The following passage is excerpted from *Inventing Atmospheric Science: Bjerknes, Rossby, Wexler, and the Foundations of Modern Meteorology*, pages 52–59, by James Rodger Fleming (2016, MIT Press, 312 pp., hardbound, $31.00, ISBN 978-0-262-03394-7).

Anne Louise Beck

"U.C. Woman Will Study in Norway" reads a headline in the *Berkeley Daily Gazette* for August 4, 1920. A similar notice appeared in the new *Bulletin of the American Meteorological Society*. Thanks to a $1,000 competitive Mowinckel fellowship from the American-Scandinavian Foundation, Anne Louise Beck, a 1918 honors graduate of the University of California, was going to the new "weather college" in Bergen to study meteorology and oceanography for a year under professors Bjerknes and Helland-Hansen. Beck had work experience as an assistant in the Berkeley astronomy department, in the San Francisco office of the U.S. Weather Bureau, and as a high school mathematics instructor. She was enrolled in a master's degree program at Berkeley and was a star pupil in Burton M. Varney's geography course 121, Current Developments in Meteorology and Climatology, which emphasized readings, reports, and conferences on current matters in these sciences. It was here she likely learned about Bjerknes's work and the fellowship program. Beck set off on her adventure from New York on the Norwegian America liner *Bergensfjord* on August 27, 1920. She did not stay with the Bjerknes family. Advertisements running in the *Bergens Tidende* and several other papers announced that a "female American fellow to study this winter at the Geophysical Institute desires a centrally located furnished room, preferably with a full pension." Her early impressions of the program appeared in the *Bulletin of the American Meteorological Society*:

> The Bergen Geophysical Institute has two divisions. The A. division in charge of Professor Helland-Hansen carries on investigations in Oceanography both chemical and physical. We have a regular schedule of lectures Wednesday and Friday from 9.45 to 10.45 A.M. Later some laboratory practice is to be taken up supplemented by actual research and observations in the nearby fjords. These lectures I am to assist in editing for publication as a possible text in Oceanography.

Geophysical Institute B., the Meteorological Division, is in charge of Professor V. Bjerknes. A weather bureau, in connection with the Institute, forms a splendid laboratory. The staff of the weather bureau includes besides the Director, Mr. J. Bjerknes, now on a lecture tour to the southern countries of Europe, two Swedish meteorologists, Mr. E. Björkdal, Director Pro. Tem., Mr. C. G. Rossby, Mr. A. Tveten and a number of assistants. Mr. Tveten is especially concerned with the problem of the nucleus of condensation in raindrops and is daily making observations by pilot balloon for use in the forecasts and for the pilot of the passenger aeroplane from Bergen to Haugesund and Stavanger. Mr. Björkdal and Mr. Rossby are in charge of the weather forecasting.

A weather chart is prepared 3 times daily, at 8 A.M., at 2 P.M., and 7 P.M. There are three forecast districts, one for northern, one for western, and one for eastern Norway, the forecast centers being at Tromsö, Bergen and [K]ristiania, respectively.

An entirely different method of forecasting from that of the U.S. Weather Bureau is used by the Norwegian Service. Messrs. Solberg, J. Bjerknes, and Bergeron, at the Bergen Institute have developed the theory that the phenomena of the weather of the Northern Hemisphere are largely dependent upon the surface of junction of polar and equatorial air. This line of discontinuity can be detected at the earth's surface by conditions of temperature, pressure, hourly pressure change, wind direction and force, humidity and visibility. The line of discontinuity passes through the centers of cyclones connecting the center of one with those of the preceding and succeeding cyclones. The polar air at the surface is identified as being cold, dry, very transparent, usually blowing from [a westerly] point, while the air identified as equatorial is warm, moist, with poor visibility, and blows from a [southerly] point.

The polar front of each cyclone or surface of demarcation of these two air types is divided into a steering surface and a squall surface. The Bergen weather bureau associates most of the phenomena of cyclones with different parts of the polar front, and in particular on all synoptic charts set out definite rain areas in connection with the two surfaces which meet in the cyclonic center. The forecasts are built almost entirely on the movement of these surfaces.

No formal lectures have as yet been given in Meteorology at Geophysical Institute B., but Professor Bjerknes has promised to give some mathematical

treatment of the problem in the very near future. Before Mr. J. Bjerknes left on his southern trip, several informal discussions of the Bergen Theory had been given.

So far you may be glad to note I have had no difficulties because I could not speak or understand the Norwegian language. Many people speak English fluently and all are willing to practice it whenever an opportunity presents itself.

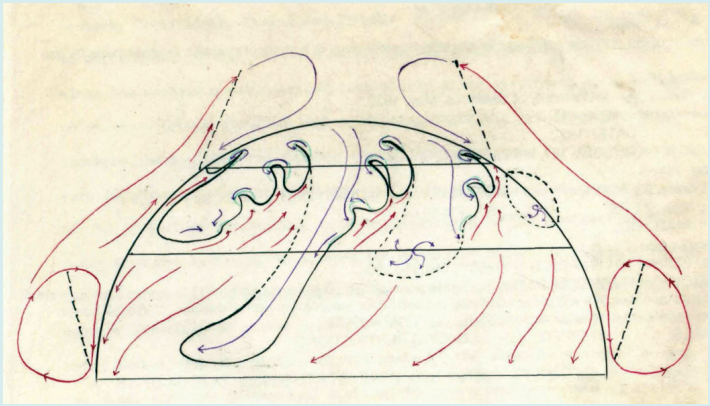

Figure 2.6. A Bergen school view of the general circulation of the Northern Hemisphere, as drawn by Anne Louise Beck [...]

Beck returned to the United States on June 6, 1921, on the steamer *Bergensfjord*, her head full of Bergen school theory and her trunk stuffed with weather maps and charts. She stopped in Washington, DC, to visit Weather Bureau director Charles F. Marvin, who had been a referee the previous year for the fellowship competition. Marvin expressed great interest in her work and, at the end of their conversation, offered her a position at Weather Bureau headquarters. She regretfully declined his offer because it was too far from her home in California. After returning to Berkeley, Beck wrote to Professor and Mrs. Bjerknes informing them that she had been awarded a fellowship in astronomy and was teaching six classes each week but had not yet decided between astronomy and geography for her master's work. Professor Varney advised her to write about the meteorological work in Bergen, which she did. Beck completed her MA in geography at Berkeley in 1922, submitting as a thesis "An Application of the Principles of Bjerknes' Dynamic Meteorology in a Study of Synoptic Weather Maps for the United States."

Her article in the *Monthly Weather Review*, derived from the thesis, presented a summary of the dynamics of the circular vortex with applications to what Bjerknes had called the "planetary vortex" in Earth's atmosphere. She had helped Bjerknes prepare the text of his 1921 paper, "On the Dynamics of the Circular Vortex with Applications to the Atmosphere and Atmospheric Vortex and Wave Motions," during her fellowship year, a paper Carl Ludvig Godske called "perhaps the most fundamental and also the most elegant and inspiring paper Bjerknes has ever written." This was in no small measure due to Anne's editorial input, and she knew the theory quite well. She explained how general hydrodynamic considerations led to the practical notions of the polar front and to families of cyclones propagating along it. She also prepared a sketch of the general circulation that linked cyclone families with larger planetary flows (figure 2.6).

She was well schooled in the history of ideas, giving proper credit to Dove's theory of the struggle between equatorial and polar currents, Helmholtz's work on the formation of a surface of discontinuity between cold polar air and warm equatorial air, and the cyclone models of Mohn, Margules, and Shaw.

Beck's references to colloquial terms are colorful and undoubtedly reflect the language used during informal discussions in the Geophysical Institute to describe new phenomena. For example, she refers to the cold circumpolar vortex as the "polar calotte" or cap, cold air pressing southward as a "spreading cold tongue," nascent waves on the polar front as spiral-formed "breakers," and the three vertical cells of the general circulation as "running like cogged wheels." Following Bergeron, she called the cyclone stage, when the cold front just overtakes the warm sector, a "seclusia" and the final stage, when the warm front is completely overtaken by the cold, an "occlusia." Summertime showery weather was referred to as "amoeba" cyclones. In discussing families of cyclones, the first wave of a new series was jestingly called "Protesilaos," the Homeric hero who returned from the dead. She recommended, as had Bjerknes, that in the future, wind directions should be recorded in more than eight compass points to help with the identification of fronts, that systematic cloud observations should be taken to document frontal passages, and most important, in agreement with Bjerknes, that some 4,500 telegraphic stations should be established across America to match the density of the ninety or so in Norway.

Beck prepared maps using Bergen techniques to analyze U.S. weather observations for the thirty-one days of January 1921. Her analysis for the first

day of January appears in figure 2.7a. In the opinion of meteorologist Lou McNally, Beck's understanding and use of the Bergen school wave-cyclone model and the procedures for identifying the polar front on a synoptic surface map placed her "at the cutting-edge of forecast theory and application." Although she was confronted by vast regions with sparse data and stations with poor observations, the discrete steps Beck learned in Bergen for identifying fronts helped her overcome these lacunae, producing a viable analysis. It was a completely different story when Beck sent the maps to the *Monthly Weather Review*. Only the map for January 1 was published and only after heavy-handed redrawing by the editor, A. J. Henry, rendering the original cold front unrecognizable and adding an unsupportable arrow indicating warm-air advection (figure 2.7b). Citing space limitations, Henry did not publish Beck's detailed discussion of the groups of cyclones that crossed the United States in January 1921. He suggested that interested readers could view them in the Weather Bureau library, where the originals "are available to students and others who may wish to consult them." They are not there; they were misplaced. Henry also criticized the idea that the United States could afford to establish and staff 4,500 weather stations; at the time they had only 200. He also believed that the Bureau could not possibly analyze the data from that many stations rapidly enough to issue timely forecasts. Weather Bureau resistance to Bergen school methods was fueled by these perceived limitations, by significant geographic differences between the two nations, by the entrenched Washington forecasting bureaucracy, and by the notion that Norway was in no position to tell the United States what to do.

Further details about Anne Louise Beck are hard to come by. She taught high school in Santa Rosa, California, for several years before joining the faculty of Santa Rosa Junior College in 1929, the year the college gained its independence from the high school. She initially taught astronomy and mathematics and later geography. Her course on meteorology was described in the catalog as "Atmospheric changes that determine weather conditions; development of weather observations into climatologic data." The students received a thorough introduction to the subject. She taught courses in art, her hobby, and advised the campus honor society Alpha Gamma Sigma.

The Great Depression took a huge toll on the college. With no work available for high school graduates, enrollments swelled, but student motivation decreased, along with faculty salaries. As described by the dean of faculty: "The junior college instructors, faced with the task of teaching students who were discouraged at the outset and made little more than a half-hearted effort to learn, were hard pressed to pursue academic paths." Education at Santa Rosa became "primarily custodial in nature" as admission standards slipped

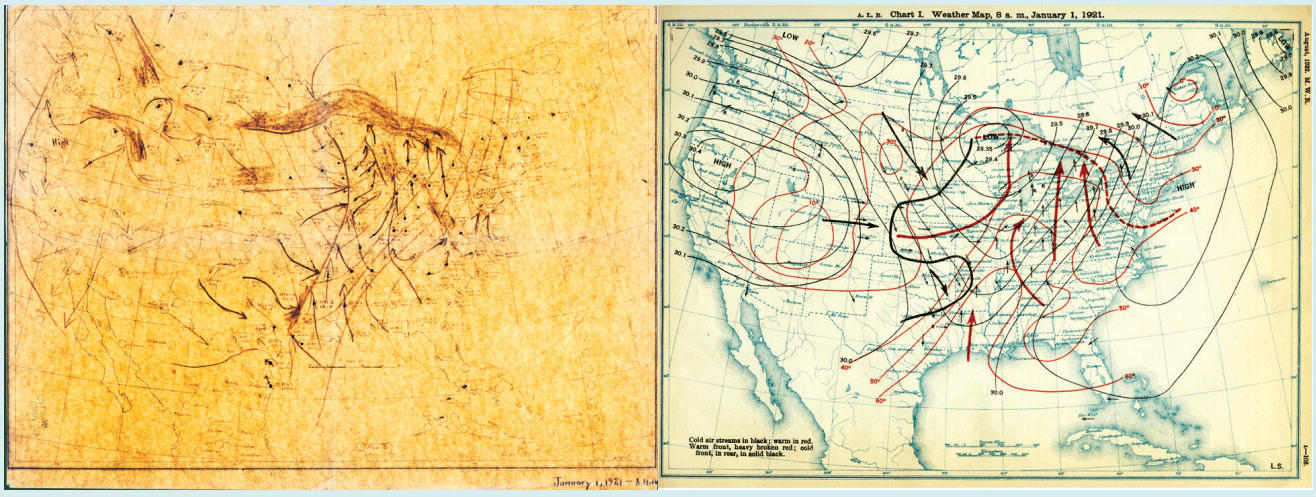

Figure 2.7. (a, left) Anne Louise Beck's original analysis for January 1, 1921, from her Berkeley thesis. Fronts, wind shifts, and shaded areas of precipitation are clearly marked. The original is drawn in white on blue drafting paper. Here the image has been inverted and the contrast enhanced. There are thirty-one maps in Beck's thesis, one for every day in January 1921. (b, right) Beck's map for the same date as published in the *Monthly Weather Review* but with heavy-handed manipulations by editor A. J. Henry.

and the original mission of the school, which had been to prepare students for more advanced study, was expanded to include vocational training and cultural programs for adult learners. Ironically, in the depths of the financial depression, the college acquired its forty-acre campus, the former experimental gardens of Luther Burbank, and inaugurated an aggressive building program.

The 1930 U.S. Census lists Anne L. Beck (born 1896, single, age thirty-four) as living at 240 Carrillo Street in Santa Rosa. Her image in figure 2.8 is from the 1930 college yearbook, the *Patrin*. The 1938 yearbook gives her married name as Anne Beck Walker. Emulating the interests of her mentor Bjerknes, she taught theory of aviation and meteorology in the Civil Aeronautics Authority program established in 1938, with the flight school conducted at the Santa Rosa Municipal Airport. After 1941, when the government banned private aviation on the Pacific coast, instruction was relocated to Ely, Nevada. The 1940 census lists Anne as living in Santa Rosa at the same address (married, head of household, age forty-four), with the annotation, "husband gone indefinitely, no further information." Her family—father Peter (age seventy-five), mother Margaret (sixty-six), and younger sister Margaret (forty-one)—still lived in Berkeley. The last mention of Anne on the Santa Rosa faculty is in the 1941 *Patrin*. She resigned from the college that year and, under contract with the U.S. Army Air Forces, joined the Cal-Aero Academy near Ontario, California, as an instructor in meteorology. Here the trail goes cold. There is a death record for Anne Beck Walker (born March 18, 1896, died November 29, 1982) in Fresno, California.

Figure 2.8. Anne Louise Beck, 1930. Image courtesy of Santa Rosa Junior College Archives, Santa Rosa, California.

Anne Louise Beck was two years older than Carl-Gustaf Rossby. She held the same type of Scandinavian exchange fellowship (but six years earlier and in the reverse sense). Beck and Rossby overlapped in Bergen in the autumn of 1920. Both had the same level of educational attainment. Both worked to bring Bergen methods to the United States. Beck wrote her MA thesis on this topic in 1922 and published a long article that same year, so her effort preceded Rossby's by several years. Her relationship with Weather Bureau chief Marvin was cordial, so far as it went, while Rossby's was not. Beck taught meteorology to pilots and Rossby established a model airway weather reporting system in Oakland, California (chapter 3), only a short distance from Beck's family home in Berkeley. Both Beck and Rossby worked in World War II weather training programs, yet there is no evidence their paths ever crossed. Beck's effort to bring Bergen methods to the U.S. Weather Bureau in the early 1920s was a first step in a process that required a massive change in Weather Bureau culture and reached completion only through the concerted efforts of many meteorologists including Rossby, working over two decades. . . .Her map of fronts and a cyclone, published in *Monthly Weather Review*, was heavily manipulated and distorted by a prejudicial editor, A. J. Henry, who had been with the weather service since 1878 and whose perspective on the value of her work was further distorted by institutional and national pride, ageism, and probably sexism. Gender expectations of the time both shaped and severely constrained Beck's subsequent career path. Her story holds added significance because the most common dating for the emergence of prominent women scholars in meteorology is 1949, when Joanne Simpson received her Ph.D. Anne Beck was twenty-seven years her senior and made a significant intellectual contribution to meteorology at a time when this advanced degree was not required or even expected.