommendation of my instructor at Stanmore. Failing the eyesight test for military service, and thereby benefiting from two "free" years, I applied for a university program in geography – the first university attendee in the family. I chose geography as it had been a long-term interest and was my best subject at grammar school. I was fortunate to receive financial support from the Sheffield City Council.

My climatological mentor at the University of Liverpool was Stan Gregory, later the founding editor of the *International Journal of Climatology* (for which I was on the Editorial Board, 1980–1989). As part of the honors BA degree, I began a dissertation on weather types, influenced by Rodney B. M. Levick's 1955 paper in *Weather*. I met Rodney at a Royal Meteorological Society (RMS) meeting in London, to which he bought my rail ticket and that was my introduction to professional meteorology. My dissertation concerned airflow types in central Scotland and the associated climatic conditions at Turnhouse, Edinburgh; Dyce, Aberdeen; Renfrew Airport; and Eskdalemuir Observatory – all of which I visited.

In June 1956, Professor F. Kenneth Hare of McGill University visited the University of Liverpool, sponsored by the British Council. Professor Hare's lectures on Arctic meteorology and Labrador-Ungava stimulated me to pursue a master's degree at McGill University after graduating in 1957. After attending McGill's summer school in Stanstead, Quebec, and further meteorological training at Dorval Airport to satisfy the Canadian Meteorological Service, I became one of four graduate student weather observers. Supervised by a senior observer, I spent 12 months of the International Geophysical Year (IGY) at the McGill Subarctic Research Laboratory in Schefferville, Quebec, making weather observations and reports for the Knob Lake station. My modest IGY contribution involved filing auroral reports on microcards. Since the Knob Lake station was near the zone of maximum auroral frequency, we saw numerous and unusual auroral displays. I also attended a lecture course offered by the Lab director, Jack D. Ives, about the physical geography and Quaternary history of northeast Canada. This awakened my interest in ice age climate and the Laurentide Ice Sheet.

I subsequently began researching the synoptic climatology of the Labrador-Ungava Peninsula (Barry, 1959, 1960b) based on the regional circulation types of Lamb (1950) for the British Isles. Synoptic climatology is the study and analysis of climate in terms of synoptic weather patterns rather than monthly averages. By the fortunate contrast in winters 1956–1957 (cold and dry) and 1957–1958 (relatively mild and moist), I was able to propose them as typical of glacial maximum and glacial onset conditions, respectively (Barry, 1960a). This laid the foundations for my subsequent work in both synoptic climatology and paleoclimatology.

In Montreal in 1958–1959, I worked with the Arctic Meteorology Research Group (AMRG) plotting 25 mb data and meridional temperature and wind cross sections in a project on the Arctic stratosphere. I attended courses offered by F.

K. Hare (dynamic meteorology and geographic methodology) and Svenn Orvig (physical meteorology) in geography, and Walter Hitschfeld (thermodynamics) in physics. I also attended discussions with PhD candidate Barney Boville (dynamic climatologist), Warren Godson (advisor to the AMRG) and Morley Thomas, all of the Canadian Meteorological Service, staff colleagues Mona MacFarlane and Cynthia Wilson, and grad students Ian Jackson, and John Raynor. Ian, after a stint at the London School of Economics lecturing on climatology, became head of Sigma Xi. John Raynor lectured in New Zealand, and then frustrated by the attitude of the New Zealand Meteorological Service to geographer climatologists moved to Ohio State University and later became Department Chair in Geography. As stated in another context, "it takes a village…".

After my MSc, I returned to the University of Liverpool in October 1959 and started on my PhD on vapor transport over Labrador-Ungava under Stan Gregory, supported by a Leverhulme Fellowship. I also began to learn Russian through a BBC radio program, partly with the ambition to read the related work of M. Budyko and other Soviet scientists. During this doctoral work, completed in 1965 at the University of Southampton, I was fortunate to meet and talk with H. H. Lamb, A. G. Matthewman, and G. B. Tucker at the Meteorological Office in London. Matthewman assisted me with an algorithm for calculating moisture flux divergence from radiosonde data and Tucker advised me on the implications of the results.

I conducted the data analysis for my MSc thesis using punched card sorting and a desk calculator, and I later wrote a note for *Erdkunde* on the geographical applications of punched cards (Barry, 1961). After returning to Liverpool to begin a PhD, I spent months learning to program in machine language the first-generation English Electric DEUCE computer to analyze moisture contents, transport, and flux divergence over Labrador-Ungava. The data on punched cards were shipped from the National Climatic Data Center (NCDC), Asheville, in a large wooden crate. After moving to University of Southampton in 1960 I had to learn to program the Pegasus computer and use paper tapes. Later, boxes of punched cards were shipped to Harwell, where they were processed. When I moved to the University of Colorado, I was able to work with a Fortran programmer. I and several of my students also used the NCAR computer.

4 Teaching and research in the UK

In October 1960, I was appointed as an assistant lecturer at the University of Southampton, where I taught weather and climate courses in all three years of the BA/BS programs. I also introduced statistical methods into the cartography classes, developed a biogeography course, and held weekly tutorials with student groups in each of the three years. My students included Allen Perry, Mike Clark, Ruth (Morris) Chambers, Hugh French, and Ray Bradley. When appropriate, C. Ian Jackson (a contemporary at McGill and then at the London School of Economics) joined forces with me to brief third-year climate students on the papers to be read at the Royal Meteorological Society meetings in London. My doctoral work was delayed by studies of the synoptic climate of south-central England for a British Association for the Advancement of Science meeting and an associated book chapter on the regional climate based on circulation types (Barry, 1963, 1964b). This strengthened my interest in synoptic climatology, which persisted over my career (Barry, 1967d, 2005a). I also supervised my first honors student dissertation by Ruth (Morris) Chambers on soil temperatures in the New Forest (Morris and Barry, 1963). While she was a master's degree student, we collaborated on albedo research using instrumentation attached to a University of Southampton Air Squadron "Chipmunk," thanks to an enthusiastic Commanding Officer and the Electrical Engineering Department's instrument shop (Barry and Chambers, 1966b). We published a summer albedo map of England and Wales using albedo data applied to county land use maps prepared by teams organized by Dudley Stamp (Barry and Chambers, 1966a). This work brought us into contact with John Davies, John Monteith, and M. J. Blackwell. We planned to prepare an energy budget atlas for Great Britain, but it had to be canceled when the Meteorological Office declined to allow Blackwell to perform this work and John Davies left for McMaster University in Ontario. John Hay also left the University of London for the University of British Columbia in 1970, and these moves boosted the physical climatology expertise in Canada.

Figure 1. Roger filling a pilot balloon with hydrogen at Tanquary Fiord, summer 1963.

In summer 1963 and spring 1964, Geoff Hattersley-Smith led "Operation Tanquary" (at Tanquary Fjord, Ellesmere Island, Northwest Territories, Canada). This was an oceanographic program conducted for the Defense Research Board of Canada. Geoff undertook pioneering exploration of the Ward Hunt Ice Shelf with dogsled teams. This was part of

Canada's awakening interest in its Arctic territories and its desire to show national sovereignty. I carried out meteorological studies (Barry, 1964a). Figure 1 shows me filling a pilot balloon with hydrogen. This research, and the completion of my PhD in 1965 on "Water vapour and its atmospheric transport over Labrador-Ungava and its paleoclimatogical significance" (Barry, 1966; 1967b), served as a springboard for my sabbatical year in Ottawa at the Geographical Branch, Department of Energy, Mines and Resources, then directed by Jack Ives. I worked on the Arctic front (Barry, 1967a) and the climatology of Baffin Island and northeastern Canada (Barry, 1967b, 1968). While there, I had the luxury of a research assistant, Simon Fogarasi, and programming support (Barry and Fogarasi, 1968). I also visited the field station of the Geographical Branch at Inugsuin Fjord and viewed the Barnes Ice Cap and surrounding areas by helicopter. These activities, building on my training at McGill, laid the foundation for my growing interest in Arctic climatology

While still in England, I worked with Joyce Lambert of the botany department to plan and develop a combined botany–geography honors degree. This degree program later morphed into environmental sciences, which is now widely taught. The first graduate, Lynn Drapier, was employed at the Geographical Branch, Ottawa, and subsequently became a consultant on many government projects. I was also invited to contribute to *Models in Geography* (Barry, 1967c) and thus began an unimagined, almost 40-year collaboration with Dick Chorley at the University of Cambridge. Building on a draft of *Atmosphere, Weather and Climate* (initially rejected by McGraw Hill, and published by Methuen), which he had prepared with a schoolteacher, the text was revised and expanded (Barry and Chorley, 1968, 2010). I surveyed published reviews of all existing introductory textbooks in weather and climate to ensure that we avoided common mistaken explanations. Over its lifetime the book has been translated into Spanish (twice), Korean, Portuguese and (illegally) Chinese.

5 New directions in Colorado

This section traces my initial activities at the University of Colorado. In 1967, the Department of Energy, Mines and Resources, Canada, decided to eliminate the Geographical Branch where I was temporarily working, and redistribute its functions among other agencies. Jack Ives and John Andrews subsequently took positions at the Institute of Arctic and Alpine Research (INSTAAR), located at the University of Colorado at Boulder. I visited INSTAAR and interviewed for a position in September 1967 before returning to England. After considering other opportunities at the University of East Anglia's (UEA) new School of Environmental Science (led by K. M. Clayton), and at the University of British Columbia, I decided to accept a position at INSTAAR in October 1968 as an associate professor, affiliated with geography and rostered in the graduate school, in what became a permanent move.

Figure 2. Roger by the weather station on the Boas Glacier, Baffin Island, summer 1970.

I was frustrated by the very limited research funding that was available in the UK at that time as I wanted to train graduate students. Hence, the opportunity to join a research institute working with individuals I knew was very appealing. This move led to my greater involvement in Arctic and paleoclimatological research and my burgeoning interest in mountain climate.

My first two graduate students – Ross Reynolds (from Reading, UK) and Waltraud Brinkmann – came through the geography department with Brinkmann having completed a master's degree with Ruth Chambers at the University of Calgary. Brinkmann's classic work on Boulder's downslope windstorms (Brinkmann, 1974) was completed in cooperation with several National Center for Atmospheric Research (NCAR) scientists, such as Doug Lilly, Ed Zipser, and Paul Julian, who provided valuable guidance on wind dynamics and facilitated NCAR's Aviation Facility flights over the Front Range.

My initial work focused on the climate and glaciation of Baffin Island, and was conducted with John Andrews and graduate students John Jacobs and Ron Weaver (Andrews et al., 1970; Barry et al., 1972a, b; Barry and Jacobs, 1973), and included fieldwork on the Boas Glacier in 1970 (see Fig. 2). I changed John Jacobs' career when I discovered that he had overwintered at Vostok in the Antarctic and entrained him into our program. Jacobs's and Weaver's interest in sea ice led to work on land-fast ice at Broughton in Home Bay (Jacobs et al., 1975; Weaver et al., 1976). Based at Cape Dyer, Jacobs and I used an NCAR QueenAir aircraft to study sea ice in Davis Strait during spring 1971. Ron Weaver coordinated some of this work while I was on leave from 1975 to 1976, and this collaboration facilitated our subsequent work together at the World Data Center (WDC)-A for Glaciology. Later, Rob Crane utilized the data collected off Broughton to

determine the synoptic controls of ablating fast ice (Crane, 1979).

Later, similar work was performed on ice conditions off northern Alaska with Jeff Rogers, Richard (Dick) Moritz (Barry et al., 1979b), and Gary Wohl, supported by the Offshore Continental Shelf Assessment Program (OCSEAP) of NOAA. This research involved the use of five years of Landsat imagery and brought me into contact with scientists in Alaska.

During this time, I also analyzed the 1952 to 1970 climatological data record collected by biologist John Marr at four elevations on the east slope of the Colorado Front Range, supported by my first independent National Science Foundation (NSF) award. These data provided one of the longest time series from the mountains of the western USA and the record is still maintained. After completing the Front Range data analysis (Barry, 1973b), I participated in the San Juan Ecology Project, directed by Jack Ives. This was focused on ecological and snow studies led by Pat Webber and Nel Caine at INSTAAR. I subsequently studied historical climatology in the Southwest with Ray Bradley, who had been an undergraduate student at Southampton University (Bradley and Barry, 1973).

Historical climatology had developed around 1965 through the work of Gordon Manley and Hubert Lamb in the UK, Hermann Flohn in Germany, and Jack Eddy in the USA. Ray Bradley studied the historical climatology of the Rocky Mountain states (Bradley and Barry, 1973, 1975) and later broadened his research focus to include climate change on many timescales. Richard Armstrong played a key role in the subsequent San Juan Avalanche Project and snow science program, which led several years later to his affiliation with the National Snow and Ice Data Center (NSIDC). The International Biological Program Tundra Biome Project, directed for Alaska by Jerry Brown at NSF, and for the Alpine component by J. D. Ives, allowed Ellsworth LeDrew to conduct energy budget studies on Niwot Ridge and perform comparative alpine/arctic energy balance analyses (LeDrew, 1975a, b; LeDrew and Weller, 1978). I was involved in syntheses of tundra biome climates (Dingman et al., 1980; Barry et al., 1981). LeDrew (1980, 1983) later investigated the dynamics of arctic synoptic systems for his doctoral thesis.

A team-taught course in arctic and alpine environments gave rise to an edited volume of the same title (Ives and Barry, 1974), in which I contributed to chapters on Arctic climate with Ken Hare, topoclimatology and microclimatology with Claudia van Wie, and paleoclimatology with Jim Larsen, as well as to the Introduction and Postscript with Jack Ives. The publication helped put INSTAAR on the map as an internationally recognized research institute on polar and alpine environments. With former University of Southampton student Allen Perry (then at the University of Swansea), I completed a book on synoptic climatology (Barry and Perry, 1973a) and several related papers (Barry and Perry, 1969, 1973b). The impetus to write the book was my desire to synthesize the work conducted on many spatial scales in the UK, the USA, Austria, Germany, and the Soviet Union and make it accessible to the English-speaking world. Forty years later the book is still cited, although an updated chapter was published by Barry and Perry (2001) in Barry and Carleton (2001). Brent Yarnal, who was a Visiting Fellow of CIRES in 1984–1985, wrote many papers utilizing synoptic climatological methods and in 1993 a text on the subject (Yarnal, 1993).

New graduate students sparked additional interests. Jill (Williams) Jaeger arrived on a fellowship and we began the first global ice age experiment using a general circulation model, collaborating with Warren Washington at NCAR (Barry, 1973a; Williams and Barry, 1975; Williams et al., 1974). This work preceded by two years the analogous experiments by the CLIMAP group. It was totally novel in that previous reconstructions of glacial maximum circulation, temperature and precipitation had been subjective. Our initial submission to the *Quarterly Journal of the Royal Meteorological Society* was rejected. I was informed by a secretary, because it was the work of geographers, despite Warren Washington's co-authorship! A proposed intercomparison of early ice age model results (involving NCAR, Oregon State University, and Geophysical Fluid Dynamics Laboratory) by the same authors was approved for NSF funding but never developed due to the groups' unwillingness to share their results, in contrast to many recent model intercomparison projects. These GCM experiments quickly led to numerous such sensitivity studies on an ever-widening list of topics. Jill Williams went on to model the effects of large energy parks at the Institute for Applied Systems Analysis in Laxenburg, Austria.

Soon afterwards, Jeff Rogers and Gerry Meehl collaborated with Harry van Loon at NCAR on teleconnections in Greenland and Scandinavia with the circulation in the North Atlantic (van Loon and Rogers, 1978; Meehl and van Loon, 1979). This revived work done by Sir Gilbert Walker in the late 19th century on climatic anomalies that are correlated over large distances. Meehl then went on to modeling analyses with W. M. Washington at NCAR that eventually led to his leading role in the Intergovernmental Panel on Climate Change (IPCC).

From 1968 to 1978, I focused on paleoclimatology and participated in several meetings of the American Quaternary Association and Congresses of the International Quaternary Association (Paris and the Dauphine, 1969; Christchurch, New Zealand, 1973; Birmingham, 1977; and Moscow and Georgia, 1982). From 1974 to 1977, I was president of the Inter-Congress Committee on Paleoclimatology, laying the groundwork for subsequent Commission activities by André Berger and Alayne Street-Perrott, who had done her master's degree work through INSTAAR. Alan Hecht at NSF played an important role in fostering paleoclimatic research in the United States (Barry et al., 1979a; Hecht et al., 1979) and this led to my serving as an advisor on dendroclimatology,

together with John E. Kutzbach, to Hal Fritts at the Tree Ring Laboratory at the University of Arizona. At a workshop there I met Henry Diaz, who later transferred from NCDC to Boulder to become one of my PhD students. We collaborated on several subsequent climate change studies (Diaz et al., 1982; Moses et al., 1987). I pursued studies on the Laurentide Ice Sheet climate with John Andrews, Jack Ives, Larry Williams, and others (Williams et al., 1972; Brinkmann and Barry, 1972; Barry, 1973a; Ives et al., 1975; Barry et al., 1975; Andrews and Barry, 1978).

In the late 1970s, climate research began to address the impacts of greenhouse-gas-induced warming and my participation in a number of workshops led to review articles and a few student theses. Jill Jaeger at the International Institute for Applied Systems Analysis (IIASA) organized a conference in 1977 (Barry, 1978a), and I participated in conferences on the cryospheric impacts of warming held in the United States and Canada. I contributed to Department of Energy (DoE) reviews of carbon-dioxide-induced climatic change effects (Barry, 1985, 1991). The DoE's Carbon Cycle program supported Florence Tramoni's and Michael Palecki's student projects on lake freeze-up and break-up, to which Jeff Key and Jim Maslanik contributed. Richard Heede made an independent assessment of energy stocks in consultation with Will Kellogg at NCAR.

Links between INSTAAR and the Laboratory for the Application of Remote Sensing (LARS) at Purdue University provided another direction in remote sensing applications, initiated by Jack Ives's work with NASA (code PY) on the Front Range. This collaboration led to some early use of Earth Resources Technology Satellite (ERTS-1) images to analyze seasonal snow cover recession and forest cover. It also provided a basis for later remote sensing studies of sea ice in the Arctic using visible and passive microwave images.

6 The World Data Center for Glaciology

From 1973 to 1977, I was a member of the Glaciology Committee of the Polar Research Board, under the chairmanship of Charles Bentley, which brought me into contact with many of the leading glaciologists of the day. In 1976, Alan H. Shapley, Director of the National Geophysical Data Center (NGDC) at NOAA, and Jack Ives presented a management plan to the Polar Research Board to operate the World Data Center-A for Glaciology at the University of Colorado, with funding support from NOAA NGDC. The library and glacier photo collections under Mark Meier's direction at the US Geological Survey's Glaciology Project Office in Tacoma, WA, were transferred to Boulder in November 1976 and we hired the first staff members. Ann Brennan Thomas, the second hire, worked at the center until 1998, and Greg Scharfen, hired in 1978, remained an employee until 2005. An important item in the small initial annual budget was support for working visits by scientists; these included Robert Vivian from the Institute of Alpine Geography in Grenoble, France, and Carl Benson (snow science) and William Stringer (sea ice) from the University of Alaska. The major initial goal was to expand into areas of interest to NOAA, so we surveyed sea ice charts and snow cover maps (Barry and Crane, 1979; WDC for Glaciology, 1979). Graduate student Rob Crane participated in these surveys. Additional resources allowed us to survey ice core data (MacKinnon, 1980), resulting in a document that NSF used in its program planning.

Early activities for WDC-A for Glaciology included visiting the WDC-B for Glaciology in the Soviet Union. Vladimir M. Kotlyakov and Natalya Dreyer from the Institute of Geography at the Russian Academy of Sciences (RAS), Moscow, had visited WDC-A for Glaciology in 1978 to obtain material for the World Atlas of Snow and Ice Resources (published in 1997). Dean Colin Bull (of Ohio State University, representing the Polar Research Board and Committee on Geophysical Data) and I, accompanied by Institute of Geography scientist Alya Voloshina, met with glaciologists at institutes in Moscow (World Data Center-B), Leningrad (Arctic and Antarctic Research Institute), Tashkent (Central Asian Hydro-Meteorological Institute, SANIGMI), and Almaty, Kazakhstan (Institute of Geography), at which I presented talks in Russian. Figure 3 shows me in Moscow with Igor Zotikov (Fig. 3), who later visited NSIDC as a Fulbright Fellow. I had met several of these glaciologists in 1978 at the World Glacier Inventory meeting in Riederalp, Switzerland (organized by Fritz Mueller). These contacts were greatly enhanced in the 1990s following *perestroika*. Pembroke Hart, Director of the WDC-A Coordination Office at the National Academy of Sciences in Washington, helped facilitate international WDC activities. In 2008 the WDC system was terminated by the International Council on Science (ICSU) and replaced by the World Data System (WDS), which includes NSIDC.

The first digital data management request to the WDC came when Dwayne Anderson, director of the Office of Polar Programs (OPP), asked the WDC to archive airborne geomagnetic and radio-echo sounding data for Greenland and Antarctica. Ed Zipser, then of NCAR, suggested the first large data set to be archived at the WDC: the collection of Defense Meteorological Satellite Program (DMSP) Operational Line Scan (OLS) images ($\sim$ one million positive transparencies). The University of Wisconsin could no longer store the collection, so we agreed to provide the archive space if NCAR would pay for the shipping. Greg Scharfen assumed responsibility for the archive, and it was managed by undergraduate students, many of them on work-study programs including Rob Bauer, who still works at NSIDC.

In 1981, NOAA Environmental Data and Information Service (EDIS) Director Thomas Potter invited other agency representatives to a briefing I gave at NOAA on the work of the WDC for Glaciology, and Potter encouraged us to seek projects of national interest. Subsequently, we became involved in managing passive microwave data with Stan Wil-

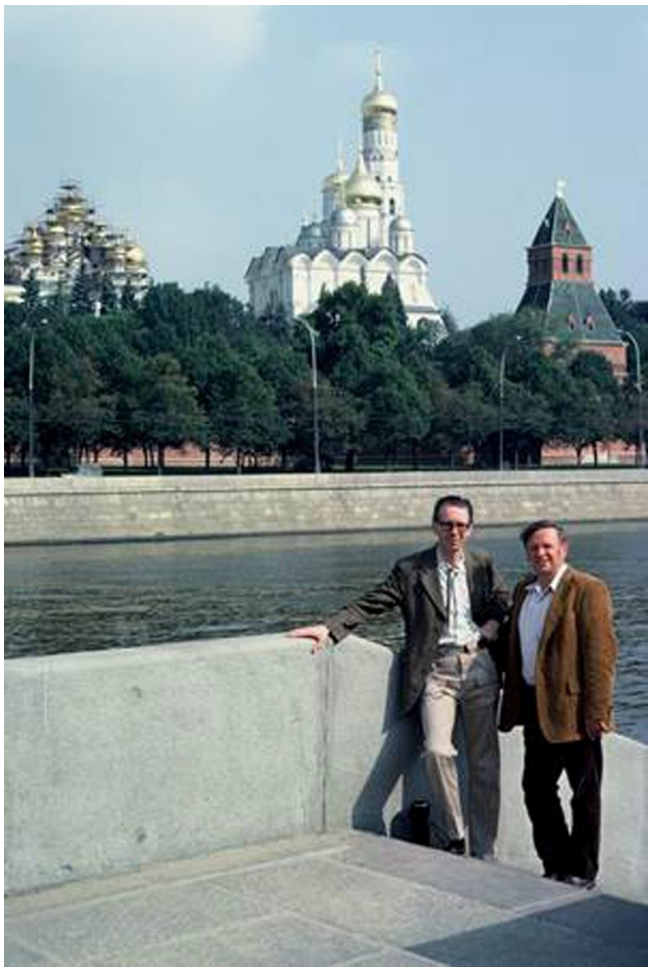

Figure 3. Roger and Soviet glaciologist Igor Zotikov near the Kremlin, Moscow, September 1979.

son of NASA's Polar Oceanography program and we also established links with the US Army Cold Regions Research and Engineering Lab (CRREL) in Hanover, New Hampshire. The management of passive microwave data from Nimbus 7 Scanning Multichannel Microwave Radiometer (SMMR) became an issue because sea ice scientists at the NASA Goddard Space Flight Center (GSFC) were apparently monopolizing the data.

In 1982, following recommendations by the Polar Research Board, Marjorie Courain, director of the National Environmental Satellite, Data and Information Service (NESDIS), authorized the WDC to assume the title National Snow and Ice Data Center (NSIDC). This enhanced our ability to seek multiagency support and led to work for NASA for passive microwave data on sea ice extent and concentration. This expanded greatly in 1993 with the award of a five-year contract to operate the Distributed Active Archive System (DAAC) for snow and ice as part of NASA's Earth Observing System Data and Information System (EOSDIS). This work has continued subsequently with renewals overseen for many years by glaciologist Robert Thomas at NASA Headquarters.

NSIDC also obtained funding for the DMSP archive from NOAA programs and grants. Scientists expressed considerable interest in the 0.6 km direct readout products, and were also interested in the consistent resolution of the 5.4 km products. Andrew Carleton, Greg Scharfen, and others used these products in their dissertation work, and other researchers used the data to produce mosaic products of the polar regions, global nighttime lights, and the tropical highly reflective cloud atlas. A later study supported by Steve Goodman (Barry et al., 1994) used DMSP products to research global nighttime lightning frequency. When digital DMSP OLS data became available, the Air Force and NGDC planned a digital archive, but NSIDC's initial participation in this activity for snow and ice products was eventually discontinued due to problems with funding and timely service to our customers. NSIDC transferred the film archive (over a million pieces of OLS imagery) to the Federal Records Center in Denver.

7 Cryosphere-climate initiatives in CIRES

The Cooperative Institute for Research in Environmental Sciences (CIRES) Climate Program was established in the late 1970s. The National Academy of Sciences had developed the framework for a National Climate Plan from 1973 to 1975, and published a report, *Understanding Climate Change – a Program for Action*, in 1975. This report originated in a 1972 conference at Brown University in Providence, RI, "The present interglacial: how and when will it end?" (Kukla et al., 1972) at which I was a participant. The meeting organizers, George Kukla and Robert Matthews, subsequently wrote to President Nixon about the need to recognize and, if possible, predict climatic fluctuations that might signal the onset of renewed glaciation – a concern at the time to some climatologists.

National climate programs within both NSF and NOAA owe much to the vision of Joe Fletcher of Ice Island T-3 fame. Fletcher, then director of the NSF Office of Polar Programs and later deputy director of NOAA' s Environmental Research Laboratories (ERL), recruited Uwe Radok from the Meteorology Department at the University of Melbourne, Australia, for a position in the NSF, where they helped develop the Office of Climate Dynamics (OCD). CIRES subsequently decided to organize a research program in climate dynamics for NOAA, and in September 1977 Radok came to Boulder to lead this effort. The CIRES Climate Research Project identified three broad objectives (Barry et al. 2002):

- to construct a global data set to describe climatic fluctuations during the past 130 years over oceans and continents
- to conduct interpretive diagnostic studies of those climatic fluctuations on timescales ranging from one month to decades

– to conduct modeling studies of polar ice sheets to clarify their evolution and their responses to climatic change.

In 1980, my appointment at INSTAAR was transferred to CIRES. The 10 WDC for Glaciology staff members were also transferred. My interests gradually shifted from paleoclimate and Quaternary glaciations to modern climate-cryosphere processes. I joined the climate group, together with Colin Ramage and Uwe Radok, at a time when both tropical climate and Greenland Ice Sheet climate were receiving attention. Uwe Radok led a project on the characteristics of the Greenland Ice Sheet (Radok et al., 1982), in which I was involved (Barry and Kiladis, 1982). By the mid-1980s the group included about 20 researchers, including five CIRES Fellows (myself, Colin Ramage, Uwe Radok, Howard Hanson, and Henry Diaz). At that time, the CIRES Fellows lacked a regular faculty member in the atmospheric sciences.

In the early 1980s, researchers began using the DMSP image archive in conjunction with passive microwave data from NASA and the planned DMSP Special Sensor Microwave/Imager (SSM/I) products through collaboration with NASA's Pilot Ocean Data System (PODS), developed at the Jet Propulsion Laboratory (JPL). These data sets were critical to the research directions of Rob Crane, Mark Anderson, Garry Wohl and, later, Axel Schweiger. The plan was to use PODS software installed on a VAX 750 computer at NSIDC. Eventually, Vince Troisi led in-house software development. The DMSP SSM/I satellite was not launched until 1987, four years after planning began, but by then NSIDC had embarked on an active program of archiving data products from remote sensing. Graduate students Andrew Carleton (using DMSP imagery), and Rob Crane, Mark Anderson and Axel Schweiger (using Scanning Multicultural Microwave Radiometer (SMMR) data) produced related remote sensing dissertations (Carleton, 1979; Crane et al., 1982; Anderson et al., 1985; Schweiger et al., 1987).

I also collaborated with Ann Henderson-Sellers at the University of Liverpool, UK, on the radiative effects of cloudiness related to the marginal cryosphere and we hired as postdoctoral fellow Keith Shine, later at the University of Reading (Barry et al., 1984). I also worked with Rob Crane on polar clouds (Crane and Barry, 1984).

In 1986, my group received a major award from the Office of Naval Research under its University Research Initiative (URI). The theme was arctic ocean ice–climate interactions. Russell Schnell, Fred McLaren (just completing his PhD), and I collaborated with the numerical modeling team of Bill Hibler and Erland Schulson at the Thayer School of Engineering at Dartmouth College. Our award was apparently approved in part because I had listed the Arctic scientists I had already trained. The stability of five-year funding allowed us to hire and train a strong research group, including Jim Maslanik, Mark Serreze, Jeff Key, and Martin Miles, all of whom have built reputations in polar sciences. Jeff Key was teaching statistics in Anchorage when I enticed him to Boulder. The first three of these individuals began advising and co-supervising graduate students, including Rob Silcox, Ciaran Hurst, and Martyn Clark. I also worked with Jeff Key on remote sensing and modeling (Key and Barry, 1989), through support from NASA's Climate Program (under R. Schiffer).

From 1986 to 1987, Konrad Steffen, from the Swiss Federal Institute of Technology (ETH), was a Visiting Fellow at CIRES, and through NASA support, stayed a second year working on polar remote sensing and validation of SSM/I sea ice products. In 1991, he was appointed to a faculty position in CIRES and the Department of Geography and this provided the necessary critical mass to establish a Cryospheric and Polar Processes Division at CIRES, for which I served as Associate Director from 1991 to 1998.

During the 1980s, several students completed dissertations independent of these main strands of funding support, but close to my interests in synoptic–dynamic climatology and cryospheric studies. These included Gerry Meehl and George Kiladis (tropical teleconnection studies), Leslie Tarleton (global blocking), Tim Brown (statistical analysis), John Newell (historical climatology of Labrador sea ice), and Susan Marshall and Mike Morassutti (snow cover modeling). Several of these students worked closely with other scientists in NOAA, NCAR, and University of Colorado departments.

Among the CIRES scientists was Carol Hahn, working with Steve Warren (University of Washington), and Professor Julius London of the Astrogeophysics Department. They collaborated on studies of global cloudiness from 1985 to 2001 (Warren et al., 1985). Around the same time, I worked on the rapid change in Arctic cloudiness in spring using DMSP optical images (Barry et al., 1987) and PhD student Jeff Key and I analyzed Arctic cloudiness using AVHRR data (Key and Barry, 1989).

8 International activities and links with China and Russia

In 1981, I joined Jack Ives on a trip to northwestern China, visiting Urumqi, Lanzhou, Glacier No. 1 in the Tien Shan, and the avalanche research station near Ining, Xinjiang. Gordon Young of Canada accompanied us, and our hosts were Qiu Jiachi (Urumqi), who had studied at the University of Colorado Mountain Research Station, Professor Shi Yafeng, Director of the Institute of Glaciology, Lanzhou, and Kang Ersi, also of the Institute of Glaciology. The visit encouraged China to establish a WDC for Glaciology in 1988, with which NSIDC has enjoyed a very fruitful collaboration.

Six Russian scientists made extended visits to NSIDC between 1986 and 2005 through the support of Fulbright Fellowships (Alexander Krenke, Olga Solomina, Tatiana Khromova, and Igor Zotikov), a NSF-NATO Fellowship (Svetlana Chudinova), and the CIRES Visiting Fellow program (Sergei Sokratov). Collaboration during these visits resulted in joint

publications on glaciers (Khromova et al., 2003; Solomina et al., 2004), snow cover (Sokratov and Barry, 2002) and frozen ground (Chudinova et al., 2006).

My various visits to Russia in the 1990s led to many joint data rescue projects facilitated by the US–Russian Bilateral Agreement for Cooperation on the Environment. The main projects involved the following institutions:

- the Institute of Geography at the Russian Academy of Sciences (RAS) in Moscow (Alexander Krenke and Lev Kitaev), and the Russian Hydrometeorological Data Center in Obninsk (Slava Razuvaev), for snow cover data, which led to important work on snow cover trends with Richard Armstrong at NSIDC;
- the Institute of Geography, RAS (Vladimir Kotlyakov), for glacier inventory data that fed into the Global Land Ice Measurement from Space (GLIMS) program with Hugh Kieffer at USGS Flagstaff and Bruce Raup at NSIDC;
- the Institute for Arctic and Antarctic Research in St. Petersburg (Ivan Frolov and Vasily Smolianitsky) for the Global Digital Sea Ice Data Bank (GDSIDB) established by the World Meteorological Organization;
- the Institute of Soil Science, RAS, in Pushchino (David Gilichinsky), for ground temperature data, which led to major collaborations with Tingjun Zhang at NSIDC;
- the State Hydrological Institute in St. Petersburg (Valeriy Vuglinsky), for river ice and precipitation data.

My visits to China relating to the World Data Center for Glaciology and Cryopedology in Lanzhou, China, also generated collaboration. I lectured for two weeks in Beijing, Lanzhou, and Shanghai in 1999, and in 2002 I traveled across the Tibetan Plateau to see the rail bed construction across the permafrost terrain. Chinese researchers have made reciprocal visits to NSIDC. The Chinese glacier inventory was made available to NSIDC.

9 Consolidation and expansion

In the late 1980s, Professor Emeritus Herbert Riehl of Colorado State University came to CIRES. I had read his work on tropical meteorology as an undergraduate. Building on his contacts at the Ministerio del Ambiente (MARNR) in Caracas, Venezuela, Roger Pulwarty and I undertook rainfall studies related to the effects of the Andes, funded by the NSF Geography Program. Figure 4 shows me in the paramo at Piedras Blancas near Merida. Rigoberto Andressen with the Universidad de los Andes (ULA) in Merida, Marta Mata (a former student of Riehl) with the Ministerio del Ambiente (MARNR) in Caracas, and the Venezuelan Air Force in Maracay assisted our research on precipitation and mountain climate (Pulwarty et al., 1992, 1998). ULA and MARNR attempted to establish a Centro de Estudios Avanzados del Clima Tropical (CEACT), but were limited by a lack of resources. Attempts to link the mountain interests of ULA and University of Colorado did not get off the ground. Nevertheless, I visited the Andes and the rain forest, and used the material in lectures and writing.

Figure 4. Roger on the paramo, Piedras Blancas, near Merida, Venezuela, June 1990.

In the 1990s, I supervised several students from the local scientific community, including Lauren Hay (through the USGS Water Resources program), Clark King (through the NOAA Environmental Research Laboratory), Dan Bedford (through the University of Colorado's Geography program) (Bedford and Barry, 1994), Andrew Tait (who worked with Richard Armstrong), Betsy Forrest, Jim Miller (who worked with Visiting Fellow Allan Frei), Geir Kvaran and Dave Korn (who worked with Ted Scambos). Their thesis and dissertation topics included mountain precipitation modeling, valley winds, glacier fluctuations in central Asia, snow cover remote sensing, weather hazards, snow cover in GCMs and remote sensing in Antarctica. My own work focused on climate change in mountains (Barry, 1990, 1992a, 2003, 2012)

and the cryosphere (Barry, 1992b, 2003, 2005b, 2009, 2014; Barry et al., 2007, 2011), and I collaborated with NSIDC colleagues, especially Mark Serreze on arctic circulation (Serreze and Barry, 2011), and Tingjun Zhang (Zhang et al., 2000, 2004) and post-doc Oliver Frauenfeld on frozen ground and the active layer. Ann Nolin was a research scientist at NSIDC from 1994 to 2002 and she collaborated with Julienne Stroeve (later at NSIDC) and Konrad Steffen in studies on the surface climate of Greenland.

In the late 1990s–2000s I directed graduate students in two new research directions. Shari (Fox) Gearheard studied Inuit traditional knowledge of climatic and environmental change, through my first Arctic Social Science grant from NSF (Weatherhead et al., 2010), while Anton Seimon worked on climate and environmental change in the high Andes of Peru (Barry and Seimon, 2000) (initially with National Geographic and other small grants and eventually through a NASA Fellowship). Later students Maria Tsukernik (working with Mark Serreze and me on Greenland cyclones), Eileen McKim (working with George Kiladis on the US Southwest Monsoon), and Matt Beedle (Yukon glaciers) followed this tradition of disciplinary diversity. Andrew Carleton and I completed *Synoptic and dynamic climatology* for Routledge. This accomplished a long-held ambition to synthesize progress in global climate dynamics and synoptic climatology for graduate students. It built on a course I had regularly taught and it also complemented Peixoto and Oort's text on *The physics of climate* (Peixoto and Oort, 1992).

10 Sabbaticals and research leaves

These leaves were varied in their foci depending on the interests of the institutions I was visiting. From 1975 to 1976, I took sabbatical leave with a faculty fellowship and spent six months at the Department of Biogeography and Geomorphology in the Research School for Pacific Studies at the Australian National University in Canberra. I worked on the rainfall climatology of New Guinea (Barry, 1978b) as there was no comprehensive study of the island, and the group of biogeographers I was working with were interested in its current vegetation and its post-glacial history. Also, during two weeks at Pindaunde (3480 m) in the Bismarck Range of Papua New Guinea, I undertook a field program on the energy budget and soil temperature conditions, which complemented Jeremy Smith's vegetation studies. I also wrote a chapter on the mountain climates of New Guinea for a book on the alpine ecology of the island edited by Peter van Royen, a botanist who I met in Honolulu (Barry, 1980). In Canberra I also outlined a book, *Mountain Weather and Climate*, which was published five years later and saw two subsequent editions (Barry, 1981, 2008) as well as Russian and Taiwanese translations. This was a synthesis of extensive work around the world that drew on Austrian research that led me into contact with Professor Franz Fliri in Innsbruck and Friedrich Lauscher at the meteorological institute in Vienna, and Swiss research by Atsumu Ohmura and Hans Turner in Zurich. In Boulder I had contact with Paul Julian on windstorms.

From March to April 1976, I held an Erskine Fellowship at Canterbury University in Christchurch, New Zealand, where I visited glaciers in the Southern Alps and met David Greenland, who later came to the Mountain Research Station at the University of Colorado.

In 1982, I received a J. S. Guggenheim Fellowship for study of historical snow and ice data. I made extended visits to several key centers: the Scott Polar Research Institute (through Terence Armstrong), the National Polar Research Institute in Tokyo (through Kou Kusunoki), and the Geographical Institute at the University of Bern (through Professor Bruno Messerli). The material I gathered formed the basis for several papers and served as a guide to subsequent data rescue studies.

In 1989 and 1990 I took sabbatical leave. I spent six weeks in Russia, mainly working at the Institute of Geography in Moscow in autumn 1989. I spent spring and summer of 1990 at the Institute of Geography at the Swiss Federal Institute of Technology (ETH) in Zurich, where I lectured on mountain weather and climate and was hosted by Atsumu Ohmura. I returned in 1997 to lecture (in German) on snow and ice and develop work on *Synoptic and Dynamic Climatology* (Barry and Carleton, 2001). In autumn 1994, I spent four months at the Alfred Wegener Institute in Bremerhaven, Germany, researching snow and sea ice albedo (Barry, 1996) in Peter Lemke's sea ice modeling group. I also visited the Climatic Research Unit at the University of East Anglia, UK, in spring 1997.

My next major leave was in spring 2001 at Moscow State University, where I lectured in Russian on snow and ice sponsored by a Fulbright Teaching Fellowship and was hosted by hydrologist Rudolf Klige and permafrost specialist Yuri Vasil'chuk. I attended a permafrost conference and also lectured at the Institute of Geography. In spring 2004, I spent three months on sabbatical at the Laboratoire de Glaciologie et Géophysique de l'Environnement (LGGE) in Grenoble, France, working on a review paper on glacier mass balance and recession (Barry, 2005b).

In 2009, taking up a suggestion by Deputy NSIDC Director Clark Judy, I contacted Dr. Ludwig Braun regarding the possibility of visiting the Glaciology Commission of the Bavarian Academy of Sciences in Munich. I was awarded a Humboldt Prize Fellowship by the German Humboldt Foundation, 1 of 28 that year and the only geophysicist. I spent May–November 2009, August–October 2010 and October 2011 in Munich. I completed writing *The global cryosphere: past, present and future* with Thian Y. Gan (Barry and Gan, 2011), a hydro-engineer from the University of Edmonton who had been a CIRES Visiting Fellow at NSIDC. My intention was to provide the first comprehensive discussion of all the elements of the cryosphere, their past history and predicted future shape. The text built on a gradu-

ate lecture course that I had regularly given at University of Colorado.

11 National and international committee activities

My first exposure to the National Research Council came through membership in the Glaciology Committee of the Polar Research Board from 1973 to 1977. I enjoyed the broad-reaching deliberations and the opportunities to meet leading scientists in related fields. Consequently, from 1985 to 1986, I served on the Committee on Arctic Integrated Ocean Information Systems of the Marine Board, and on the Glaciology Committee of the Polar Research Board ad hoc Panel on Remote Sensing of Snow and Ice from 1985 to 1987. From 1987 to 1991, I served as a member of the Polar Research Board (chaired by Gunter Weller). From 2003 to 2008, I served on the Committee on Climate Data Records from Operational Satellites.

Although I was involved in climate studies with the WMO in the 1970s, it was not until the 1980s that I became involved with sea ice mapping and coding through work on the Sea Ice Grid (SIGRID) code with Bill Markham at the Atmospheric Environment Service (AES) in Canada and Tommy Thompson at the Swedish Meteorological and Hydrological Institute (SMHI) in Sweden. This collaboration led to a working group on sea ice under the WMO Commission for Maritime Meteorology, and later to the establishment of a Global Digital Sea Ice Data Bank (GDSIDB). The group was formed at a meeting in St. Petersburg, Russia, in 1991, chaired by Ivan Frolov, the new director of the Arctic and Antarctic Research Institute (AARI). I attended the meeting, along with Vince Troisi. I also attended subsequent meetings in St. Petersburg, Copenhagen, Ottawa, Boulder, Hamburg and Geneva. Florence Fetterer also participated in the last three meetings. I also participated in the US–Russia Environmental Working Group Atlas Climatology project, designed to create an electronic arctic climate atlas covering oceanography, sea ice, and meteorology and climate. This project was inspired by Vice President Al Gore. NSIDC produced the last of these atlases on CD and on the Web (Environmental Working Group, 2000). I also participated in international meetings in Seattle and St. Petersburg on the sea ice atlas.

Major activities relating to permafrost (ground frozen over two summers) occupied me from 1988 to 2008. In 1988, I attended my first International Permafrost Conference in Trondheim, Norway, and presented the first paper ever on permafrost data (Barry, 1988) In 1989, the International Permafrost Association (IPA) Working Group on Permafrost Data was established. A series of workshops led to the development of the Global Geocryological Database (GGD). With the encouragement and support of Jerry Brown, we produced a CD of permafrost data, metadata, and map information, including significant Russian data. The Circumpolar Active Layer Permafrost System (CAPS) CD was prepared for the 1997 International Conference on Permafrost (ICOP) in Yellowknife, NWT, Canada, and we released CAPS-2 for the 2003 conference in Zurich, Switzerland.

In 1995, I joined the Terrestrial Observation Panel for Climate (TOPC), part of the Global Terrestrial Observing System (GTOS). The main task for TOPC was to define the essential climate variables for the land cryosphere (snow cover, glaciers, and frozen ground) and develop plans to implement improvements, such as the Global Terrestrial Network for Glaciers (GTN-G) and for Permafrost (GTN-P). The former activity became linked to the World Glacier Monitoring Service and the latter to the International Permafrost Association.

In 1994, I began participating in the World Climate Research Programme (WCRP). I attended the Arctic Climate System (ACSYS) Science Conference in Gothenburg, Sweden, and became a member of the ACSYS Scientific Steering Group (then chaired by Knut Aagard and later by Howard Cattle). The WCRP Joint Scientific Committee (JSC) was concerned about the lack of a focus on the role of the cryosphere in climate. In February 1997 in Cambridge, England, a group of experts met to review this topic and to recommend possible strategies to address it. They considered focusing on both bipolar and cold regions, but decided to aim for a global climate and cryosphere project (Barry, 1998). The JSC set up a task force under the ACSYS Scientific Steering Group (SSG) to develop a project plan, which the task force accomplished during two meetings, held in Utrecht and Grenoble (co-chaired by Ian Allison and myself), and through the advice and input of the SSG. In March 2000, the WCRP JSC established the Climate and Cryosphere (CliC) project, which ran concurrently with ACSYS, until that project ended in 2003. CliC has continued independently through the present. Ian Allison and I became co-vice chairs of the SSG in 2000, under chairman Howard Cattle succeeded by Barry Goodison and Greg Flato. The activities gave rise to a WCRP project called the Global Cryosphere Watch. A further cryospheric activity in 2002 was chairing a Task Force of W. Haeberli and J. O. Hagen for the International Commission of Snow and Ice (ICSI) and the International Permafrost Association (IPA) to prepare a proposal that the ICSI attain Association status within the International Union of Geophysics and Geodetics (IUGG) structure. This new Association of Cryospheric Sciences (IACS) was formally approved by the IUGG Council at the General Assembly in Perugia, Italy, in 2007.

I also contributed to the Intergovernmental Panel on Climate Change (IPCC) assessments in 1990, 1995, and 2001 on cryosphere and mountain climate topics, and was a review editor for Working Groups 1 (Chapter 4 on the cryosphere) and 2 (Chapter 15 on the polar regions) for 2007, the activity of which resulted in the group award of the Nobel Peace Prize to the IPCC. Providing a similar review input for the Arctic Climate Impact Assessment (ACIA) in 2005 was another valuable role for me.

Figure 5. Roger with colleagues and graduate students on the University of Colorado campus celebrating his award of the title Distinguished Professor. Back row: Rich Keen, Ray Bradley,Tim Brown, Fred McLaren, Mark Anderson, Gerry Meehl, Martin Clarke, George Kiladis, Jason Box, Greg Scharfen, Rich Cianflone, Richard Moritz, Ron Weaver, Ells Ledrew. Front row: Warren Washington, Henry Diaz, Eileen McKim, Andrew Carleton, Roger, Lesley Tarleton, Jeff Dozier, Roger Pulwarty, Lauren Hay, Atsumu Ohmura. Seated: Shari Gearheard, Andrea Ray, Maria Tsukernik, Natalya Barry.

12 "Retirement"

After retiring in December 2010, in February 2011 I was a lecturer on a small cruise ship the *Antarctic Dream* sailing from Ushuaia, Argentina, across the Drake Passage to the South Shetland Islands and the Antarctic Peninsula, a great experience. In April 2011 I taught a course on mountain weather and climate to graduate students at the Cold and Arid Regions Environmental and Engineering Research Institute (CAREERI) in Lanzhou, China.

In summer 2012, I applied for the position, and after the interview was appointed, as the Director of the International CLIVAR Project Office housed at the National Oceanography Centre in Southampton, UK, where I had begun my career 52 years earlier! CLIVAR (re-defined as Ocean and Climate Variability, Predictability and Change in 2013) is the largest of the WCRP's four projects. I supervised a staff of four in Southampton, one in Trieste, Italy, and one in Buenos Aires, Argentina. The position term was from late August 2012 to March 2014, when the Southampton office closed. I attended the annual meeting of the Scientific Steering Group held in Kiel in May 2013 and prepared reports. During that time my wife and I completed an introductory climatology text *Essentials of the Earth's climate system* (Barry and Hall-McKim, 2014; Barry, 2002). Serreze and Barry (2014) published the second edition of *The Arctic Climate System*.

13 Epilogue

Undoubtedly, my principal professional satisfactions include working with so many brilliant graduate students (see Fig. 5); communicating the basics of several areas of climatology to a wide audience via textbooks and lectures, and occasionally having the pleasure of someone saying, "I used your book"; making cryospheric data management a reality and establishing NSIDC as a worldwide resource.

So, where should we go from here? Climatology has become a "respectable" and respected discipline over the last two to three decades. The scope of climatology has broadened immensely, indicated by the growing number and range of dedicated journals, from essentially none in 1960 to around 10 currently. Scientists like Hubert Lamb, Murray Mitchell, and Reid Bryson played key roles in this, as did program leaders such as Alan Hecht and Gene Bierly at NSF, Joe Fletcher at NOAA-ERL, and Robert Schiffer

at NASA. The availability of gridded meteorological fields and remotely sensed data products has made climate research much easier. Also, advances in numerical modeling and computing power allowed scientists to apply GCMs to problems of global climate past, present, and future. Leaders like Warren Washington Jr. at the National Center for Atmospheric Research (NCAR), Larry Gates at Oregon State University (OSU), Syuke Manabe at the NOAA Geophysical Fluid Dynamics Laboratory (GFDL), and Jim Hansen at the Goddard Institute for Space Studies (GISS) also recognized the importance of interacting with the observational and paleoclimate communities.

Climate change is now receiving attention at the highest levels of government, with the Climate Change Science Program in the United States and the Framework Convention on Climate Change (FCCC) in the United Nations. A major driver was the First World Climate Conference in 1979 (in which Jill Jaeger played an important role) and the subsequent establishment of the World Climate Programme by WMO and ICSU in 1980. The most successful and active part of that has been the World Climate Research Programme (WCRP), with the Global Energy and Water Cycle Experiment (GEWEX), Climate Variability and Predictability (CLIVAR), ACSYS, and now CliC. Mark Serreze, Richard Armstrong, and myself (from NSIDC) and Konrad Steffen (from CIRES) were all involved in CliC.

Climate science is heading in new directions that include regional socioeconomic assessments, where Henry Diaz and Roger Pulwarty at NOAA have been active, and studies of Inuit Traditional Environmental Knowledge of climate change impacts in Nunavut, conducted by Shari Fox Gearheard. Scientists are also conducting comprehensive modeling and analysis of the integrated earth system (for instance, researchers in China are operating a 33-petaflop supercomputer, twice as fast as the next two in the USA!). As geographers, we know that most things on Earth are interrelated, and these interconnections merit our attention.

My messages to current “third-generation” students would be to

- persevere with what you consider to be important,
- continually retool your techniques,
- know who is doing what, not only in the English-speaking world, but internationally,
- network with others of the clan!

Appendix A: Student statistics

Between 1971 and 2011, Roger Barry supervised a total of 67 graduate students, 12 of whom were women. A total of 36 students received their PhD degrees, 31 received their master's degrees and 8 received both degrees at the University of Colorado. Seven students were from the United Kingdom, five from Canada and four from other Commonwealth countries. Two of the students had worked earlier with Ken Hare at University of Toronto, and some were second-generation students who studied under Ruth Chambers, Ray Bradley, John Jacobs and Ellsworth LeDrew.

Student career outcomes (based on 55 graduates to 2012)	
Associate/full professors, chairs, deans	18 %
Senior researcher in government laboratory	9 %
Senior researcher in academic institutes	11 %
Other teaching or research	36 %
Applied geography/GIS/remote sensing	9 %
Scientific/data management	7 %
Unrelated to degree/unknown	9 %

Appendix B: Personal information

Roger Barry received training at the following institutions.

Institution	Supervisor	Dates
University of Liverpool (BA hons)	S. Gregory	1954–1957
McGill University (MSc)	F. K. Hare (S. Orvig, B. W. Boville) J. D. Ives	1957–1959
University of Southampton, UK (PhD)	F. K. Hare (external examiner)	1965

Barry taught and conducted research at the University of Southampton, UK (from 1960 to 1968), and at the University of Colorado Department of Geography and INSTAAR/CIRES (from 1968 to December 2010).

Short-term appointments

Leverhulme Research Fellow	University of Liverpool	October 1959–August 1960
Research Scientist Geographical Branch	Department of Energy, Mines and Resources, Ottawa, Canada	1966 to 1967
Visiting Professor	Australian National University, Canberra	July–December 1975
Erskine Visiting Fellow	University of Canterbury, Christchurch, New Zealand	March–April 1976
Visiting Professor	Institute of Astronomy, Université catholique, Louvain-la-Neuve, Belgium	May 1980
Visiting Associate	Clare Hall, Cambridge (and Scott Polar Research Institute)	August–September 1982
Visiting Professor	Geographical Institute, University of Bern, Bern, Switzerland	May–June 1983
Hart Visiting Professor	Department of Geography, University of Sheffield, England	May 1986
Visiting Professor	Institute of Geography ETH, Zurich, Switzerland	April–August 1990
Visiting Scientist	Alfred Wegener Institute for Polar and Ocean Research, Bremerhaven, Germany	September–December 1994
Visiting Professor	Climate Research Unit, University of East Anglia, Norwich, UK	March 1997
Visiting Professor	Institute of Geography, ETH, Zurich, Switzerland	April–June 1997
Visiting Scientist	Laboratoire de Glaciologie et Géophysique de l'Environnement, Grenoble, France	June–August 2004
Humboldt Prize Fellow	Glaciology Commission, Bavarian Academy of Sciences, Munich, Germany	May–October 2009 and August–October 2010
Director	CLIVAR International Project Office, National Oceanography Centre, Southampton, UK	September 2012–March 2014

Honors

Fellow	Arctic Institute of North America, 1978
Fellow	American Geophysical Union, 1999
Fellow	Fulbright Teaching Fellowship, Geography Faculty, Dept. of Cryology, Moscow State University, Moscow, Russia, April–June 2001
Foreign Member	Russian Academy of Environmental Sciences (RAEN), 2001
Distinguished Professor	University of Colorado, 2004

Awards

Leverhulme Research Fellowship	University of Liverpool, 1959–1960
Faculty Fellowship	University of Colorado, 1975–1976
Erskine Visiting Fellow	University of Canterbury, Christchurch, New Zealand, March–April 1976
Honors Award	Association of American Geographers, 1986
Faculty Fellowship	University of Colorado, 1982–1983
J. S. Guggenheim Memorial Fellowship 1982–1983	
Lifetime Career Award	Climate Group, Assoc. Amer. Geographers, 2001
Lifetime Career Award	Mountain Specialty Group, Assoc. Amer. Geographers, 2002
Goldthwait Polar Medal	Byrd Polar Research Center, Ohio State University, 2006
Francois Emile Matthes Award	Cryospheric Specialty Group Assoc. Amer. Geographers, 2007
Founder's Medal	Royal Geographical Society, London, 2007
Member of the IPCC team that shared the 2007 Nobel Peace Prize	
Humboldt Prize award	Kommission für Glaziologie, Bavarian Acad. Sciences, Munich, May–November 2009, August–October 2010, September 2011

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References

Anderson, M. R., Crane, R. G., and Barry, R. G.: Characteristics of Arctic Ocean ice determined from SMMR data for 1979: Case studies in the seasonal sea ice zone, Adv. Space Res., 5, 257–261, 1985.

Andrews, J. T. and Barry, R. G.: Glacial inception and disintegration during the Last Glacial Maximum, Ann. Rev. Earth Sci., 6, 205–228, 1978.

Andrews, J. T., Barry, R. G., and Drapier, L.: An inventory of the present and past glacierization of Home Bay and Okoa Bay, east Baffin Island, N.W.T., and some climatic palaeoclimatic considerations, J. Glaciol., 9, 337–362, 1970.

Barry, R. G.: A synoptic climatology for Labrador-Ungava, Publication in Meteorology No. 17, Montreal, Arctic Meteorology Research Group, McGill University, 1959.

Barry, R. G.: The application of synoptic studies in palaeoclimatology, a case-study for Labrador-Ungava, Geograf. Annal., 42, 36–44, 1960a.

Barry, R. G.: A note on the synoptic climatology of Labrador-Ungava, Q. J. Roy. Meteorol. Soc., 86, 557–567, 1960b.

Barry, R. G.: The punched card and its application in geographical research, Erdkunde, 15, 140–142, 1961.

Barry, R. G.: Aspects of the synoptic climatology of central south England, Meteorological Magazine, 92, 300–308, 1963.

Barry, R. G.: Weather conditions at Tanquary Fiord, summer 1963, Operation Hazen Report No. 23., Defense Research Board of Canada, Ottawa, 1964a.

Barry, R. G.: Weather and climate, in: A survey of Southampton and its region, edited by: Monkhouse, F. J., British Association for the Advancement of Science and Southampton University Press, Southampton, 73–92, 1964b.

Barry, R. G.: Meteorological aspects of the glacial history of Labrador-Ungava with special reference to vapor transport, Geography Bulletin (Ottawa), 8, 319–340, 1966.

Barry, R. G.: Models in meteorology and climatology, in: Models in Geography, edited by: Haggett, P. and Chorley, R. J., 97–144, Methuen, London, 1967a.

Barry, R. G.: Variations in the content and transport of water vapor over northeastern North America during two winter seasons, Q. J. Roy. Meteorol. Soc., 93, 535–543, 1967b.

Barry, R. G.: Seasonal location of the Arctic Front over North America, Geography Bulletin, 9, 79–95, 1967c.

Barry, R. G.: The prospect for synoptic climatology: a case study, in: Liverpool Essays in Geography, edited by: Steel, R. W. and Lawton, R., Longmans, London, 85–106, 1967d.

Barry, R. G.: Meteorological field program, in: North-Central Baffin Island Field Report, 1967, Report Series No. 2, Ottawa, Inland Waters Branch, Department of Energy, Mines and Resources, 103–113, 1968.

Barry, R. G.: The conditions favoring glacierization and deglacierization in North America from a climatological viewpoint, Arctic Alpine Res., 5, 171–184, 1973a.

Barry, R. G.: A climatological transect on the east slope of the Front Range, Colorado, Arctic Alpine Res., 5, 89–110, 1973b.

Barry, R. G.: Cryospheric responses to a global temperature increase, in: Carbon Dioxide Climate and Society, edited by: Williams, J., Pergamon Press, Oxford, 169–180, 1978a.

Barry, R. G.: Aspects of the precipitation characteristics of the New Guinea mountains, J. Tropical Geogr., 47, 13–30, 1978b.

Barry, R. G.: Mountain climates of New Guinea, in: Alpine Flora of New Guinea, edited by: van Royen, P., Cramer, Braunschweig, 75–109, 1980.

Barry, R. G.: Mountain Weather and Climate, London, Methuen, Cambridge University Press, Cambridge, 311 pp., 3rd Edn., 1981.

Barry, R. G.: The cryosphere and climate change, in: Detection of CO_2-Induced Climatic Change, edited by: MacCracken, M. C. and Luther, F. M., Washington, DC, U.S. Dept. of Energy, DOE/ER-0235, 109–148, 1985.

Barry, R. G.: Permafrost data and information: status and needs, in: Permafrost: fifth international conference proceedings, vol. 1, edited by: Senneset, K., Tapir Publishers, Trondheim, Norway, 119–122, 1988.

Barry, R. G.: Changes in mountain climate and glacio-hydrological responses, Mountain Res. Develop., 10, 161–170, 1990.

Barry, R. G.: Observational evidence of changes in global snow and ice cover, in: Greenhouse gas-induced climatic change: a critical appraisal of simulations and observations, edited by: Schlesinger, M. E., Elsevier, Amsterdam, 329–345, 1991.

Barry, R. G.: The significance of global snow and ice cover for global change studies, GeoJournal, 27, 293–297, 1992a.

Barry, R. G.: Mountain climatology and past and potential future climatic changes in mountain regions: A review, Mountain Res. Develop., 12, 71–86, 1992b.

Barry, R. G.: The parameterization of surface albedo for sea ice and its snow cover, Progr. Phys. Geogr., 20, 61–77, 1996.

Barry, R. G. (Ed.): Organization of internationally-coordinated research into cryosphere and climate, in: Proceedings of a Meeting of Experts on Cryosphere and Climate, WCRP-102, WMO/TD No.867, World Meteorological Organization, Geneva, 1998.

Barry, R. G.: The role of snow and ice in the global climate system: A Review, Polar Geogr., 24, 235–246, 2002.

Barry, R. G.: Mountain cryospheric studies and the WCRP Climate and Cryosphere (CliC) Project, Special issue, J. Hydrol., 282, 177–181, 2003.

Barry, R. G.: Synoptic climatology, in: World Encyclopedia of Climatology, edited by: Oliver, J. E., Springer, Dordrecht, NL, 700–704, 2005a.

Barry, R. G.: The status of research on glaciers and global glacier recession: A Review, Progr. Phys. Geogr., 30, 285–306, 2005b.

Barry, R. G.: Mountain Weather and Climate, 3rd Edn., Cambridge University Press, Cambridge, 2008.

Barry, R. G.: Cryosphere models, in: Encyclopedia of Complexity and System Science, edited by: Meyers, R. A., Springer, Vol. 2, 1704–1718, 2009.

Barry, R. G.: Recent advances in mountain climate research, Theoret, Appl. Climatol., 110, 549–553, 2012.

Barry, R. G.: Cryosphere, measurements and application, in: Encyclopedia of Remote Sensing, edited by: Njoku, E. G., Springer, New York, 104–118, 2014.

Barry, R. G. and Carleton, A. M.: Synoptic and Dynamic Climatology, London, Routledge, 2001.
Barry, R. G. and Chambers, R. E.: A preliminary map of summer albedo over England and Wales, Q. J. Roy. Meteorol. Soc., 92, 543–548, 1966a.
Barry, R. G. and Chambers, R. E.: Variations of albedo in southern Hampshire and Dorset, Weather, 21, 60–65, 1966b.
Barry, R. G. and Chorley, R. J.: Atmosphere, Weather and Climate, Methuen London, 1968.
Barry, R. G. and Chorley, R. J.: Atmosphere, Weather and Climate, 9th Edn., Routledge, London, 2010.
Barry R. G. and Crane, R. G.: Inventory of data on snow cover and sea ice extent, in: Inventory of Snow Cover and Sea Ice Data, edited by: Crane, R. G., 1–3, Glaciological Data, Report GD-7. Boulder, CO, World Data Center-A for Glaciology, 1979.
Barry, R. G. and Fogarasi, S.: Climatology studies of Baffin Island, Northwest Territories, Inland Waters Branch, Technical Bulletin No. 13, Inland Waters Branch, Department of Energy, Mines and Resources, Ottawa, 1968.
Barry, R. G. and Gan, T. Y.: The Global Cryosphere: Past, Present and Future, Cambridge University Press, Cambridge, 2011.
Barry, R. G. and Hall-McKim, E. A.: Essemtials of the Earth's climate system, Cambrisge University Press, Cambridge, 259 pp., 2014.
Barry, R. G. and Jacobs, J. D.: Glaciological and meteorological studies on the Boas Glacier, Baffin Island, for two contrasting seasons, International Association of Hydrological Sciences Publication (Role of snow and ice in hydrology), 107, 371–382, 1973.
Barry, R. G. and Kiladis, G. N.: Climatic characteristics of Greenland, in: Climatic and Physical Characteristics of the Greenland Ice Sheet, Parts 1 and 2, edited by: Radok, U., Barry, R. G., Jenssen, D., Keen, R. A., Kiladis, G. N., and McInnes, B., CIRES, University of Colorado, Boulder, 1982.
Barry, R. G. and Perry, A. H.: Weather-type frequencies and the recent temperature fluctuation, Nature, 222, 463–464, and 226, p. 634, 1969.
Barry, R. G. and Perry, A. H.: Synoptic climatology: methods and applications, Methuen, London, 1973a.
Barry, R. G. and Perry, A. H.: Recent temperature changes due to changes in the frequency and average temperature of weather types over the British Isles, Meteorological Magazine, 102, 73–82, 1973b.
Barry, R. G. and Perry, A. H.: Synoptic climatology and its applications, Chapter 7, in: Synoptic and Dynamic Climatology, edited by: Barry, R. G. and Carleton, A. M., Routledge, London, 2001.
Barry, R. G. and Seimon, A.: Research for mountain area development: Climate fluctuations in the mountains of the Americas and their significance, Ambio, 29, 364–370, Corrigendum Ambio, 30, p. 69, 2000.
Barry, R. G., Andrews, J. T., Bradley, R. S., Miller, G. H., and Williams, L. D.: Past and present glaciological responses to climate in eastern Baffin Island, Quaternary Res., 3, 303–316, 1972a.
Barry, R. G., Williams, L. D., and Andrews, J. T.: Application of computed global radiation for areas of high relief, J. Appl. Meteorol., 11, 526–533, 1972b.
Barry, R. G., Andrews, J. T., and Mahaffy, M. A.: Continental ice sheets: conditions for growth, Science, 190, 179–181, 1975.
Barry, R. G., Hecht, A. D., Kutzbach, J. E., Sellers, W. D., Webb III, T., and Wright, P. B.: Climatic change, Rev. Geophys., 17, 1803–1813, 1979a.
Barry, R. G., Moritz, R. E., and Rogers, J. C.: The fast ice regimes of the Beaufort and Chukchi Sea coasts, Alaska, Cold Reg. Sci. Technol., 1, 129–152, 1979b.
Barry, R. G., Courtin, G. M., and Labine, C.: Tundra climates, in: Tundra Ecosystems: A Comparative Analysis, edited by: Bliss, L. C., Heal, A. W., and Moore, J., Cambridge University Press, Cambridge, 81–114, 1981.
Barry, R. G., Henderson-Sellers, A., and Shine, K.: Climate sensitivity and the marginal cryosphere, in: Climate Processes and Climate Sensitivity, edited by: Hansen, J. E. and Takashi, T., Amer. Geophys. Union, Geophys. Monograph, 29, 221–237, 1984.
Barry, R. G., Crane, R. G., Schweiger, A., and Newll, J.: Arctic cloudiness in spring from satellite imagery, J. Climatol., 7, 423–451, 1987.
Barry, R. G., Scharfen, G. R., Knowles, K. W., and Goodman, S. J.: Global distribution of lightning mapped for night-time visible band DMSP satellite data, Revue Generale d'Electricite, 6, 13–16, 1994.
Barry, R. G., Hanson, H. P., and Radok, U.: Atmospheric and oceanic research in CIRES: Atmospheric physics, cryospheric and polar processes and climate dynamics, in: CIRES, 1967–2002: Pioneering a Successful Partnership, edited by: Kisslinger, K., CIRES, Boulder, CO, 87–108, 2002.
Barry, R. G. (Lead Author), Armstrong, R., Callaghan, T., Cherry, J., Gearheard, S., Nolin, A., Russellm, D., and Zaeckler, C.: Snow, Chapter 4, Global Outlook for Ice and Snow, Earthprint, UNEP, Paris, 39–62, 2007.
Barry, R. G., Jania, J., and Birkenmajer, K.: Review article "A. B. Dobrowolski – the first cryospheric scientist – and the subsequent development of cryospheric science", Hist. Geo Space. Sci., 2, 75–79, doi:10.5194/hgss-2-75-2011, 2011.
Bedford, D. P. and Barry, R. G.: Glacier trends in the Caucasus, 1960s to 1980s, Phys. Geogr., 15, 414–424, 1994.
Bradley, R. S. and Barry, R. G.: Secular climatic fluctuations in southwestern Colorado, Mon. Weather Rev., 101, 264–270, 1973.
Bradley, R. S. and Barry, R. G.: Secular fluctuations of precipitation in the Rocky Mountain region, in: Proceedings of the WMO/IAMAP symposium on long-term climatic fluctuation, WMO Publication No. 421, World Meteorological Organization, Geneva, 215–222, 1975
Brinkmann, W. A. R.: Strong domwnslope winds at Boulder, Colorado, Mon. Weather Rev., 102, 596–602, 1974.
Brinkmann, W. A. R. and Barry, R. G.: Palaeoclimatological aspects of the synoptic climatology of Keewatin, Northwest Territories, Canada, Palaeogeogr. Palaeocl., 11, 87–91, 1972.
Carleton, A. M.: A synoptic climatology of satellite-observed extratropical cyclone activity for the Southern Hemisphere winter, Arch. Met. Geophys. Biolim., B27, 265–279, 1979.
Chudinova, S. M., Frauenfeld, O. W., Barry, R. G., Zhang, T.-J., and Sorokovikov, V. A.: Relationship between air and soil temperature trends and periodicities in the permafrost regions of Russia, J. Geophys. Res., 111, F02008, doi:10.1029/2005JF000342, 2006.

Crane, R. G.: Synoptic controls on the energy budget regime of an ablating fast ice surface, Arch. Met. Geophys. Bioklim., A28, 53–70, 1979.

Crane, R. G. and Barry, R. G.: The influence of clouds on climate with a focus on high latitude interactions, J. Climatol., 4, 71–93, 1984.

Crane, R. G., Barry, R. G., and Zwally, H. J.: Analysis of atmosphere- sea ice interactions in the Arctic Basin using ESMR microwave data, Int. J. Remote Sens., 3, 259–276, 1982.

Diaz, H. F., Barry, R. G., and Kiladis, G.: Climatic characteristics of Pike's Peak, Colorado (1874 to 1888) and comparisons with other Colorado stations, Mountain Res. Develop., 2, 359–357, 1982.

Dingman, S. L., Barry, R. G., Weller, G. Benson, C., LeDrew, E., and Goodwin, C.: An Arctic Ecosystem: the coastal Tundra at Barrow, Alaska, in: Climate, Snow Cover, Microclimate and Hydrology of the Arctic Coastal Plain, edited by: Brown, J., Miller, P. C., Tieszen, L. L., and Bunnell, F. L., Dowden, Hutchinson, and Ross, Stroudsburg, PA, 30–65, 1980.

Environmental Working Group (Fetterer, F. and Radionov, V. F., Eds.): Environmental Working Group Arctic Meteorology and Climate Atlas, National Snow and Ice Data Center,Boulder, Colorado USA, doi:10.7265/N5MS3QNJ, 2000.

Geiger, R.: Das Klima der bodennahen Luftschicht, Braunschweig, 1927.

Hecht, A. D., Barry, R. G., Fritts, H., Imbrie, J., Kutzbach, J. E., Mitchell, J. M., and Savin, S. M.: Paleoclimatic research: status and opportunities, Quaternary Res., 12, 6–17, 1979.

Ives, J. D. and Barry, R. G. (Eds): Arctic and Alpine Environments, Methuen, London, 1974.

Ives, J. D., Andrews, J. T., and Barry, R. G.: Growth and decay of the Laurentide ice sheet and comparisons with Fenno-Scandinavia, Naturwissenschaften, 62, 118–125, 1975.

Jacobs, J. D., Barry, R. G., and Weaver, R. L.: Fast ice characteristics with special reference to the eastern Canadian Arctic, Polar Record, 17, 521–536, 1975.

Key, J. R. and Barry, R. G.: Cloud cover analysis with Arctic AVHRR data: cloud detection, J. Geophys. Res., 94, 18521–18535, 1989.

Khromova, T. E., Dyurgerov, M. B., and Barry, R. G.: Late twentieth century changes in glacier extent in the Ak-Shirak Range, Central Asia, Determined from Historical Data and ASTER Imagery, Geophys. Res. Lett., 30, 1863, doi:10.1029/2003GL017233, 2003.

Kukla, G., Matthews, R. K., and Mitchell, J. M.: The end of the present Interglacial, Quaternary Res., 2, 261–269, 1972.

Lamb, H. H.: Types and spells of weather around the year in the British Isles: annual trends, seasonal structure of the year, singularities, Q. J. Roy. Meteorol. Soc., 76, 393–438, 1950.

Lamb, H. H.: Climate past, present and future, Vol. 2. Climatic history and the future, Methuen, London, 835 pp., 1977.

Lamb, P. J.: The climate revolution: A perspective, Climatic Change, 54, 1–9, 2002.

Landsberg, H.: Physical climatology, Pennsylvania State College, 1941.

LeDrew, E. F.: The Estimation of Clear Sky Atmospheric Emittance at High Altitudes, Arctic Alpine Res., 7, 227–236, 1975a.

LeDrew, E. F.: The Energy Balance of a Mid-Latitude Alpine Site During the Growing Season 1973, Arctic Alpine Res., 7, 301–314, 1975b.

LeDrew, E. F.: Eigenvector Analysis of the Vertical Velocity Field Over the Eastern Canadian Arctic, Mon. Weather Rev., 108, 1992–2005, 1980.

LeDrew, E. F.: The Dynamic Climatology of the Beaufort Sea – Laptev Sea Sector of the Polar Basin for the Summers of 1975 and 1976, J. Climatol., 3 335–359, 1983.

LeDrew, E. F. and Weller, G.: A Comparison of the Radiation and Energy Balance During the Growing Season of an Arctic and Alpine Tundra, Arctic Alpine Res., 10, 665–678, 1978.

Levick, R. B. M.: Mapping the weather, Weather, 10, plate after p. 12, 1955.

MacKinnon, P. K.: Ice cores, Glaciol. Data Report, GD-8., Boulder, CO: World Data Center-A for Glaciology, 139 pp., 1980.

Morris, R. E. and Barry, R. G.: Soil and air temperatures in a New Forest valley, Weather, 19, 325–331, 1963.

Meehl, G. A. and van Loon, H.: The seesaw in winter temperatures between Greenland and northern Europe, Part III: Teleconnections with lower latitudes, Mon. Weather Rev., 107, 1095–1106, 1979.

Moses, T., Kiladis, G. N., Diaz, H. F., and Barry, R. G.: Characteristics and frequency of reversals in mean sea level pressure in the North Atlantic sector and their relationship to long-term temperature trends, J. Climatol., 7, 13–30, 1987.

Peixoto, J. P. and Oort, A. H.: The physics of climate, Princeton University Press, Princeton, 520 pp., 1992.

Pulwarty, R. S., Barry, R. G., and Riehl, H.: Annual and seasonal patterns of rainfall variability over Venezuela, Erdkunde, 51, 273–289, 1992.

Pulwarty, R. S., Barry, R. G., Hurst, C. M., Selinger, K., and Mogollon, L. F.: Precipitation in the Venezuelan Andes in the context of regional climate, Meteorol. Atmos. Phys., 67, 217–238, 1998.

Radok, U., Barry, R. G., Jenssen, D., Keen, R. A., Kiladis, G. N., and McInnes, B.: Climatic and physical characteristics of the Greenland ice sheet, Parts 1 and 2, CIRES, Boulder, CO, 1982.

Schweiger, A. J., Armstrong, R., and Barry, R. G.: Snow cover parameter retrieval from various data sources in the Federal Republic of Germany using passive microwave data, in: Large-scale effects of seasonal snow cover, edited by: Goodison, B. E., Barry, R. G., and Dozier, J., International Association of Hydrological Sciences, Publ. No. 166, IAHS Press, Wallingford, Oxfordhire, 353–364, 1987.

Sellers, W. D.: Physical Climatology, University of Chicago Press, Chicago, 1965.

Serreze, M. C. and Barry, R. G.: Processes and impacts of Arctic amplification: A research synthesis. Global Planet. Change. 77. 85–96, 2011.

Serreze, M. C. and Barry, R. G.: The Arctic climate system, Cambridge University Press, Cambridge, 2014.

Sokratov, S. A. and Barry, R. G.: Intraseasonal variations in the thermoinsulation effect of snow cover on soil temperatures and energy balance, J. Geophys. Res., 107, 1–7, 2002.

Solomina, O., Barry, R., and Bodnya, M.: The retreat of Tien Shan glaciers (Kyrgyzstan) since the Little Ice Age estimated from aerial photographs, lichenometric and historical data, Geograf. Annal., 86A, 205–215, 2004.

van Loon, H. and Rogers, J. C.: The seesaw in winter temperatures between Greenland and northern Europe. Part I: General description, Mon. Weather Rev., 106, 296–310, 1978.

Warren, S., Hahn, C. J., and London, J.: Simultaneous occurrence of different cloud types, J. Clim. Appl. Met., 24, 658–667, 1985.

Weatherhead, E. C., Gearheard, S., and Barry, R. G.: Changes in weather persistence: insight from Inuit knowledge, Global Environ. Change, 20, 523–528, 2010.

Weaver, R. L., Jacobs, J. D., and Barry, R. G.: Fast ice studies in western Davis Strait, in: Third International Conference on Ports and Ocean Engineering Under Arctic Conditions, Vol. 1, 455–466, University of Alaska, Fairbanks, 1976.

Williams, J. and Barry, R. G.: Ice age experiments with the NCAR general circulation model, in: Climate of the Arctic, edited by: Weller, G. and Bowling, S. A., University of Alaska, Fairbanks, 163–169, 1975.

Williams, J., Barry, R. G., and Washington Jr., W. M.: Simulation of the atmospheric circulation using the NCAR Global Circulation Model with Ice Age boundary conditions, J. Appl. Meteorol., 13, 305–317, 1974.

Williams, L. D., Barry, R. G., and Andrews, J. T.: Application of computed global radiation for areas of high relief, J. Appl. Met., 11, 526–533, 1972.

WDC for Glaciology: Workshop on snow cover and sea ice data, Glaciological Data Report GD-5, World Data Center for Glaciology, Boulder, CO, 1979.

Yarnal, B.: Synoptic climatology in environmental analysis, Belhaven Press, London, 1993.

Zhang, T.-J., Heginbottom, J. A., Barry, R. G., and Brown, J.: Further statistics on the distribution of frozen ground and permafrost, Polar Geography, 24, 126–131, 2000.

Zhang, T.-J., Barry, R. G., and Armstrong, R. L.: Application of satellite remote sensing techniques to frozen ground studies, Polar Geography, 28, 163–196, 2004.