3

Stockholm

A Climate Science Node

July 2, 1957, was a bright summer day in Kiruna, a remote mining town in northernmost Sweden. Surrounded by low mountains full of rich veins of iron ore, Kiruna sits in the Swedish Arctic and in the heart of *Sápmi*, the homeland of the Sámi, a hunting and reindeer-herding Indigenous people.[1] On this particular day, an unusual set of high-ranking guests had gathered, linked by their connections to the International Geophysical Year 1957/58 (IGY) and to American security interests. Among those present was Lloyd V. Berkner, one of the IGY initiators, then vice president of the National Science Foundation (NSF). He was among a small group of scientists who had been present on April 5, 1950, when physicist James A. van Allen and his wife Abbie threw a dinner party in their suburban Washington, DC, home, where the idea of a third international polar year (IPY) was first voiced by Berkner.[2] The previous Polar Years were held in 1882/83 and 1932/33. The upcoming one was envisioned a quarter century ahead of schedule because the 1930s depression had

[1] The Sámi are a diverse Indigenous ethnic community in Sápmi, a wide transboundary area in northern Scandinavia, Finland, and North-Western Russia. Reindeer herding, emblematic of the image of Sámi, is the main preoccupation of only a minority of the Sámi in Sweden, most of whom live outside Sápmi and belong in families that may not have conducted reindeer herding at all. Lars Ivar Hansen & Bjørnar Olsen, *Hunters in Transition: An Outline of Early Sámi History* (Leiden: Brill, 2014).

[2] Alan A. Needell, "Lloyd Berkner and the International Geophysical Year Proposal in Context: With Some Comments on the Implications for the Comité Spéciale de l'Année Géophysique Internationale, CSAGI, Request for Launching Earth Orbiting Satellites," In: R. D. Launius, J. R. Fleming & D. H. DeVorkin, eds., *Globalizing Polar Science: Palgrave Studies in the History of Science and Technology* (New York: Palgrave Macmillan, 2010), 205.

shrouded so many efforts in the previous IPY, including those by the United States, but also because of the Cold War and the mounting security interests around the poles, especially the Arctic. Also present, both in Kiruna and at the Van Allen dinner, was J. Wallace Joyce, who headed the American IGY office at the NSF.

The reason the Americans had made the long trip was the launch of the Kiruna Geophysical Observatory (KGO). But since the eighteen-month IGY, starting July 1, 1957, and ending on December 31, 1958, to allow summer season fieldwork at both poles, had no official opening, the Kiruna event could be seen as an unofficial version with some of the leading lights present, with little fuss and few headlines. The Americans celebrated the successful start of a new and promising observatory that might contribute to the IGY and certainly was part of Sweden's IGY effort. They were also firmly involved in the new Swedish institute, regardless of the IGY. The NSF provided some of its basic instrumentation, and the US Air Research and Development Command funded much of the research during its first decade of operation. Indeed, for several years, US funding exceeded 50 percent of the funds. The Americans wanted the geographically well-placed Swedes to monitor the activities of Sputnik, as soon as it was launched in October 1957, and they received assistance in monitoring Soviet nuclear tests in a comprehensive research program.[3] On this special opening day, NSF also announced a 25,000-dollar donation to the new institute.[4]

The observatory was headed by Director Bengt Hultqvist, a young aspiring physicist, and news of it was published in top-level science journals.[5] On the first board of the Kiruna Observatory were the highest noblesse of Swedish physics, including plasma physicist Hannes Alfvén, later recipient of the 1970 Nobel Prize in Physics, and Rolf Sievert, a radiation specialist at the Karolinska Institute who had since the war years advocated a radiophysics institute in Lapland.[6] There were good

[3] Sverker Sörlin & Nina Wormbs, "Rockets and Reindeer: A Swedish Development Pair in a Northern Welfare Hinterland," In: Per Lundin, Johan Gribbe & Niklas Stenlås, eds., *Science for Welfare and Warfare: Technology and State Initiative in Cold War Sweden* (Sagamore Beach, MA: Science History Publications, 2010), 131–152, on 140–141.

[4] "Kiruna Geofysiska Observatorium embryo till ett vetenskapligt centrum i norr," *Norrbottens-Kuriren* July 3, 1957.

[5] Bengt Hultqvist, "The Kiruna Geophysical Observatory, Sweden," *Nature* 180(1957): 828–830; idem, "Swedish Geophysical Observatory," *Science*, 126(1957):3276, 691.

[6] Hans Weinberger, *Sievert: Enhet och mångfald: En biografi över den svenska radiofysikens, radiobiologins och strålskyddets grundare Rolf Sievert* (Uppsala: Almqvist & Wiksell, 1990); idem, "Physics in Uniform: The Swedish Institute of Military Physics,

scientific reasons for the Swedes to establish the Observatory. An Arctic location meant less polluted skies and optimal conditions to study solar wind and other solar phenomena, including the northern lights. No less tangible were the geopolitical circumstances prompting the Americans to be of assistance, adding yet another, and particularly well-placed, center in the vicinity of the Soviet Union, to their network of Cold War observation sites in Europe and beyond.[7] The Arctic was a hot zone in the Cold War, potentially a Theatre of War, should tensions between the superpowers spiral beyond control.[8]

Ironically, these were the crass geopolitical circumstances, when science, politics, and local elites met in modernist, peaceful, non-aligned *Folkhem* Sweden on July 2, 1957 – to host the event that can be seen, in retrospect, as the unrecognized opening of the IGY. To further emphasize the role of Kiruna as a temporary hothouse of IGY creativity, we may note that Lloyd Berkner in his Kiruna hotel room drafted a six-page handwritten letter inviting Stockholm glaciologist Hans W. Ahlmann, then President of the International Geographical Union, to take the lead in organizing the post-IGY organization of Antarctic science. The idea that took shape in Berkner's mind under the midnight sun in Kiruna was in essence an early blueprint of what would become the Antarctic Treaty regime of a continent "by and for science." Ahlmann responded with regret, however, that he was too busy to take on the challenge.[9]

A GEOPHYSICAL PLANET IS EMERGING

The IGY was one of the largest single, coordinated actions of science ever to take place. It mobilized sixty-seven nations and an estimated 60,000 scientists and staff in operations around the world that focused on establishing a comprehensive understanding of the entire geophysics of the planet: from the stratosphere and the ionosphere, down through the

1939–1945," In: Svante Lindqvist, ed. *Center on the Periphery* (Canton, MA: Science History Publications, 1993). Hans Weinberger, "Sievert, Rolf Maximilian," *Svenskt biografiskt lexikon*, 156(2003): 150–156.

[7] John Krige, *American Hegemony and the Postwar Reconstruction of Science in Europe* (Boston, MA: The MIT Press, 2006).

[8] Ronald Doel, "Constituting the Postwar Earth Sciences: The Military's Influence on the Environmental Sciences in the USA after 1945," *Social Studies of Science* 33(2003):5, 635–666.

[9] Lloyd V. Berkner to Hans W. Ahlmann, July 4, 1957, Ahlmann Collection, vol. 22, and Ahlmann to Berkner, July 13, 1957, Ahlmann Collection, vol. 20, both in Royal Swedish Academy of Science Archives, Stockholm [henceforth: KVA Archives].

atmosphere, and the oceans down to the sea floor. A major interest was the cryosphere, although that concept, coined already in 1923 by Polish scientist Antoni Dobrowalski, was not much in circulation.[10] Nor was the biosphere, Vladimir Vernadsky's 1925 invention, and comparatively little research was devoted to the life sciences during IGY.[11] Nevertheless, the IGY took the entire "environment," as the US military called it, under its command. Jacob Hamblin has called it "arming Mother Nature," and certain regions, such as the Arctic, mountain regions, and the tropics, became of particular strategic interest in this armament quest.[12] In retrospect, it can also be seen as an early effort to approach the entire planet not as a mere piece of stone in the universe but as an *elemental* property. The Earth consisting of fluids, fields, and forces that were held together as a gigantic system – or rather a system of systems, with a wide set of interacting temporalities of change[13] – that was fundamentally possible to study, understand, predict, and, perhaps, also manage, although that last aspect would turn out to be quite a challenge.

Sweden had already gained a certain reputation as a partner in geophysical research and it was no coincidence that the Americans chose Kiruna and Sweden as a point of departure for the IGY. Establishing the Geophysical Observatory was a logical step on the way of building a Swedish scientific superpower on the northern periphery. Sweden had remained neutral when her neighboring Norway and Denmark joined NATO in 1949, and, with Finland closer to the Soviet sphere, Swedish policy became to maintain the awkward middle space by building a military force that was big and strong enough to make an enemy attack if not impossible at least so costly that it wouldn't be worthwhile. This in turn required massive investment in relevant scientific research and

[10] Antoni Boleslaw Dobrowolski, *Historia naturalna lodu* [The Natural History of Ice] (Warsaw: Kasa Pomocy im. Dr. J. Mianowskiego, 1923), with a summary in French. R. G. Barry, J. Jania & K. Birkenmajer, "A. B. Dobrowolski – the First Cryospheric Scientist – and the Subsequent Development of Cryospheric Science," *History of Geo- and Space Sciences* 2(2011):1, 75–79.

[11] Vladimir Vernadsky, *La biosphere* (Paris: Librairie Félix Alcan, 1929), Russian orig. 1926. Engl. Transl. Vladimir I. Vernadsky, *The Biosphere*, ed. Mark McMenamin (New York: Copernicus, 1998).

[12] Jacob Darwin Hamblin, *Arming Mother Nature: The Birth of Catastrophic Environmentalism* (New York: Oxford University Press, 2013).

[13] Erik Isberg, "Multiple Temporalities in a New Geological Age: Revisiting Reinhart Koselleck's *Zeitschichten*." *Geschichte und Gesellschaft* 46(2020):4, 729–735. Sverker Sörlin & Erik Isberg, "Synchronizing Earthly Timescales: Ice, Pollen, and the Making of Proto-Anthropocene Knowledge in the North-Atlantic Region," *Annals of the American Association of Geographers* 111(2021):3, 717–728.

defense technologies. Geophysics was one of these relevant research areas, perhaps the largest of all, along with atomic research in the quest to develop Swedish nuclear weapons.[14]

Environment and climate, as terms, were hardly mentioned at all in Swedish defense and security planning in these years and they were not part of the language used in the context of the July 2 ceremony in Kiruna either. Still, the links to Sweden's emerging trajectory as a strong performer in these domains were there, however implicit. In this chapter, we will corroborate this perhaps mysterious statement. It means embarking on a history that will take us back some time in the Swedish geophysical and environmental field sciences, to periods when "environment" and "climate" were marginal and had not even acquired their modern understanding and significance. The year 1957 could be seen as a watershed year. Environment and climate were then already in the air, and not just there. Climate change, or rather the possibility of it, was a topic of concern in the IGY. It was part of the planning of IGY as a truly global enterprise, which spread as a "Big Science" model to other field sciences as well.[15]

President of the Swedish IGY committee was Carl-Gustaf Rossby, a world-leading meteorologist and a pioneer in atmospheric science. A key turning point came in August, the same year that Rossby died of a heart attack at age 58, only weeks after the Kiruna event. Leadership of the International Meteorological Institute (IMI) was passed to his PhD student and protégé Bert Bolin, who only a year after his PhD had to unexpectedly take up the legacy of his supervisor, assuming the chairmanship of the Meteorological Institute Rossby had started at Stockholm Högskola (from 1961 Stockholm University) and also the presidency of the Swedish IGY committee. Bolin went on to become one of the most

[14] Thomas Jonter, *Nuclear Weapons Research in Sweden: The Co-operation Between Civilian and Military Research, 1947–1972*, SKI Report 02:18 (Stockholm: Swedish Radiation Safety Authority, 2002). Jonter, "The Swedish Plans to Acquire Nuclear Weapons, 1945–1968: An Analysis of the Technical Preparations," *Science & Global Security* 18(2010):2, 61–86.

[15] Christy Collis & Klaus Dodds, "Assault on the Unknown: The Historical and Political Geographies of the International Geophysical Year," *Journal of Historical Geography* 34(2008):4, 555–567. Elena Aronova, Karen S. Baker & Naomi Oreskes, "Big Science and Big Data in Biology: From the International Geophysical Year through the International Biological Program to the Long Term Ecological Research (LTER) Network, 1957-Present," *Historical Studies in the Natural Sciences* 40(2010):2, 183–224. Goossen, "A Benchmark for the Environment." On IGY as a case of scientific internationalism, see Frank Greenaway, *Science International: A History of the International Council of Scientific Unions* (Cambridge: Cambridge University Press, 1996), 149–159.

influential climate scientists of the second half of the twentieth century and a respected science organizer and institution builder. A mere decade later, Bolin himself was one of the leading lights in climate change research, paving the way for the 1972 United Nations Conference of the environment in Stockholm. In 1988, he became the founding chairman of the UN Intergovernmental Panel on Climate Change (IPCC). Something had been cooking underneath the crass Cold War surface in Kiruna on July 2, 1957.

The focus of this chapter is on the institutional foundations of international climate science several decades before climate change became a major issue of international environmental politics. It centers on Stockholm University, where, at the turn of the twentieth century, Svante Arrhenius pursued pioneering work on the effects of carbon dioxide on global temperature, and the founding of the International Meteorological Institute by the internationally renowned Rossby in 1955. This followed Rossby's return to Sweden from the United States in 1947, and his initiative also in 1949, to establish the influential climate journal *Tellus*, originally published by the Swedish Geophysical Society and by IMI since 2007. Since its founding, and with dedicated funding from the Swedish government, IMI served to bring leading climate scientists to Stockholm for shorter and longer sabbaticals to share expertise and collaborate with Swedish colleagues. Together with *Tellus* – where seminal articles on the carbon dioxide theory of anthropogenic global warming were published[16] – IMI and its cadre of climate experts made Stockholm University a central node in the evolution of climate science.

This was a particularly important period of international scientific collaboration due to the 1957–1958 International Geophysical Year, during which Charles David Keeling began his tracking of atmospheric carbon dioxide concentrations. He, too, published early results in *Tellus*,[17] including what can be considered an early incarnation of the Keeling Curve, and continued his calculations during a sabbatical year at IMI in

[16] Gilbert N. Plass, "The Carbon Dioxide Theory of Climate Change," *Tellus* 8(1956):2, 140–154. Roger Revelle & Hans E. Suess, "Carbon Dioxide Exchange between Atmosphere and Ocean and the Question of an Increase of Atmospheric CO_2 during the Past Decades," *Tellus* 9(1957): 1, 18–27. Plass also published in more popular fora, such as *Scientific American* and his research hit major news media, for example, Waldemar Kaempffert, "Warmer Climate on the Earth May Be Due to More Carbon Dioxide in the Air," *New York Times*, October 28, 1956. www.nytimes.com/1956/10/28/archives/science-in-review-warmer-climate-on-the-earth-may-be-due-to-more.html.

[17] Charles David Keeling, "The Concentration and Isotopic Abundances of Carbon Dioxide in the Atmosphere," *Tellus* 12(1960):2, 200–203.

FIGURE 3.1 Netherlands-born Paul Crutzen, Nobel Laureate in Chemistry in 1995 for his work on the ozone hole, was essential in the formation of Stockholm into a global hub of environmental and climate science. He was employed by Stockholm University as a computer programmer in 1959 and wrote foundational papers from the year 2000 proposing the Anthropocene as a new geological epoch. Photo: Courtesy of the Archives of the Max Planck Society.

1961–1962, working together with Bolin. The late 1950s also included the incidental hiring of a certain Dutch civil engineer specializing in bridge construction, Paul Crutzen (Figure 3.1), who had been living in the central Swedish city of Gävle with his Finnish wife. Answering a newspaper ad for a computer programmer, Crutzen would become employed by the Meteorological Institute, where he also took courses and subsequently began his PhD training with Bert Bolin as his supervisor. During his time at Stockholm University, Crutzen would also contribute important early articles on stratospheric ozone depletion to *Ambio*, a journal based at the Royal Swedish Academy of Sciences for which he also served on the editorial board.[18] After graduating in 1973, Crutzen fairly rapidly became recognized as a world-leading atmospheric scientist. He was

[18] Ole John Nielsen & Merete Bilde, "Reflection on Two Ambio Papers by P. J. Crutzen on Ozone in the Upper Atmosphere," *Ambio* 50(2021):1, 40–43.

awarded a Nobel Prize in Chemistry in 1995 (co-explaining the thinning of the ozone layer) and launched on the global scene both the idea of "nuclear winter" (that he first termed "twilight at noon" in 1982) and "the Anthropocene" (in 2000).[19]

LINKING THREE CENTURIES OF STOCKHOLM CLIMATE CHANGE

In December 1956, Carl-Gustaf Rossby's portrait graced the cover of *Time Magazine*, and inside the writer did not mince words: "The history of modern meteorology is inescapably paralleled by Rossby's career."[20] This was at the time of the breakthrough for computerized weather forecasts, the beginning of the jet aircraft era, and the height of the Cold War, and Rossby had a role in all of them. To be heralded as the foremost expert in this field was remarkable, and the fact that it was, of course, an American perspective that was expressed in *Time* did nothing to diminish this because the United States at the time had achieved a world-leading position, in no small way thanks to this "likable, high-spirited, round-faced Swede." Most of the leading meteorologists in the United States and the world in the twentieth century were students or colleagues of Rossby (Figure 3.2), and he himself founded some of the world's foremost meteorological institutions at MIT and the University of Chicago. His own name lives on today in the term "Rossby waves" – the most powerful waves in the atmosphere, carrying jet stream energies in a regular circumpolar pattern from west to east – which he identified and co-developed a mathematical formula for. His name and career were also a main, yet little known, lead into the career of Sweden and Stockholm as a hub of environment and climate.

Born and bred in the province of Gotland, an island in the Baltic, Carl-Gustaf Rossby had been a student at Stockholm Högskola in the late 1910s, where he met Bergen meteorologist Vilhelm Bjerknes, former professor at the Högskola, who that year returned to hold a lecture. Rossby was mesmerized and started what was to become a long and meandering international career with Bjerknes at Bergen's vibrant meteorological institute, where the concept of the "Polar front" was invented,

[19] Paul J. Crutzen & John W. Birks, "The Atmosphere after a Nuclear War: *Twilight at Noon*," *Ambio* 11(1982):2–3, 114–125. Paul J. Crutzen & Eugene F. Stoermer, "The 'Anthropocene'," *Global Change Newsletter* 41(2000):17–18.

[20] "Man's Milieu," *Time* 68 (December 17, 1956): 68–79.

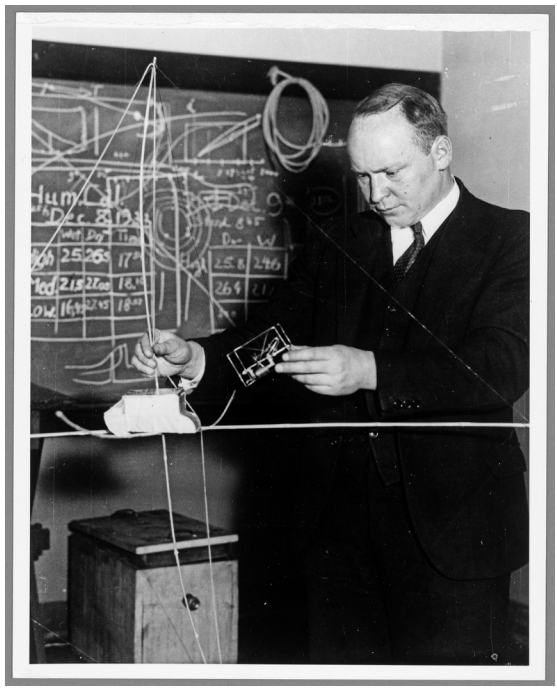

FIGURE 3.2 After a more than twenty-year long career in the United States, Carl-Gustaf Rossby returned to his native Sweden and did foundational work to establish an internationally leading climate science node in Stockholm. A pioneering advocate for the modern orthodoxy of carbon dioxide climate forcing, he was the quintessential science organizer. He also recruited Bert Bolin as his PhD student. Photo: Courtesy of the MIT Museum, Cambridge, Massachusetts.

a term Bjerknes had taken from the World War I trenches and applied to the behavioral patterns of the atmosphere.[21] Rossby threw himself into balloon experiments, storm predictions, and cartographic analysis – all the while losing himself in the kind of frenzy he demonstrated in every task he took on for the rest of his life. His innovations included assigning colors to the two types of fronts: blue for cold fronts and red for warm ones. He subsequently left for Germany where he worked at the Prussian *Aeronautisches Observatorium* in Lindenberg, close to Berlin, and in Leipzig where the Bjerknes school had good connections. Another stay

[21] Friedman, Robert Marc, *Appropriating the Weather: Vilhelm Bjerknes and the Construction of a Modern Meteorology* (Ithaca, NY: Cornell University Press, 1989).

in Bergen followed in summer 1922, when, before incredulous colleagues, Rossby tried to launch aerological balloon ascents of the type he had recently encountered in Germany. Returning to Stockholm, he started working as a meteorologist at the Swedish Meteorological and Hydrological Institute (SMHI). He participated in a series of scientific expeditions to the North Atlantic, where he gained firsthand experience with ice floes, a "witch's dance" around the vessel's hull, to the North Sea, and to Portugal and Madeira.[22] He gained his Licentiate degree in mathematics at Stockholm University in 1925 but, somewhat typical of his high-speed career, never completed his doctorate, although he found the mathematics he learnt very useful.[23]

The next stop was the US Weather Bureau in Washington, DC. When he left for the United States in 1925, he carried in his pocket a letter of recommendation signed by no less than Svante Arrhenius, Nobel Laureate in Chemistry in 1903 and by the 1920s hailed as an outstandingly broad thinking scientist with genius qualities. Arrhenius had been interested in climate change himself, suggesting in a famous article in 1896 that historic changes in climate may have caused the ice ages that had been so important for the Nordic countries. Climate change could, by implication, also explain the geographical features of Sweden, not least the fertile soils caused by postglacial seas covering land that rose as the several thousand-meter thick ice receded.[24]

Through his career that spanned almost forty years, Rossby as a person thus connects Bert Bolin, the IPCC, and the climate Nobel Peace Prize of 2007 – that went to Al Gore and Bolin and his IPCC

[22] Tor Kvinge, "The 'Conrad Holmboe's' Expedition to East Greenland Waters in 1923," *Årbok for Universitetet i Bergen* (1963).

[23] Biographical details in this and following paragraphs, see James Roger Fleming, *Inventing Atmospheric Science: Bjerknes, Rossby, Wexler, and the Foundations of Modern Meteorology* (Cambridge, MA: The MIT Press, 2016); H. R. Byers, "Carl-Gustaf Rossby, the Organizer," In: Bert Bolin, ed., *The Atmosphere and the Sea in Motion: Scientific Contributions to the Rossby Memorial Volume* (New York: Rockefeller Institute Press & Oxford University Press, 1959), 56–59. Sverker Sörlin, *Carl-Gustaf Rossby 1898–1957* (Stockholm: Royal Swedish Academy of Engineering Sciences, 2015).

[24] Svante Arrhenius, "On the Influence of Carbonic Acid in the Air upon the Temperature of the Ground," *The London, Edinburgh, and Dublin Philosophical Magazine and Journal of Science* 41(1896):251, 237–276. Sverker Sörlin, "Rituals and Resources of Natural History: The North and the Arctic in Swedish Scientific Nationalism," In: Michael T. Bravo & Sverker Sörlin, eds., *Narrating the Arctic: A Cultural History of Nordic Scientific Practices* (Canton, MA: Science History Publications, 2002), 73–122. Christer Nordlund, "'On Going up in the World': Nation, Region and the Land Elevation Debate in Sweden," *Annals of Science* 58(2001):1, 17–50.

colleagues – directly with Arrhenius and the formation of the Nobel Prize institution more than a century earlier. The Rossby–Arrhenius–Bolin atmospheric chain of brains also links climate science with the formation of Stockholm as an academic center. Arrhenius was for five years the President of Stockholm Högskola and was passionate about the capital as the center of a new kind of useful knowledge that he was convinced could only be forged in a major modern city.[25] He had been severely critiqued by his former colleagues at the University of Uppsala, then a small college town, where he received his PhD. He quickly left, or fled, Uppsala for his European *Wanderjahre* and never returned. Instead, he took up his new position in Stockholm with a fresh outlook and a regained sense of confidence. He would forever argue that science thrived in diverse urban centers, and that it was hindered in small, inward-looking college towns. This was a recurring debate in Sweden that intensified whenever examination and other academic rights were offered to new institutions, such as Stockholm Högskola, which received such rights in 1904, two years after the end of Arrhenius' presidency.[26]

TRANSNATIONAL CLIMATE CHANGE

Rossby, the prodigal son going west, was inspired by both sides of Arrhenius. The bold scientist who explained planetary climate change and ice ages and launched spectacular ideas of industrial use of fossil fuels, and the academic entrepreneur who believed in close collaboration between science and society. He left for the United States in a spirit not totally unlike that of Arrhenius when he had broken up from Uppsala, in disappointment of the ungenerous and narrow-minded attitudes of his colleagues. For Rossby, it became second nature to break up and start afresh. He left Bergen once his ideas were established there. He also left the SMHI, a bureaucracy, he thought, controlled more by

[25] Elisabeth T. Crawford, *Arrhenius: From Ionic Theory to the Greenhouse Effect* (Canton, MA: Science History Publications, 1995). Sverker Sörlin, "Arrhenius, Svante August," In: Noretta Koertge, ed. *New Dictionary of Scientific Biography*, vol. 1 (of 8) (New York: Charles Scribner's Sons, 2007), 111–113.

[26] Elisabeth Crawford, *The Beginnings of the Nobel Institution: The Science Prizes, 1901–1915* (Cambridge: Cambridge University Press, 1987). The argument would come up again in the interwar years when the KTH Royal Institute of Technology in Stockholm received the right to confer the doctoral degree, much to Uppsala's chagrain. Henrik Björk, *Teknikens art och teknikernas grad: Föreställningar om teknik, vetenskap och kultur speglade i debatterna kring en teknisk doktorsgrad, 1900–1927*. Stockholm papers in history and philosophy of technology (1992).

rules and routines than by imaginative new thinking. A fellowship from the newly started (1919) Sweden–America Foundation allowed him to spend part of 1926 at the US Weather Bureau, where he studied dynamic meteorology.

Rossby soon left the Weather Bureau as well, again disappointed, but also enticed by new prospects. In 1926, the Daniel Guggenheim Fund for the Promotion of Aeronautics announced that it intended to allocate USD 2.5 million for a program to promote education and research in aviation, "particularly in its use as a regular means of transportation of both goods and people." Aviation safety needed to be ensured. The same year federal legislation was prepared pertaining to airports, aeroplanes, and rules for air traffic and its supervision. It became clear that the aviation sector and the US Weather Bureau should work together. This led to contacts between the Guggenheim Fund and Rossby, whose ideas and enthusiasm made such a strong impression that the Fund employed him to run its newly formed aviation program. Military applications were in the picture from an early stage. Chemical engineer and naval lieutenant Francis W. Reichelderfer was an intermediary between Rossby and Guggenheim. Reichelderfer and Rossby were both members of the Guggenheim Interdepartmental Committee on Aeronautical Meteorology, which began its work in 1927. Other members were representatives for the military, the weather service, and the ministry of trade.

In the years that followed, intensive efforts were made to establish what would be called "aerial roads," in other words the air space equivalent of the motorways being built for rapidly expanding motor vehicle traffic. These flight corridors were based on the work of a network of weather observers in cooperation with airlines, telecommunications operators (to communicate weather information), and government authorities. California was selected as a test case, partly because there was a great need there, with the fast changes in weather where the Pacific met the Sierra Nevada mountain range, and partly because the Guggenheim Fund was at the time building up aeronautical engineering research capacity at the California Institute of Technology in Pasadena. Rossby was appointed to head the project, and in the unrestricted, experimental space of the Guggenheim Fund, with his natural leadership skills, his capacity for work, and his endearing, diplomatic disposition, he was able to thrive and his star rose quickly on the US meteorological firmament. The most important outcome of his fellowship period was something he had not planned on at all: for the first time, Rossby felt that he was

part of something where he could really play a role. He would stay for a year, but remained in the United States for more than twenty years, as an American citizen from 1939. He was essentially equal parts American and Swedish for the remainder of his life.[27]

Rossby became the golden boy of American meteorology, heading the US war effort in his field and serving as a close aid to the War Office, founding institutes first at MIT, then at Chicago, where hundreds of wartime meteorologists were trained.[28] Aerial and maritime warfare, but also nuclear weapons testing, drove demand for improved weather predictions in the US Navy and the US Air Force, and also by the atomic warfare authorities, including the Atomic Energy Commission.[29] Computers held out a promise that the enormous calculation work could be done by machines, and in the early days of the Cold War, Rossby was wooed to lead the Princeton Computer Project housed at the Institute for Advanced Study in Princeton, New Jersey. Insisting invitations came both from John von Neumann, the Hungarian born Cold Warrior mathematician, and J. Robert Oppenheimer, who headed the Institute.[30] Instead, in 1947, at the height of his career in the United States and with top security clearance in the Pentagon, where he continued to serve into the 1950s, Rossby suddenly returned to Sweden and Stockholm, where a new, remarkable career took off. One that would with time give him a crucial role in the critical early phase of Stockholm's rise as a site of global environmental governance. The move was blessed by the prime minister himself, Tage Erlander, a signal that able leadership of Swedish

[27] For Rossby's early years in the United States, see Fleming, *Inventing Atmospheric Science*.

[28] Douglas R. Allen, "The Genesis of Meteorology at the University of Chicago," *Bulletin of the American Meteorological Society* 82(2001):9, 1905–1910. Doel, "Constituting the Postwar Earth Sciences." Fleming, *Inventing Atmospheric Science*.

[29] Generally on the development of numerical meteorology in the United States in Kristine Harper, *Weather by the Numbers: The Genesis of Modern Meteorology* (Cambridge, MA: MIT Press, 2008), which also presents some of the key Scandinavian connections. More detail, not least on the latter, can be found in Kristine Harper, *Boundaries of Research: Civilian Leadership, Military Funding, and the International Network Surrounding the Development of Numerical Weather Prediction in the United States*, unpublished Ph.D. diss. (Corvallis, OR: Oregon State University, 2003).

[30] Jule Charney tells Rossby in a letter dated "Electronic Computer Project, Princeton New Jersey, March 16, 1949" that he had spoken to John von Neuman who was "immediately taken with the idea and expressed a desire to know more about the possibilities." Rossby collection, Stockholm Meteorological Institute Archives, Stockholm University. This may have been the first of what became a long string of invites and cajoles to Rossby. See multiple letters from von Neumann and Robert Oppenheimer from 1949 through 1953. Institute for Advanced Study Archives, Princeton, New Jersey.

Cold War meteorology was an issue at the highest political level.[31] Right after the most devastating war that the world had seen, this was a small but significant move to improve Swedish meteorology for times of peace and war. Nobody could imagine what the future would hold instead.

A COMPUTER IN STOCKHOLM

In the following years, Rossby gathered members of his large international network in the Swedish capital at the Meteorological Institute of Stockholm Högskola (later acronym: MISU), which he had founded in 1947 upon his return to Sweden. The natural born institution builder, Rossby, in 1955 established within MISU the International Meteorological Institute, which with government funding has since helped solidify Stockholm's standing as a hub for climate science by facilitating visits of top scientists for seminars, sabbaticals, and the exchange of ideas. His new journal, *Tellus*, was also published by MISU/IMI. In the United States, he had already founded the *Journal of Meteorology* (later changed to the *Journal of the Atmospheric Sciences*), which had quickly become a leading forum. *Tellus* was equally successful. In its very first year (1949), it published articles by some of the biggest names in meteorology from all around the world. Many papers in the early years were devoted to the intense work in both Stockholm and Princeton on numerical weather prediction by the likes of John von Neumann, and Rossby's Chicago protégé, Jule Charney. In the course of the 1950s, it was in *Tellus* that ground-breaking studies of the new emerging orthodoxy of *anthropogenic* climate change were published. Canada-born physicist Gilbert Plass, who was the first to scientifically re-establish the Arrhenius theory of the effect of carbon dioxide on global warming in a famous article in 1956, and Roger Revelle at Scripps were visiting scientists who published in the journal, along with a growing band of Rossby's own students and colleagues in Stockholm, including Bolin.[32]

[31] The Prime Minister also blessed the proposal for public funding of Rossby's IMI in 1951 (see later). Sverker Sörlin, "Narratives and Counter Narratives of Climate Change: North Atlantic Glaciology and Meteorology, ca 1930–1955," *Journal of Historical Geography* 35(2009):2, 237–255.

[32] Gilbert N. Plass, "The Carbon Dioxide Theory of Climatic Change," *Tellus* 8(1956):2, 140–154; Roger Revelle & Hans E. Suess, "Carbon Dioxide Exchange between Atmosphere and Ocean and the Question of an Increase of Atmospheric CO_2 during the Past Decades," *Tellus* 9(1957):1, 18–27, argued along similar lines, reinforcing the revival of Callendar's hypothesis. Bert Bolin, "On the Exchange of Carbon Dioxide between the Atmosphere and the Sea," *Tellus* 12(1960):3, 274–281.

In comparison with the big Princeton project, Stockholm may at first have seemed like a dead end, but in practice it was almost the opposite. The Swedes were determined to build their own computer, the so-called BESK, *Binär Elektronisk Sekvenskalkylator*, plans for which were fully known in Princeton, especially since the computer there, which took a full five years to complete, was used as a model for BESK.[33] The project found a home at the Royal Institute of Technology's former location on Drottninggatan in Stockholm's old "Latin Quarter," near the eighteenth-century Observatory on the top of a hill overlooking the entire city center of the rapidly growing Stockholm conurbation. One of the main stakeholders in Swedish computers was the Swedish Air Force, which had an interest in computer-based support for airplane construction at SAAB industries, but also hoped for better and automated forecasts. Rossby understood (even better now that the Princeton project had started) the enormous potential of computers and wrote to von Neumann to make sure that the Swedes traveling to the United States to learn about them would receive the best possible help. What he meant was of course that they would get what they needed to build a computer in Sweden. Erik Stemme was one of the several Swedes who went to the United States to learn more about computers. His destination was Princeton, and when he returned in 1950, he was assigned the task of developing BESK, which was put into operation in 1953.[34]

Meanwhile, Bert Bolin (Figure 3.3), then an Air Force meteorologist, also spent a year in the United States, 1950–1951, first in Chicago, then six months in Princeton with Charney. When Bolin was there, the computer was not sufficiently developed, so in order to test weather forecasts, the Princeton team had to go down to the US military base in Aberdeen, Maryland, where the already famous ENIAC computer, programmed by a group of women, was already in operation.[35] Bert Bolin acted as a bridge between the Air Force and Rossby's department at Stockholm University, where he became a research student and started

[33] A. Wiin-Nielsen, "The Birth of Numerical Weather Prediction," *Tellus A: Dynamic Meteorology and Oceanography* 43(1991):4, 36–52, on 46. Kristine Harper, *Weather and Climate: Decade by Decade* (New York: Facts on File, 2007), 109–110. Anders Persson, "Early Operational Numerical Weather Prediction Outside the USA: An Historical Introduction: Part 1: Internationalism and Engineering NWP in Sweden, 1952–69," *Meteorological Applications* 12(2005):2, 135–159.

[34] Bert Bolin, "Carl-Gustaf Rossby: The Stockholm Years, 1947–57," *Tellus A* 51(1999), 1: 9.

[35] Thomas Haigh, Mark Priestley & Crispin Rope, *ENIAC in Action: Making and Remaking the Modern Computer* (Cambridge, MA: MIT Press, 2016).

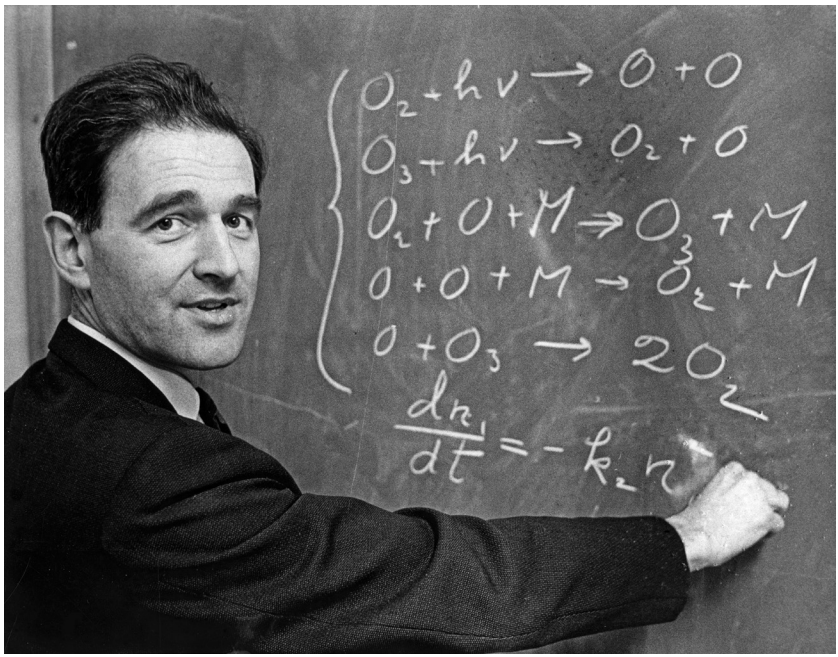

FIGURE 3.3 Bert Bolin early in his career. Trained as a meteorologist, Bolin became a PhD student of Carl-Gustaf Rossby in the late 1940s and succeeded him as leader of the Meteorological Institute on Rossby's death in 1957. Photo: Sam Stadener/Scanpix.

to teach. He was also essential in the daily operational leadership in the work on numerical weather predictions, especially since Rossby spent long periods every year in the United States.[36]

With Norman Phillips, who Rossby had met in Chicago, also joining the team, a project to determine how a computer could be used for weather forecasts supported by the Swedish Board of Computing Machinery (*Matematikmaskinnämnden*) was launched in the autumn of 1953. Phillips' role was to rewrite the code that existed for ENIAC for BESK.[37] Rossby's brother, Åke, also had a small role to play. The Swedish National Defence Radio Establishment (FRA), where Åke was bureau chief from the time the agency was established in 1942, was a big

[36] Wiin-Nielsen, "The Birth." Henning Rodhe, "Bert Bolin (1925–2007) – A World Leading Scientist and Science Organiser," *Tellus B: Chemical and Physical Meterology* 65(2013): 1, 1–9.

[37] Bolin, "Rossby," 9. Persson, "Early Operational Numerical Weather Prediction," 145.

stakeholder in a Swedish computing device, but, for reasons of secrecy, could not be at the forefront. The two brothers were, however, in touch with each other. Thus, early Swedish computer development was able to benefit from two Rossby brothers collaborating.

The weather project was an experimental workshop for what had been called the early mainframe computers' "elite users," that is, public authorities, researchers, and the military. They worked around the clock for two months as the autumn nights grew longer. Bert Bolin had described how the Swedish Air Force created weather maps that were sent by military couriers to the computer on Drottninggatan in Stockholm, where observational data was extracted and fed into the computer. The computer worked throughout the night, and early in the morning, the results were couriered back to the Air Force, which could then produce a weather forecast for the following day and two days ahead. This was autumn 1953, and it would take a year and a half before the Americans were able to produce their first forecast, in July 1955.

It could be regarded as a race between the BESK team and the Princeton team to see who would be first to generate computer-supported numerical forecasts. In reality, the opposite was the case; it was a close cooperation, led by Rossby and von Neumann and with large security policy interests in the balance. The two teams consisted of a long series of personal connections. The results and information were exchanged on an ongoing basis that was facilitated by Rossby serving as the common denominator for the projects, building relationships between individuals, groups, and authorities, and ultimately between nations, a diplomatic scientist role of a kind that his PhD student Bert Bolin would adopt and develop even further. Rossby himself, commuting between the two continents, had numerous opportunities to communicate information to the American side. The Americans thought highly of the BESK computer at KTH. It performed at least as well, if not better, than the one in Princeton.[38]

"A UNIQUE EXPERIMENT OF PLANETARY DIMENSIONS"

The meteorological world that was taking shape in the 1950s focused not only on civil aviation and military strategy needs. A world with a growing population and dramatically increasing consumption of

[38] Harper, *Boundaries of Research*, 419.

natural resources and energy was also a world in which the composition of the atmosphere was changing. In an article on "Current Problems in Meteorology" (1956/1959), Rossby took up the new lines for the science he had shaped in a fundamental way. The composition of air, not least "air pollution" as people were then starting to say, impacted both humans and their environment. This is also how Rossby was presented in the *Time Magazine* article in 1956, "Man's Milieu" – literally the same name as that of the Stockholm Conference, "The Human Environment" – for which he was the cover image.[39]

Rossby would not be Rossby if he had not, in his typical style, started to take an interest in entirely different problems at the same time. Air pollution was one of his interests. Several of his research colleagues in Stockholm had gathered data on the chemical composition of the atmosphere and it was clear that large quantities of acidifying substances were entering Swedish air space from Denmark, Germany, and the British Isles. Over the next few decades, this would be an important environmental issue – a term that in the mid-1950s was not yet used – and would lead to negotiations between the countries involved. Rossby was also interested in nitrogen and how it could be carried into the atmosphere affecting the nutritional content of the ground and water, leading to eutrophication. Immediate inspiration came from agricultural scientists in Sweden, but he had been sensitized to large-scale issues through work he was engaged in on the Dust Bowl, the erosion disaster that hit the American mid-west in the 1930s.[40]

There was also the related issue of climate. Could climate also change as a result of human impact on the composition of the atmosphere? The idea was not a new one. Theoretically, the greenhouse effect had been known about since the 1800s, but after Arrhenius' article in 1896, ideas about the impact of carbon dioxide were largely forgotten. The general conception for more than half a century had been that humans did not have the power to impact anything as large as the planet or its climate. Only a few voices expressed a different view. One belonged to the British engineer Guy Stewart Callendar, who in 1938 made detailed calculations of the Earth's increasing

[39] "Man's Milieu," *Time* 68 (December 17, 1956): 68–79. Sverker Sörlin & Maria Bohn, "Commentary on C. G. Rossby," In: Libby Robin, Sverker Sörlin & Paul Warde, eds., *The Future of Nature: Documents of Global Change* (New Haven, CT: Yale University Press, 2013), 451–153.

[40] His Dust Bowl work at MIT was supported by the US Department of Agriculture. See "Man's Milieu."

average temperature since the 1800s, and related them to human use of fossil fuels. Few, including meteorologists and atmospheric scientists, agreed with Callendar's ideas.[41] But in the first half of the 1950s, they started to circulate. Rossby did pay attention to them, and in his 1957 "Current Problems" article, he discussed Callendar's ideas, and his data, at length, including a diagram that showed the long-term increase of CO_2 content in the atmosphere.

He had already shown occasional signs of interest in the issue. One of his first PhD students, Chaim Pekeris, had been interested in the CO_2 problem as early as the 1930s. Rossby had also established contact with Finnish chemist Kurt Buch, who had been gathering data for many years on CO_2 uptake in the ocean and had found that amounts were constantly increasing. At the beginning of the 1950s, Buch contacted Rossby again and explained that he was thinking along the same lines as Callendar. Receptive and curious as always, Rossby picked up on the idea. He did not launch a comprehensive research program at first, but gradually allowed more space for the study of atmospheric chemistry in his department, including carbon dioxide. His department at Stockholm University took the initiative to build a Scandinavian network tasked, among other things, with measuring CO_2 levels in the air.[42] In that process, the Scandinavians learned a lot, especially that there were major differences between sites.

The obvious remedy, thought Rossby, was to find locations of measurement in the "free atmosphere," far from large concentrations of people and industry. He laid this out in his "Current Problems" piece: the Arctic, Antarctica, Andean mountain tops, and Pacific islands. He also said that such a "rather extensive observational program will be conducted during the International Geophysical Year."[43] As Chairman of the Swedish IGY Committee and with Bert Bolin as his secretary and right-hand man, Rossby made sure that CO_2 measurements were included in the Swedish program. On the completion of Bolin's PhD in 1956, he also advised his student to now turn his attention to

[41] James R. Fleming, *The Callendar Effect: The Life and Work of Guy Stewart Callendar (1898–1964)* (Boston: American Meteorological Society, 2007).

[42] Maria Bohn, "Concentrating on CO_2: The Scandinavian and Arctic Measurements," In: J. R. Fleming & Vladimir Jankovich, eds., *Osiris 26: Klima* (Chicago, IL: The University of Chicago Press, 2011), 165–179. See also, Stig Fonselius & Folke Koroleff, with a preface by Kurt Buch, "Microdetermination of CO_2 in the Air, with Current Data for Scandinavia," *Tellus* 7(1955):2, 258–265.

[43] Rossby, "Current Problems in Meteorology" (orig. in Swedish 1957), English transl., in Bolin, *The Atmosphere*, 9–50, on 15.

atmospheric chemistry and problems of pollution in the air, including "biogeochemical cycles," which to a large extent came to mean greenhouse gases.[44] Now things started to move swiftly. Already in 1959, Bolin published (with Erik Eriksson) a seminal article on "Changes in the carbon dioxide content of the atmosphere and sea due to fossil fuel combustion" in the large Rossby memorial volume that Bolin also edited.[45]

Rossby was directly involved in the discussions about where and how Charles David Keeling's measurements of greenhouse gases – an IGY project – should be pursued, just as he indicated in the "Current Problems" article.[46] Few contributions to climate change science have meant more than the iconic rising curve of CO_2 that Keeling's instrument has provided since 1958, when he first installed it at 3,200 meters above sea level on the top of the Mauna Loa mountain in Hawaii. Al Gore has reported in his film and book *An Inconvenient Truth* (2006) how he as a student at Harvard encountered the curve in Roger Revelle's science classes, and how he became mesmerized and convinced it had profound implications. The curve itself is probably also the single most important piece of evidence to demonstrate the anthropogenic element in rising CO_2 levels in the atmosphere. There is simply no other reasonable explanation available, and Mauna Loa has turned into what sociologist of science Thomas Gieryn has called a "truth spot," a site where evidence accumulates to underwrite a complex claim, which is not otherwise easily confirmed.[47]

It is also worth noting how this curve, with its seemingly unstoppable upward trend, put geophysics into the growing category of upwardly slanting curves that signified various forms of growth: economic, demographic, and social. These environmental visuals with time grew into a genre of their own, but not until the early 2000s were they assembled to demonstrate how they all hung together, not just chronologically, all moving rapidly upward from around 1950. But also causally in the sense that it became evident that it was the economic and social curves, reflecting the enormous rise in human activity, that drove the steep rise in environmental indicators. In 2004, the phenomena that the curves reflected

[44] Rodhe, "Bert Bolin," 2.

[45] Bert Bolin & Erik Eriksson, "Changes in the Carbon Dioxide Content of the Atmosphere and Sea Due to Fossil Fuel Combustion" in Bolin, *The Atmosphere*, 130–142.

[46] Correspondence between Rossby and Keeling in 1956 and 1957 in MISU archives.

[47] Thomas F. Gieryn, *Truth-spots: How Places Make People Believe* (Chicago: University of Chicago Press, 2018).

were given a name, "the Great Acceleration."[48] Among all these curves, the Keeling curve has been the most iconic.

In the Swedish IGY program, CO_2 measurements were made from a base on Spitsbergen. Several articles were published in *Tellus* presenting then current ideas about climate change, at a time when these were regarded as new and perceived by most people as wild guesswork. Rossby also refuted the more common idea of a new ice age. Hence, in the mid-1950s, which in this context was very early, he was on the side of those who kept an open mind about whether or not humans were responsible for large-scale climate change:

> It has been pointed out frequently that mankind is now performing a unique experiment of impressive planetary dimensions by now consuming during a few hundred years all the fossil fuel deposited during millions of years. The meteorological consequences of this experiment are as yet by no means clarified, but there is no doubt that an increase of carbon-dioxide content in the atmosphere would lead to an … increase of the mean temperature of the atmosphere.[49]

Thus spoke Rossby. His voice in *Time Magazine*, just like that of Greta Thunberg, on the cover of the same magazine 63 years later, drew on the widest possible international networks and could certainly be linked to the United States. The voice now came from Stockholm, an emerging global "truth spot" where a few people had started to believe in the emergence of a new, and perhaps very different human–Earth relationship.

ARRIVING AT THE RIGHT TIME

Rossby was in the middle of a workshop at his alma mater, Stockholm Högskola, when he died suddenly and unexpectedly of a heart attack on August 19, 1957. Restlessly active to the very end, he had just returned from yet another of his many trips to the United States. As a visionary, he was typically focused on the future and on opportunities, rather than

[48] Will Steffen, Angelina Sanderson, Peter Tyson, Jill Jäger, Pamela Matson, Berrien Moore III, Frank Oldfield, Katherine Richardson, John Schellnhuber, B. L. Turner II & Robert Wasson, *Global Change and the Earth System: A Planet under Pressure*, IGBP Book Series (Berlin, Heidelberg, New York: Springer, 2004). Robert Costanza, Lisa J. Graumlich & Will Steffen, eds., *Sustainability or Collapse? An Integrated History and Future of People on Earth*, Dahlem Workshop Report 96 (Cambridge, MA: MIT Press, 2007). Will Steffen, Wendy Broadgate, Lisa Deutsch, Owen Gaffney & Cornelia Ludwig, "The Trajectory of the Anthropocene: The Great Acceleration," *The Anthropocene Review* 2(2015):1, 81–98.

[49] Rossby, "Current Problems" (1959), 14.

what he had already achieved. As a research director, he had qualities that sociological research has identified as fundamental for successful research environments. He was charismatic, a visionary with a strategic focus and good relationships with funding sources, and a leader able to incentivize and generate enthusiasm for the projects he wanted to implement. Those around him felt as if they were taking part in something big and important.

He nurtured talent in research students, including Horace Byers from Berkeley who came to MIT, Jule Charney who received his PhD from the then less enticing meteorology environment at UCLA and was brought into Rossby's magic circle, and Bert Bolin who was the wise and multitalented meteorologist whom he could entrust with anything, knowing that he would always be useful. Their careers all followed a similar pattern. They met Rossby as a teacher or mentor, then, through dialogue or mutual understanding, adopted his research agenda and worked faithfully on it within the network. Rossby retained his leadership role through all turns in the road and regardless of the subsequent successes of the individual members of his network. In many ways, they outshone him in individual achievements, not least in mathematics or research methods. But there was never any doubt about which roles his collaborators had. Few of them seemed to question this arrangement, although some would occasionally find him hard to get into dialogue with, unsurprisingly given his frequent travel, extensive networks, and dense portfolio of activities. Similarly, Rossby was never envious; the more successful his acolytes, the better it was for him.

Personal qualities, however eminent, can only explain part of Rossby's significance. Another key explanation was that he was active in Stockholm – one of the research environments in the world where geophysical issues had long had a high status, and where links to Bergen and Bjerknes were already established. He was catapulted from the Nordic region out into the world and like a boomerang, he came back. The ties between the Nordic environments had been established since the end of the 1800s. Bjerknes' chair at Stockholm University was the most important one. They were strengthened after World War I by geographer and glaciologist Hans Ahlmann's work in Western Norway with Bergen as the base, and by Tor Bergeron, who became the Bergen School's unofficial emissar in Sweden.[50] It was Ahlmann who in a

[50] Tor Bergeron, "The Young Carl-Gustaf Rossby," In: *The Atmosphere and the Sea in Motion*, 51–55.

public inquiry with Uppsala professor Harald Norinder had first suggested that Rossby should be invited to return to Sweden.[51] He was also the one to first suggest that the Rossby family should be allowed to take over the Ahlmann family's flat at the top of the Observatory on "the Hill" when Ahlmann, since 1930 Professor of Geography at Stockholm University, became Ambassador to Oslo in 1950. The cupola overlooking the Swedish capital became their home until 1954.[52] Although its core activity was astronomy, Observation Hill in Stockholm had always been a site of climate- and weather-related science. It kept a temperature record from 1756 (in Sweden only preceded by a record from Uppsala since 1722) and during Ahlmann's time as the leading glaciologist and climate scientist in the country, Stockholm Högskola's Geography Department moved into the building in 1934. Civil weather services started to emerge in several countries during the second half of the 1800s, and what is now called the Swedish Meteorological and Hydrological Institute was instigated in 1873.

It was also a matter of timing. Rossby returned to Stockholm just as the very first phases of "the environment" were taking shape in the post-World War II years, with his first full year in Sweden, 1948, being the breakthrough moment for the new understanding of the concept.[53] He was a top US researcher with unique institutional resources and was recruited to come to Sweden to work in a field and during a period when Sweden and the United States had extensive security policy collaboration, and where Swedish research was also greatly motivated by military needs, especially when the technically advanced Swedish Air Force – in need of regularly updated and accurate weather forecasts – was expanding rapidly.

Rossby's visions were, perhaps paradoxically, easier to realize in Sweden, and in Stockholm, where he managed to assemble all the institutional, academic, and political networks that he needed into a small workable space of operation. As we have seen, the Prime Minister

[51] Their report, "Sakkunnige rörande organisationen av den meteorologiska forskningen och undervisningen" (1946), Riksarkivet/Swedish National Archives, SE/RA/321102, was submitted to the Department of Ecclesiastical affairs January 26, 1946. Further details in Sverker Sörlin, "Ice Diplomacy and Climate Change: Hans Ahlmann and the Quest for a Nordic Region beyond Borders," In: Sörlin, ed., *Science, Geopolitics and Culture in the Polar Region: Norden beyond Borders* (Farnham: Ashgate, 2013), 23–54, on 43–46.

[52] Personal information by Staffan Helmfrid, Ahlmann's student, later President of Stockholm University. Interviewed by Sverker Sörlin, February 22, 2011.

[53] Warde et al., *The Environment*, ch. 1.

seconded, and funded, his move from the United States to Stockholm and then his expansion to an international institute. The Air Force supported him, and the university employed him and hosted him. KTH and the Swedish state, through the Board of Computing Machinery, provided world-class computing capacity, and several public agencies and funding councils also stepped in. However, he would have gotten nowhere with his visions if the additional funding he needed could not be found in American military sources, which were not limited in their geographical distribution. From this massive institutional backing, just as much as from his personal charisma and creativity, rose the convening power that he then used skillfully. Rossby brought to Stockholm ever-growing networks of scientists from several countries – not just from the trans-Atlantic sphere but also from the developing world that was starting to rise after the partition of India in 1947 and the following decade.

He translated his visions to Stockholm and started a tradition to build Earth System science institutions on a grand scale. One of the early elements of such an evolution, *avant la lettre*, was Arrhenius' Nobel Institute, which then followed an orientation to nuclear physics with the Stockholm accelerator, just across the yard on the extended Stockholm University campus north of the city (now the main campus). Later would follow massive growth in the geosciences and in environmental science, and the neighboring Academy of Sciences would transform with the work of, among others, Bolin and his student in turn, the young Paul Crutzen. Decades later, the Stockholm Environment Institute was formed, followed by the Stockholm Resilience Center, the latter on the same campus.

In retrospect, this was all a legacy ultimately derived from Rossby. His passion and curiosity for the unknown included the entire Earth. What these non-linear forces had in store for us could ultimately not be figured out in the middle of the 1950s. There was an element of idealism and internationalism in his project. His vision was that it would serve the common good if there was more collaboration, as "an altruistic post-war idealistic idea, as a way for Sweden to extend its resources and influence." In the same spirit, he founded *Tellus*, as an explicit attempt to de-nationalize the circulation of ideas, hitherto separated into journals for the French and the British, and to mix Europeans with Americans.[54] In the 1956 issue of *Time Magazine* with Rossby on the cover, he concluded

[54] Persson, "Early Operational Numerical Weather Prediction," quote on 140.

by saying: "We should have a great deal of respect for the planet on which we live."[55] His words were prophetic in more than one sense: they inadvertently also heralded the forging of institutions in Stockholm to turn these words into deeds.

A PART OF "HIGHER DIPLOMACY"

One major question remains unanswered – why did Rossby return to Sweden at all? How should this remarkable start of what proved to be a central role for Sweden as a player in the emerging environmental and Earth system sciences be explained? It was certainly not planned. In the early post-war years, nobody could imagine what would come: the rise of "the environment," the understanding of anthropogenic climate change, and the entire idea that humanity must manage its relationship with "the planet" in entirely new ways. Zooming out, a broader view of the events leading up to the peak moment in the summer of 1957, we find that much is explained by institutions, and by path dependencies from earlier work that is taken up by individual system actors who can see opportunities and act boldly and convincingly.

In early 1945, when World War II was coming to an end, the Swedish Government commissioned Stockholm University geography professor Hans Ahlmann and Uppsala professor in atmospheric electricity Harald Norinder to explore how to strengthen meteorology in Sweden. These men would propose a new infrastructure involving new professorships, better education programs, and other necessary measures. One of the first measures proposed in their report was to contact Rossby. This happened even before there was time to consider anything else. Such was Rossby's status.

Such was also the status of meteorology. Ahlmann wrote to his friend Harald Ulrik Sverdrup, the Norwegian oceanographer who headed the Scripps Institution in La Jolla, California, in April 1945, that he considered the assignment to be part of "the higher diplomacy."[56] A statement which, at first glance, may seem strange – a simple, academic inquiry – if it wasn't already clear what significance atmospheric sciences and geophysics were beginning to have at that time. World War II had been a high-tech war with air and naval forces playing important roles, and it revealed the need for knowledge of what would soon be called "the

[55] "Man's Milieu," 79.
[56] Ahlmann to Sverdrup, April 12, 1945, Ahlmann Collection, KVA Archives, vol. 8.

environment" – the US armed forces were among the first to talk seriously about "the environment" in the modern sense.[57] Warfare had verticality, from the sea floor to the stratosphere; the atmosphere was key. The status of the most prominent experts in the field rose quickly. Sverdrup wrote to Ahlmann in October 1945 about how Vilhelm Bjerknes would be an obvious candidate for the Nobel Prize in Physics. "[W]eather forecasting has played an important part in winning the war." But even "men trained by him" had played a very significant role, claimed Sverdrup.[58] One of them was Rossby.

A main recommendation in the Ahlmann-Norinder report was to establish Rossby in Sweden and build a program with him at the helm.[59] A meeting was organized in Stockholm in January 1946 when Rossby met with Ahlmann and Norinder as well as Minister of Ecclesiastical Affairs, Tage Erlander. Another suggestion was to strengthen the meteorology program in Uppsala. This would change later on, partly because Rossby had more faith in locating his activities in Stockholm, where ties could be created with the weather service whose staff also needed to be trained. In Uppsala, the shift toward Stockholm was of course unpopular. A letter in the winter of 1946 confirms the fact that Ahlmann kept Rossby informed about the obstacles that existed in establishing the program at Stockholm University as well as SMHI, which was expecting the new meteorological capacity to be built up there.[60] Tage Erlander, on the other hand, was on board, both as Minister for Ecclesiastical Affairs when Rossby's professorship was granted and again in 1951 when, as Prime Minister, he supported Rossby's plans for a department of meteorology at the university with the diligent Lund physicist Torsten Gustafson, Erlander's trusted science advisor, providing the connection.[61]

Exactly how and when the idea of bringing Rossby back to Sweden first came about is unclear. There is evidence that Rossby had wanted to come back for some time.[62] Among other things, he wanted to apply for a position in Lund in the mid-1930s. In 1935, Jacob Bjerknes wrote to his Swedish colleague Tor Bergeron (who had spent a long time in Bergen)

[57] Doel, "Constituting the Postwar Earth Sciences."
[58] Sverdrup to Ahlmann, October 26, 1945. Ahlmann Collection, KVA Archives, vol. 19.
[59] Ahlmann and Norinder, Report to the Department of Education (January 1946).
[60] Ahlmann to Rossby, February 20, 1946, one undated (February 1946). Ahlmann Collection, KVA Archives, vol. 9.
[61] Tage Erlander, *Dagböcker 1950–1951*, ed. Sven Erlander (Stockholm: Gidlunds, 2001), on 310. Gustafson to Rossby, March 7, 1951. Rossby collection, MISU.
[62] Bolin, "Carl-Gustaf Rossby" (1999).

to say that Rossby was interested in the position as Director General of the Meteorological and Hydrological Service following Axel Wallén, who had once been Rossby's boss when he received his fellowship to go to the United States a decade earlier. How serious he was about this is hard to judge, but it is clear at least that he visited Sweden during several summers in the 1930s and on a few occasions Bergen as well. He arranged for his Stockholm relatives to visit him in Boston in the late 1930s. Whatever he felt during these years, his growing commitments and the new, tempting opportunities that always came in between made it difficult for him to leave the United States; and when the war broke out, it became impossible.

That Rossby and Ahlmann knew about each other was clear; they both had a strong connection to Bergen and both were renowned internationally in their fields. Ahlmann also had expertise in polar climate change, which proved to be important to the Americans during the war. He had already confirmed that warming was happening in the Arctic. At a lecture for the Swedish Society for Anthropology and Geography in March 1943, Ahlmann suggested that melting was also taking place in Antarctica, which would explain the rising sea levels that had been observed since the 1800s.[63] This lecture would be translated (we do not know exactly when) into English by Swedish-born Karin A. Gleim, who worked in Rossby's department in Chicago and was sent from there in February 1947 to Captain Howard Hutchinson at the Office of Naval Research (ONR). Everything to do with knowledge of ice and cold had gained strategic significance as the military plans for the Arctic entered a more intense phase during the Cold War.[64]

Another motive for Ahlmann could be that he saw the potential in a scientific collaboration with Rossby. Ahlmann, who was already convinced that climate change was happening on a large scale in the polar regions, needed the support of meteorological research to further his hypothesis, and Rossby could provide him with this. Rossby could also open doors for him in the US. There appeared to be a mutual interest. Rossby invited Ahlmann to a meeting attended by leading European climate scientists in

[63] Ahlmann, "Is och hav i Arktis" [Ice and Sea in the Arctic], *Kungl. Svenska Vetenskapsakademiens årsbok* 41(1943), 327–336.

[64] Doel, "Constituting the Postwar Earth Sciences." Janet Martin-Nielsen, "'An Orgy of Hypothesizing': The Construction of Glaciological Knowledge in Cold War America," In: Julia Hertzberg, Christian Kehrt & Franziska Toma & Julia Lajus, eds., *Ice and Snow in the Cold War* (New York: Berghahn, 2019), 69–88. Stephen Bocking & Daniel Heidt, eds., *Cold Science: Environmental Knowledge in the North American Arctic during the Cold War* (New York: Routledge, 2019).

Stockholm in 1948. This was a typical move by Rossby, one that would immediately give him a key role in his new position and place Stockholm meteorology on the map. Rossby, in turn, was kept informed by Ahlmann about the upcoming Norwegian–British–Swedish Antarctic Expedition (NBSX), and Rossby published an essay by Ahlmann in *Tellus* in which Ahlmann launched his plans. Rossby worked with Ahlmann's students in preparation of a Festschrift entitled *Glaciers and Climate* honoring their professor on his sixtieth birthday in November 1949.[65]

During the same period, in 1945–1946, when contacts with Rossby intensified, and by all accounts helped by these, Ahlmann forged his own relationships with leading figures in the military meteorological institutions in the United States, including the military. His request to be on board a US flight over Greenland was finally confirmed, after months of correspondence, by Colonel Dan Yates, who had a leading position in the Air Weather Service of the US Army and was part of Rossby's personal wartime network. Yates made flights available to him and at the same time took the opportunity to ask Ahlmann to inform him about the results of the visit.[66] Ahlmann's interest could have been motivated by the trip he made in the summer of 1945 to Leningrad and Moscow, where he obtained plausible information on the strong Soviet development in technology and science in the Arctic, with obvious military implications.[67] His interest in Soviet Arctic science, glaciology in particular, had always been strong, both linked to his connections in Bergen and to his own professional network, which now came in handy.[68]

After the war, and as the Soviet Union also had its own nuclear weapons from 1948, and when the United States started testing nuclear weapons at home in Nevada in 1950, scientific intelligence was becoming increasingly significant, not least in cold regions. It was clear that Rossby had maintained his contacts with those in political and military circles in the US, even after he moved back to Sweden. He was a member of the powerful Research Development Board and was directly involved during the legendary Vannevar Bush's leadership of strategic US research planning

[65] Letters from Rossby to Ahlmann February 7, March 4, and April 1, 1946, Ahlmann collection, vol. 19, KVA Archives.

[66] Yates to Ahlmann June 24, 1946, Ahlmann Collection, KVA Archives, vol. 19. For the full context, see Sörlin, "Ice Diplomacy," on 35–38, esp. footnote 43.

[67] Ahlmann reported on his Soviet trip, "Geographer in the Soviet Union," *Geographical Journal* 106(1945), 217–221. Sörlin, "Ice Diplomacy," 35–36.

[68] Julia Lajus & Sverker Sörlin, "Melting the Glacial Curtain: The Politics of Scandinavian-Soviet Networks in the Geophysical Field Sciences between Two Polar Years, 1932/33-1957/58," *Journal of Historical Geography* 44(2014), 44–59.

in the post-war years. Rossby's good connections came in handy when Ahlmann, in May and June 1947, went on an extended trip to the United States to lecture at some thirty universities and institutions around the country. During the trip, Ahlmann and Rossby visited the Pentagon, where Ahlmann held a lecture about the impact of climate change on the conditions for warfare in the Arctic. The conclusion was that the Americans needed to strengthen their ties with Swedish research, and that they should send officers and students to Stockholm. There were many indications that the planning for the US trip was the work of Rossby in cooperation with Harald Ulrik Sverdrup in La Jolla. It was Rossby's, and to some extent Sverdrup's, network of individual contacts and institutions that were visited and it was Rossby's questions, with a focus on the implications of the climate change studied by Ahlmann, that were on the agenda.

The contacts continued when Rossby came to Stockholm. He was part of an arrangement with the US Air Force's research department in Cambridge, Massachusetts, involving sending officers from there for advanced training in Stockholm. From 1947 up to the mid-1950s, there were always several US military personnel there at any given time. They were able to take the knowledge and methods they learned about back with them to the United States. Rossby also developed a proposal for the ONR in March 1949 about acting as a central "screening" venue for young, gifted meteorologists so that the best would be selected and enticed to the United States where they could be useful to the US Navy. The idea was based on the way things had worked at his international seminar in Chicago, where there was a strong inflow of foreign talent. Rossby now thought the same thing could happen in Stockholm, but with an emphasis on Europe and Great Britain. He created a budget for twenty "visitors" a year, each of whom would spend a couple of weeks in Stockholm. In other words, Rossby and his colleagues would separate the wheat from the chaff for the US Navy. "The weakest factor in any system of direct importation of scientific talent into the U.S.A. is the lack of real knowledge relative to the actual or potential capabilities of suggested or possible candidates." At the same time, he took it upon himself, with the help of his colleagues, to send reports, seminar papers, and other materials that could be of interest to the Americans. For this service, the ONR would pay USD 4,800 a year, which was equivalent to more than Rossby's full grant for his professorship, including "assistants and expenses" (a total of SEK 21,100).[69]

[69] Rossby collection. MISU archives, Stockholm University, Department of Meteorology. Thanks to PhD student Maria Bohn for identifying these documents.

Could the Americans gain anything from Rossby's move to Sweden? Regardless of the initial intentions, the answer was apparently yes. Although the United States had unparalleled research capacity domestically, they could not do everything on their own. At the same time, they needed access to all possible kinds of intelligence because their geopolitical role had gone global. The Scandinavian countries were already prominent in meteorology and climate research. Rossby knew it, and the United States knew it too. Ahlmann was the undisputed authority on polar climate change. The Scandinavians had also been outstanding in weather forecasting ever since the early days of the Bergen School. Under Rossby, Stockholm could be developed into a European center of excellence. This would be entirely in line with the official US post-war strategy, which, as historian John Krige has shown, was to allow various centers of excellence in Europe to work uninhibited but with financial support from US sources so that the Americans could get access to the results.[70] An American military man, Flight Lieutenant and meteorologist Philip D. Thompson, who was the first director of the computer project in Princeton in 1948–1949 and who had very good insight into research in both the United States and Europe, considered Rossby's Department of Meteorology in Stockholm to be a perfect "listening post" for meteorological intelligence.[71]

This is also how we can understand the sympathetic stand that the American military and research establishment took in relation to Sweden. Rossby, and other scientists working in a similar trans-Atlantic setting, gained considerable respect not only for the scientific quality of their work but also for their collaborative capacity. Rossby's MISU institute was soon to receive, through sometimes winding institutional roads, substantial funds from American military sources. The CIA's Office of Scientific Intelligence (OSI) had in its August 1949 report "The State of Science in Sweden" concluded that Swedish science was of a high standard and thus contributed to countering the earlier notion that neutral Sweden could be a threat to US ambitions.[72] The US Air Force also

[70] Krige, *American Hegemony*.

[71] Kristine C. Harper, "Research from the Boundary Layer: Civilian Leadership, Military Funding and the Development of Numerical Weather Prediction (1946–1955)," *Social Studies of Science* 33(2003):5, 667–696, on 686.

[72] Ronald E. Doel & Allan A. Needell, "Science, Scientists, and the CIA: Balancing International Ideals, National Needs, and Professional Opportunities," In: Rhodri Jeffreys-Jones & Christopher Andrew, eds., *Eternal Vigilance?: 50 Years of the CIA* (London & Portland, 1997), 70–71.

concluded that involvement, including funding, in Rossby's new institute in Stockholm would benefit the Princeton Project. The Princeton Project and the new program at MISU were thus essentially linked, institutionally and through their US military funding, and through a steady stream of military staff from the United States visiting Rossby's institute.[73]

Rossby mobilized military support in Sweden, connecting with the Air Force in particular.[74] In many organizational ways, the Swedish development resembled the American. In 1950, when the Swedes started building their own computer, which was crucial for the work on numerical weather predictions, the Swedish Air Force played an important role.[75] The military dimension of meteorology was both an everyday thing and somewhat of a red herring. First of all, neutral Sweden did in fact maintain clandestine links with the United States all throughout the Cold War to an extent that was not disclosed until public inquiries studied this in the 1990s (e.g., the Neutrality Commission).[76] Nonetheless, Rossby was cautious to make sure that the funds were "decontaminated" via a civilian institution, for example, the Woods Hole Oceanographic Institution.[77] Even after the demise of the idea of a Nordic Defense Union in the winter of 1949, when Denmark and Norway joined NATO, Norway and Sweden maintained their cooperation in selected areas of strategic interest. One of these areas was meteorology.[78]

[73] This paragraph and the following are based on Harper, *Boundaries of Research*, 299–300.

[74] Bert Bolin interview (Sörlin), June 2, 2005; Harper, *Boundaries of Research*. Sörlin, "Narratives," documents evidence of MISU funding from the Swedish Air Force as well as from the US Air Force and from the ONR.

[75] Per Lundin, ed., *Att arbeta med 1950-talets matematikmaskiner: Transkript av ett vittnesseminarium vid Tekniska museet i Stockholm den 12 september 2005* [Working with the Computing Machines of the 1950s: Transcript of a Witness Seminar] (Stockholm: Filosofi och teknikhistoria, 2006), 21–23. In his statement at the witness seminar, Bolin underscores the close cooperation with the Swedish Air Force, which provided funding and, perhaps more importantly, provided the necessary weather maps and staff for the drawing of maps and for tests of the computer-based models in regular prognostication activities. This statement is also corroborated by numerous documents in the Military Archives of Sweden (Stockholm), for example, a document dated March 1, 1956, regarding "running of BESK [acronym for the Swedish computer] during military training operation," ref. 25(578: 5). See also Germund Dahlquist, "Väderleksberäkningar på BESK" [Weather Computations on BESK], *Teknisk tidskrift*, 1955, 293–296.

[76] Thomas Jonter, "Det amerikanska spåret: En undersökning av IB:s bildande och eventuella kopplingar till USA," SOU 2002:95 *Forskarrapporter till Säkerhetstjänstkommissionen*, 135–191.

[77] Thompson to Chief, Atmospheric Analysis Laboratory, c. November 1953 (Thompson papers, Correspondence 1953–1954); see Harper, *Boundaries of Research*, 420.

[78] "Plan for coordination of military meteorological service" was one of five, out of a total of twelve, points in a memo from the Head of the Swedish Defence Staff

CONVENING AND CONVINCING – INSTITUTIONS AND NETWORKS

This brings the story back to where we started – in Kiruna on July 2, 1957, on the second day of the IGY. Another research environment that benefited from US military links was the Kiruna Geophysical Observatory KGO, founded in 1957 as part of the Swedish effort in the International Geophysical Year and renamed twice to become in 1987 the Swedish Institute for Space Physics (under the Swedish acronym IRF). The Institute was formed under the Swedish Academy of Sciences and was initially part of the Academy's network of northern research stations.[79] Public funding became available since the Institute was a centerpiece of Swedish IGY planning.[80] The Institute's first director Bengt Hultqvist at Stockholm Högskola prepared during his break between his PhD exam and his move to Kiruna by following Hannes Alfvén's seminars at KTH and by making an extended trip to the United States in the autumn of 1956. Among his stops was the Geophysical Institute in College, Alaska, near Fairbanks, and the Cambridge Air Force Research Center in Massachusetts, where Rossby had connections.[81]

In the following years, the Kiruna Institute undertook contract research for the US Air Force according to a constantly growing

[Försvarsstabschefen] that were approved by the Swedish Government and were also followed up by operational contacts in the following years. Memo, September 3, 1949, and details of coordination quoted by the Neutrality Commission, SOU 1994:11 *Had there been a war--: preparations for the reception of military assistance 1949–1969: Report of the Commission on Neutrality Policy*, chapter 6, and by Magnus Petersson, *"Brödrafolkens väl": Svensk-norska säkerhetspolitiska relationer 1949–1969* ["The Welfare of Our Sister Nation": Swedish Security Relations 1949–1969] (Stockholm: Santerus, 2003), 234–235. However, the politics of the weather-computing revolution were not easy, and the activities in Stockholm should not be equated with the political agenda on the American side, nor, in particular, the one represented by von Neumann, who was a zealous anti-Communist. Rossby seems rather to have fostered an internationalism that went far beyond the demarcation lines of the Cold War, a spirit that was to be continued in the department. Persson, "Early Operational Numerical Weather Prediction," on 140.

[79] These also comprised the Abisko research station, founded in 1906, the Tarfala station for glaciological research, founded in 1945, and a small observatory on the Pårte Mountain in the alpine area of Sarek.

[80] Bengt Hultqvist interview (Sörlin), March 13, 2007. Ingrid Sandahl, "Rymden" [Space], in *Kunskapsarena Norrland* [Knowledge Arena Norrland] (Umeå, 2007).

[81] Bengt Hultqvist, "Reserapport rörande studiebesök i U.S.A.," [Report from a Study Tour in the U.S.], Report to the Board of the Royal Swedish Academy of Sciences' Research Stations in northern Norrland, December 7, 1956, Mimeo, Institutet för rymdfysik [Archives of the Swedish Institute of Space Physics, hereafter IRF], Kiruna.

program on "HF- and VHF-Auroral zone propagation." The first quarterly report comprised the period October 15, 1957, to January 15, 1958, and reports were issued regularly until 1967, when the program ended. By and large, the Americans funded basic research, and they encouraged the publication of results in peer-reviewed journals. Nonetheless, they also secured, in Kiruna as at many other research sites in Europe, observations and data that were collected by their funded partners. The first equipment to be furnished by the Air Research and Development Command was delivered to Kiruna on January 13, 1958.[82] In 1958, after Sputnik, a new task was added to the program: to track satellites and provide data concerning the time for the closest approach, by telegraphic means, to the Space Group of the Air Force Cambridge Research Center, during the first days after the launch of a new satellite. Likewise, the Swedish Institute was to provide the American military with Doppler data of every new Sputnik "for ten days to two weeks," and the scientists in Kiruna delivered.[83] The obvious reason for the Americans to be interested in the Kiruna Institute was its geographical location, far north of the Arctic Circle and in the vicinity of Soviet territory. The close proximity to the northern Soviet Union also came in handy when the Americans wanted information on upper atmosphere effects of the nuclear weapons tests in Novaya Zemlya between September and November 1961 and Semipalatinsk in October 1962 (twice).[84]

The US military funds were crucial for the fledgling institute, which could probably do little but applaud the booster they received. In 1960, a full 55 percent of all funds at the Institute came from the US Air Force, in 1959 and 1961, the contribution was at 40 percent, and still in 1963, a third of the income came from the American military.[85] With increasing criticism of the United States in Swedish politics and the media, the Air Force program attracted negative attention.

[82] "Studies on HF- and VHF-Auroral zone propagation: Quarterly Technical Status Report No. 1, October 15, 1957–January 15, 1958," by Bengt Hultqvist, Contractor & Johannes Ortner PI., Contract No. AF 61(514)-1314, IRF Archives.

[83] *Quarterly Report*, January 5, 1959, on 8.

[84] Terence Elkins and Alv Egeland, *Ionospheric Effects Associated with Nuclear Weapon Tests July–December 1962*. Scientific Report KGO 63 2, March 1, 1963; B[engt] Hultqvist et al., *Report on Observations Made at Kiruna Geophysical Observatory during the Series of Nuclear Weapon Tests Carried Out at Novaja Zemlja between 10 Sept. and 4 Nov. 1961*, Scientific Report KGO 611, December 11, 1961.

[85] Swedish Institute for Space Physics, Report to the Space Commission [Synpunkter på rymdutredningen], memo, January 4, 1995, Table 6. IRF Archives.

Ultimately, it was also questioned by the Swedish Government and subsequently terminated in 1967. Thus closed a special Cold War chapter of science-politics relations between Sweden and the United States. However, as we have seen, another development was still only in an early phase at this point and had received a tremendous boost by the trans-Atlantic networks. The initial rise of Stockholm as a global environmental hub actually occurred as an effect of events taking place in Washington, DC, at MIT in Cambridge and the nearby Air Force base in Massachusetts, in Princeton, New Jersey, in Chicago, in Fairbanks, Alaska, and at the Scripps Institution in La Jolla, California. Not only in the United States, but also in Svalbard, Norway where some of the most essential Swedish research was conducted, and in Oslo, where some of the best mathematicians and physicists in the computer project were based, and in Kiruna, where the new geophysical observatory took shape. Rossby's world-leading hub of atmospheric science, with profound implications for environmental and climate knowledge, was a fermenting element. The work that took place there was evidence of a capacity to collaborate – connect, convene, conceptualize, and contribute to what was now becoming central developments in human–Earth understanding.

Nothing comes from nothing. There was already something, and that something already had a wide geography spatially and a wide reach conceptually. Yet, its energies were concentrated in Stockholm, and especially in a set of institutions and buildings scattered in available public buildings and lands on the northern edge of the city. This is where the Observatory was located, neighbor with university premises and a range of institutions, including the KTH Royal Institute of Technology's early buildings where the BESK computer was hosted. A step further away were both the new KTH campus, opened in 1917, and the Karolinska Institute, where Rolf Sievert had his laboratory. Yet another step in the same direction, along the tramline to the leafy northeastern suburbs, was an area formerly called *Vetenskapsstaden*, Science City. This is now where the Stockholm University campus is located, but its roots go back to the eighteenth century, when, on royal grounds, experimental agriculture was initiated. In the nineteenth century, the Experimental Field, as it was called, grew in size. In the early part of the twentieth century, both the Royal Swedish Academy of Sciences and the copious Museum of National History with all its collections and comprehensive research moved out from the city to be located here, as well as Svante Arrhenius' Nobel Laboratory of

Physical Chemistry.[86] In the 1960s and 1970s, most of the university followed, breaking up from its inner city addresses, where Rossby had worked on his return to Sweden and also had once been a mathematics and physics student. The Arrhenius Laboratory, the new home to the Stockholm University meteorologists, opened in 1973. Forces were coalescing to shape a center and these forces found a spatial manifestation in the form and planning of the city itself.

[86] On the spatial evolution of Stockholm science and scholarship, see Beckman, *Naturens palats* (1999), which discusses the notion of a Stockholm "Science City" external to the city center with references to London (Kensington) and Berlin (Dahlem; "ein deutsches Oxford"), 119–137, quote on 127; Fredric Bedoire & Per Thullberg, *Stockholms universitet 1878–1978* (Uppsala: Almqvist & Wiksell, 1978); Inga Elmqvist et al., eds., *Kunskapens kvarter: Husen runt Observatorielunden* [The Streets of Science: Houses around the Observatory] (Stockholm: Stadsbiblioteket, 2000); Julia Lindqvist, *Att bygga kunskapsstaden: En studie av högskolornas framväxt i Stockholm 1850–1960* [To Build a Scientific City: A Study of the Institution of Science in Stockholm 1850–1960] (Stockholm: KTH, 2008).