Norway Comes to New Zealand

Edward Kidson, Jørgen Holmboe, and the
Modernization of Australasian Meteorology

Ciaran Doolin

ABSTRACT: Edward Kidson, Director of the Meteorological Service of New Zealand from 1927 until his death in 1939, was an instrumental figure in modernizing Australasian meteorology. Throughout the 1920s, Kidson promoted the methods of synoptic analysis emanating from the Bergen School of Meteorology. However, it was not until the 1930s that he began in earnest to apply these methods to weather charts for the Australasian region. This development was aided by two visits he made to Bergen and by a personal correspondence he maintained with Jacob Bjerknes during the 1930s. In 1932, Kidson presented the first Norwegian-style analysis conducted for a Southern Hemisphere region, promptly following this with a more extensive study. However, these analyses were not of a sufficient standard at that stage to be adopted in forecasting practice. It was the fortuitous visit to New Zealand of Norwegian meteorologist Jørgen Holmboe, in 1934, that finally facilitated the transition. Holmboe was attached to the Lincoln Ellsworth Antarctic Expedition, but damage to their aircraft caused them to spend the winter of 1934 in New Zealand. Holmboe was engaged at the Meteorological Service in Wellington during this period, working with Kidson to apply Norwegian methods to the region. Kidson had hoped to further embed this practice by employing Tor Bergeron in New Zealand during 1938. Bergeron had accepted an offer from Kidson but canceled at the last minute after contracting rheumatic fever. Nevertheless, shortly after Holmboe's visit, daily analyses were being conducted along Norwegian lines, bringing Australasian meteorology into the twentieth century.

<https://doi.org/10.1175/BAMS-D-20-0058.1>

Corresponding author: Ciaran Doolin, ciaran.doolin@metSERVICE.com

In final form 6 August 2020

©2020 American Meteorological Society

For information regarding reuse of this content and general copyright information, consult the [AMS Copyright Policy](#).

AFFILIATIONS: Doolin—Meteorological Service of New Zealand Limited, Wellington, New Zealand, and School of Geography, Environment and Earth Sciences, Victoria University of Wellington, Wellington, New Zealand

“This paper arises from a desire ... that the maximum possible advantage should be gained from the presence in New Zealand of a Norwegian Meteorologist versed in the methods of analysis of synoptic weather reports developed in the Bergen school.”

(Kidson and Holmboe 1935a, p. 3)

So began a paper that represented the culmination of over a decade of work by Edward Kidson, Director of the Meteorological Service of New Zealand, to modernize meteorology in Australasia. It was Kidson's concerted efforts that resulted in the introduction of Norwegian methods of weather analysis to the region. As one survey of Southern Hemisphere synoptic meteorology concludes: “Of the men who contributed to the knowledge of Southern Hemisphere meteorology prior to WW II the names of W. Meinardus and E. Kidson should top the list” (Taljaard 1972, p. 160).

Previous historical studies of Kidson have focused on his achievements as an administrator and organizer of new meteorological services in New Zealand, particularly for aviation (de Lisle 1986; Henry 2009, 2014, 2015, 2017). However, the scientific work that made these organizational advances possible—namely, the introduction of Norwegian methods to Australasia—has received scant attention [two studies have included some commentary on Kidson's work: Palmer (1942) and Taljaard (1972)]. This paper examines Kidson's meteorological investigations and the connections he established with international scientific networks which aided the transfer of knowledge from Europe to New Zealand. It is clear, however, that this knowledge transfer was not a matter of simply transposing the ideas derived in Bergen to a New Zealand context. The peculiarities of the location and geography of New Zealand, and the Southern Hemisphere more generally, required considerable original investigation on Kidson's part to adapt Bergen ideas to local conditions.

The emergence of the so-called Bergen School of Meteorology, which was founded by Vilhelm Bjerknes and operated from the Geophysical Institute at the University of Bergen in Norway during the inter-war years, was

one of the principal turning points in the development of the modern science. For many meteorologists, the Bergen school ... actually represents the birth of a comprehensive science of the weather (Friedman 1999, p. 29).

Among their many innovations, the Bergen scholars are best known for their emphasis on the centrality of fronts to extratropical weather. In their view, not only are fronts responsible for much of the cloud and precipitation in the middle and high latitudes, but they are also the source of cyclonic development. They conceived of cyclones emerging as a “wave disturbance” along the frontal boundary between warm and cold currents—now known as the Norwegian Cyclone Model (NCM) (Bjerknes 1919; Bjerknes and Solberg 1922). Their form of synoptic analysis, therefore, emphasized the identification of different air masses and the fronts separating them.

Prior to the Bergen School, meteorology had undergone a “generally positive but erratic” theoretical development (Newton and Newton 1999, p. 41). Little of this, however, had filtered through to the practice of weather forecasting. In the United States, for example, at that time synoptic analysis focused on the surface pressure field, and the main technique for forecasting the movement of high and low pressure systems was extrapolation, informed by storm track climatology and isallobaric indications (Newton and Newton 1999). In Southern Hemisphere meteorology, this tradition was represented by W. Meindarus, H. C. Russell, M. W. C. Hepworth, W. J. S. Lockyer, and others [for an account of this period, see Palmer (1942)]. The Bergen scholars offered a new conceptual framework that promised to put practical meteorology on a sound theoretical footing. But the new ideas

did not just have implications for the practice of meteorology: “[Vilhelm] Bjerknes came to believe that close contact between theoretical dynamic meteorology and daily practical forecasting was essential for the progress of both” (Friedman 1999, p. 32). Although the reception of these new ideas through Europe and the United States was initially frosty, by the Second World War the Bergen School had become the preeminent research group (Harper 2012, p. 87).

The spread of Bergen School ideas through the Northern Hemisphere has been the subject of extensive study (e.g., Fleming 2016; Friedman 1989, 1999; Harper 2012; Jewell 1981; Namias 1981, 1983; Newton and Newton 1999). The literature on their dissemination in the Southern Hemisphere, on the other hand, is sparse [although there is some coverage in Cushman (2005), Day (2007), de Lisle (1986), Gibbs (1945, 1997), Howkins (2008), Palmer (1942), and Taljaard (1972)]. This paper, therefore, adds a new dimension to the international literature on the Bergen School, showing how their ideas and professional relationships were quickly embraced in the antipodes.

Kidson graduated with an MSc in electricity and magnetism from Canterbury College in 1905, before joining the Magnetic Observatory in Christchurch, New Zealand, as a magnetic observer. In 1908 he obtained a post in the Department of Terrestrial Magnetism at the Carnegie Institution of Washington, participating in magnetic surveys in South America and Australia. His interest in meteorology began through war service with the Royal Engineers from 1915 to 1919. Recruited by Sir Napier Shaw, Director of the London Meteorological Office, he served in the Balkans Campaign, for which he received Officer of the Order of the British Empire (O.B.E.) and was mentioned in dispatches. After the war he briefly worked in London at the Meteorological Office, before returning to the Carnegie Institution in charge of a new observatory at Watheroo, Western Australia. He left magnetism work in 1921 to join the Commonwealth Bureau of Meteorology in Melbourne, Australia. Because of his wartime experience, he was assigned responsibility for the upper-air branch of the Bureau and, in 1923, its Research Division. In 1924 he was elected a fellow of the Institute of Physics and was awarded a DSc from the University of New Zealand for his research on cloud heights. Kidson then joined the Meteorological Service of New Zealand as Director in 1927 (Fig. 1; Brodie 1998; de Lisle 1986, 43–44).

The institution Kidson inherited in 1927 could barely be described as such. With only four staff members, just one of whom was an experienced meteorologist, Kidson could be forgiven for saying, “New Zealand appears to have been living for many years in a meteorological backwater” [quoted in de Lisle (1986, p. 44)]. Kidson showed great determination in his efforts to modernize meteorology in New Zealand, laboring in a period of fiscal retrenchment during the Great Depression. Much of his scientific research was completed in his own time, with administrative and operational responsibilities absorbing the lion’s share of his

Fig. 1. Dr. Edward Kidson, O.B.E., ca. 1927. Reference: S. P. Andrew, PAColl-6303-39, Alexander Turnbull Library, Wellington, New Zealand.

work hours. He also dedicated considerable effort to raising the scientific credibility of the Meteorological Service in the eyes of the public. Henry (2015) details the various tussles between Kidson and lay weather forecasters that played out in the popular press during the 1930s as Kidson tried to establish meteorology as a scientific discipline. Furthermore, Kidson (1929) envisaged a program of meteorological education to help the public make better use of forecasts.

Kidson's interest in the Bergen School of Meteorology

Kidson showed an early interest in the ideas emanating from the Bergen School. In a paper presented to the Australasian Association for the Advancement of Science, Kidson (1923) summarized the results of the early investigations of Vilhelm Bjerknes, Jacob Bjerknes, and Halvor Solberg on the polar front, cyclone structure, and general circulation. Kidson contrasted the NCM with traditional theories of cyclones:

Though it does not tell the whole story, their account certainly is remarkably consistent and inspiring. It is far more satisfying, at least, than the stereotyped description of a cyclone which appears in most textbooks – a description which, in Australia, one never sees borne out in practice (Kidson 1923, p. 142).

He concluded that “so far as I know, no attempt has been made to apply [Norwegian methods] to our own conditions” (Kidson 1923, p. 152). “It is particularly regretted that [in this paper] it has not been possible to deal with the application of the theory to Australian and New Zealand conditions” (Kidson 1923, p. 141). Noting that the Bergen School studies had been made for high latitudes, and in a hemisphere with much greater landmasses, Kidson speculated that “New Zealand conditions should be fairly similar, but the elucidation of those in Australia will require a considerable extension of their investigations” (Kidson 1923, p. 152).

Norway is located at a higher latitude than New Zealand, with the north of the country extending into the Arctic circle. New Zealand's climate is, therefore, more temperate than Norway's, with weather systems of tropical origin affecting the country as well those coming from higher latitudes. Furthermore, whereas Norway is at times affected by dry, continental air, the air masses that affect New Zealand are of an exclusively maritime character; although continental air often comes off Australia, it is greatly modified by passage across the Tasman Sea (Sturman and Tapper 2006, 131–136).

Throughout the rest of the 1920s, Kidson (1925, ca. 1928a, 1929) continued to promote Norwegian analysis methods. However, at the end of the decade he was still lamenting that

the practical application to [New Zealand] conditions [of Norwegian methods] would be very difficult owing to the country's isolation, its great topographical relief, and its narrowness in an east-to-west direction. It has not yet been shown that the accounts ... of the structure and life-history of cyclones are precisely applicable to the conditions of the Southern Hemisphere (Kidson 1929, p. 1).

He emphasized, nevertheless, that there “can be little doubt that it is by the methods used by Bjerknes in attacking the problem that future advances in forecasting weather in New Zealand are to be made” (Kidson 1929, p. 1).

The proper application of Norwegian methods depended on an adequate number of observations. As the passage of synoptic features across the New Zealand region typically happens from west to east, data from the Tasman Sea and Australia are particularly important to New Zealand meteorologists. Furthermore, because New Zealand's mountainous

terrain significantly distorts surface fields of pressure, temperature, etc., observations from land stations require careful interpretation (Sturman et al. 1999). In the 1930s, observations from the Tasman came exclusively from ships. The distribution and number of such reports was never adequate and often nonexistent (Meteorological Branch 1934). A telegraph cable had been laid under the Tasman in 1876, which enabled Australian weather reports to be communicated to New Zealand. However, these were given a low priority by telegraph companies, the result being that a limited number of reports from Australia were available and they often arrived long after they could prove useful for forecasting (Henry 2009). Although there were more observations available by wireless telegraph broadcast from Australia, the Meteorological Service in New Zealand did not have the technological capacity to intercept them—a problem which extended to wireless ship observations (Meteorological Branch 1933).

The first opportunity to get a greater appreciation of Norwegian methods came with the 1929 Empire Meteorological Conference in London. This coincided with the International Meteorological Organization's (IMO) Conference of Directors of Meteorological Services in Copenhagen. In a memorandum to Dr. E. Marsden, Secretary of the Department of Scientific and Industrial Research (DSIR) in New Zealand—of which the Meteorological Service was a part—Kidson asked to attend the conferences, citing, among other things, a desire “to get in touch with modern developments, especially ... the Norwegian system of forecasting” (Kidson 1928b, p. 2). Marsden agreed and recommended to his Minister that Kidson attend the meetings. Surprisingly, the Minister dissented, instead deciding that Kidson's predecessor, Reverend D. C. Bates, whom the government had kept on as a meteorological advisor, should attend—much to Kidson's disappointment (de Lisle 1986, 46–47).

“Most stimulating ... in view of the isolation in which one works in New Zealand”: Visit to Bergen in 1931

In late 1930, Andrew Thomson, a former colleague of Kidson's at the Meteorological Service (later a senior figure in the Canadian Meteorological Service), sent a letter to the High Commissioner for New Zealand in London. Having decided that he needed to refresh his knowledge, Thomson had traveled to Europe in 1930 to study in Germany and Norway (Thomas 2004). Thomson enquired about the amount of money the New Zealand government was setting aside for the 1932–33 Polar Year and reported that Sweden and Norway were considering sending a research student to the Southern Hemisphere to measure the height of the Aurora Australis. “A New Zealand expedition would benefit greatly by association with an investigation coming from the Bjerknes school” (Thomson 1930, 1–2). He encouraged the government to approach the Norwegian and Swedish Meteorological Services about sending a research student to the region. It is unclear whether this was followed up.

In early 1931, the High Commission received another letter from Thomson. Thomson had spent several days with Tor Bergeron in Leipzig. Bergeron had come from Russia where he had spent some months teaching Soviet meteorologists Norwegian analysis methods. Thomson related that Bergeron had a “great interest in Australasian meteorology” and was keen to join with Thomson and Jacob Bjerknes in a study of New Zealand weather (Thomson 1931, p. 1). For Thomson the purpose was to demonstrate the applicability of the Norwegian theories to weather forecasting in New Zealand. Thomson was to provide the local knowledge necessary to understand the differences in observations from station to station. Bergeron and Bjerknes were to conduct the analysis. Thomson requested that the High Commission cable Kidson to source synoptic charts for analysis. This was duly done: Kidson forwarded a series of charts from early 1931, expressing his hope that “some interesting and valuable suggestions will arise from the Norwegian's [sic] study of these charts” (Department of Scientific and Industrial Research 1931; Kidson 1931a, p. 1). What became of the proposed study is uncertain.

In September of 1931, Kidson attended the Centenary Meeting of the British Association for the Advancement of Science in London, as one of the delegates from the Australasian Association. A small grant of £150 was offered by the British Association toward the expenses of each delegate. The New Zealand government did not provide any financial assistance, but gave Kidson leave to attend the conference, so he traveled to Europe mainly at his own expense. After the Centenary Meeting, Kidson proceeded to Locarno, to attend a meeting of the International Meteorological Committee of the IMO on the invitation of Sir George Simpson, Director of the London Meteorological Office (Kidson 1931b; Meteorological Branch 1932).

From Locarno, Kidson traveled to Bergen in mid-October. During the British Association meeting, Kidson had arranged with Jacob Bjerknes, Professor of Meteorology at the Geophysical Institute in Bergen, to spend a week there in order to study Norwegian methods of weather analysis. A room was allocated to Kidson, where Bjerknes and Sverre Petterssen, Director of the Meteorological Institute, devoted much time to discussing with Kidson the current weather charts; Petterssen made copies of the charts for Kidson to refer to later. General theoretical questions were also discussed, with Bjerknes taking a keen interest in papers authored by Kidson, such as a paper on a heavy rain event in Hawke's Bay in the North Island of New Zealand (Kidson 1930, 1933a). Kidson also met with Harald Sverdrup, with whom he discussed problems of polar meteorology—an area of research in which Kidson was particularly interested (e.g., Kidson ca. 1928a, 1932a, 1947). Kidson described the experience as “most stimulating and gratifying in view of the isolation in which one works in New Zealand” (Kidson 1931b, p. 3).

In summarizing his impressions of meteorological science in Europe for the Secretary of the DSIR, Kidson remarked:

I feel that we are aiming in the right direction in New Zealand as regards the development of the Meteorological Services. The principal need is for the improvement of the standard of our observations. Increased accuracy, reliability, completeness and continuity are required. As regards forecasting, the principal need is for more, and more detailed, reports from Australia ... When these requirements are met I have good hopes that the Norwegian methods may be applied with considerable success (Kidson 1931b, p. 4).

Kidson's first Norwegian-style analysis

“A preliminary attempt has been made to apply Norwegian methods of forecasting to Australian and New Zealand conditions,” Kidson reported to Parliament in 1932 (Meteorological Branch 1932, p. 45). The analysis for 10 October 1931 which appeared in a paper by Kidson (1932b) was presumably the outcome of this first effort (see Fig. 2). As Palmer (1942) relates in his survey of the literature of the time, Kidson (1932b) shares the honor of being the first to apply Norwegian analysis methods to a Southern Hemisphere weather chart with Lammert (1932). Subsequent papers by Kidson (1933b,c) evinced a more extensive series of analyses along Norwegian lines.

Both Lammert (1932) and Kidson (1932b), using synoptic charts and meteograms, identified the trough between the migratory anticyclones as a cold front. Furthermore, they recognized that a warm front was difficult to find in the vicinity of Australia. Lammert attributed this to heating of the returning cold air as it transited over the Australian interior. In an earlier paper Kidson had argued: “On the southward extension of the low pressure trough Bjerknes' cyclone family should appear. Australia is too far north for us to get a good account of the cyclones” (Kidson 1925, p. 7). This idea was implicit in Kidson's analysis of 10 October 1931, as well as in Kidson (1933b,c), and Lammert seemed to have held a similar view. It was not until later that Kidson was willing to admit

Fig. 2. Kidson's earliest Norwegian-style analysis for Australasia, Saturday 10 Oct 1931, the first such analysis for a Southern Hemisphere region. Cold front is indicated by the dashed line and warm front by the dotted line. Pressure units are inches of mercury. From Kidson (1932b, p. 73).

that cyclogenesis could occur in the trough or even in the col between the anticyclones (Kidson and Holmboe 1935a,b).

The Australian observations used by Kidson (1932b) were received in the post from Sydney courtesy of the Commonwealth Meteorologist and his staff. As the problem of receiving observations to the west of New Zealand in a timely fashion was unresolved, analyses like these were of academic interest, but of little value for weather forecasting. However, in his report to Parliament in 1932, Kidson expressed optimism that the Meteorological Service would soon have the capacity to receive wireless reports (Meteorological Branch 1932).

"The new methods seemed impossible to learn from books": Visit of Jørgen Holmboe to New Zealand

"It is very difficult for a single worker to become expert in frontal meteorology merely by reading published papers," Kidson reported to Parliament in 1934:

Fortunately for this Branch, however, an experienced Norwegian forecaster in the person of Mr. Jørgen [sic] Holmboe ... has spent a considerable time at the Meteorological Office, Wellington (Meteorological Branch 1934, p. 58).

This was a view shared by one of the leading figures of the Bergen School, Tor Bergeron: "[T]he new methods seemed impossible to learn from books and could only be taught by prolonged personal contact with adepts of these new methods" (Bergeron 1941, p. 255).

Kidson heard from Petterssen that one of his staff, Jørgen Holmboe, had been appointed as meteorologist to the Lincoln Ellsworth Antarctic Expedition. Holmboe's responsibilities

included making upper-air soundings of temperature and wind from the base station in the Antarctic, and producing forecasts for the aircraft carried by the expedition's ship *Wyatt-Earp*. As Kidson had a specialty in Antarctic meteorology, he was asked to brief Holmboe when the expedition passed through New Zealand in late 1933 on its way to Antarctica. Holmboe spent a week in Wellington discussing with Kidson Norwegian methods of analysis (de Lisle 1986, p. 52).

Damage to the expedition's aircraft occurred when the ice shelf in the Bay of Whales cracked, forcing a return to New Zealand in January 1934. The brief stay in Antarctica meant there had been no time for radiosonde flights. The aircraft had to be sent back to the factory in Los Angeles for repairs. The expedition planned to return to the Antarctic in the spring to establish a base in the Weddell Sea once the plane had made it back to New Zealand. Holmboe agreed to spend this period (seven months in the end) at the Meteorological Service in Wellington (Fig. 3; Evening Star 1935; de Lisle 1986, p. 55).

Much of Holmboe's time was spent analyzing synoptic charts and providing New Zealand meteorologists with instruction in Norwegian methods. He worked mainly with Kidson and Clarence E. Palmer. Palmer later became a leading tropical specialist and colleague of Holmboe's at University of California, Los Angeles (Holzer et al. 2011). While in Wellington, Holmboe participated actively in the city's social life, attended meetings of the Royal Society and even gave lessons in skiing during a Tramping Club expedition to the Tararua mountain range north of Wellington (Evening Post 1934a,b).

In his report to Parliament in 1934, Kidson observed:

Owing to New Zealand's isolation, [Holmboe's research and instruction] is not likely to lead to any revolutionary improvement in the weather forecast, but it will add greatly to the interest and understanding of weather processes ... For the method to be used successfully, however, we need ... the Australian reports (Meteorological Branch 1934, p. 58).

Kidson's subsequent reports to Parliament indicate that arrangements were made during the second half of 1935 for the Meteorological Service to receive much more complete reports from Australia (Meteorological Branch 1935, 1936). In addition, to expedite the receipt of telegrams, an operator from the Post and Telegraph Department had been seconded to the Meteorological Service. As a result, weather charts could be plotted and analyzed along Norwegian lines four times daily (Meteorological Branch 1936).

The results of this period of experimentation were presented in a paper by Kidson and Holmboe (1935a,b). Holmboe conducted the analysis, while Kidson wrote the discussion. A mixture of current analyses and reanalyses of notable historical events was presented, chosen according to the "types ... such as occur frequently in this region with only slight modifications" (Kidson and Holmboe 1935a, p. 3). In this paper, mature Norwegian-style analysis was

Fig. 3. Members of the Lincoln Ellsworth Antarctic Expedition, ca. 1933. Lincoln Ellsworth, expedition leader, in front row wearing a bow tie; Hubert Wilkins, expedition supervisor, to Ellsworth's immediate left; Jørgen Holmboe, immediately behind and in between Ellsworth and Wilkins. Reference: 1/2-112426-F, Alexander Turnbull Library, Wellington, New Zealand.

finally in evidence. So far as possible, Norwegian convention was followed for the drawing of the charts and plotting of weather reports, and fronts were marked with the now-familiar symbols, which had first been proposed by Bergeron in early 1924 (Jewell 1981).

Perhaps the most significant theoretical advance from the earlier papers of Kidson (1932b, 1933b,c) and Lammert (1932), was that Kidson and Holmboe (1935a,b) identified the east coast of Australia and the Tasman Sea as a region of cyclogenesis in the form of wave disturbances along frontal boundaries (see Fig. 4). This result has been borne out by subsequent operational experience and climatological studies (e.g., Simmonds and Keay 2000; Sinclair 1995, 1997). During winter, the moist, low-static-stability environment over the East Australian Current provides highly favorable conditions for genesis, including of an explosive character. In a letter to Bjerknes, Kidson explained the evolution of his thinking:

The idea I have now is that small cyclones form as waves on the long cold fronts [between the migratory anticyclones] and move polewards. Just after I had started working on that idea Holmboe came along and it seemed to fit in with his views. I had not recognised these waves before because of their being very poorly developed over the land surface of Australia, the only large area we have with a reasonably close network of reports, and because of their smallness. The succession of waves would correspond with your cyclone family (Kidson 1934a, p. 1).

The final series of analyses, for the period 27 December 1932 to 5 January 1933, offers a window into a now-forgotten period in tropical meteorological thought. From 1 January to

Fig. 4. Holmboe's analysis of cyclogenesis in the Tasman Sea. The authors argued that a succession of waves formed on the front and moved poleward: the first wave developed east of Tasmania on 31 Mar, and had moved out of range by 1 Apr; the second formed east of the Bass Strait on 1 Apr, and was located over southern New Zealand on 2 Apr; the third developed off the coast of New South Wales on 2 Apr. (top left) 30 Mar 1931; (top right) 31 Mar 1931; (bottom left) 1 Apr 1931; (bottom right) 2 Apr 1931. Pressure units are inches of mercury; areas of precipitation are shaded. From Kidson and Holmboe (1935b, 2–3).

Series IV.

Fig. 5. Holmboe's analysis of a tropical cyclone northeast of Fiji on Monday, 2 Jan 1933. Pressure units are inches of mercury; areas of precipitation are shaded. From Kidson and Holmboe (1935b, p. 15).

5 January a tropical cyclone was analyzed forming north of Fiji and transiting eastwards across the island groups of the western Pacific. What is particularly interesting is that Kidson and Holmboe analyzed this system as a wave disturbance on a "front" (see Fig. 5). The success of Bergen School theories in explaining high-latitude weather had led its proponents to apply them to tropical regions (Anduaga 2019; Palmer 1951). With observations even more sparse than in the Australasian region, the analyses of the January 1933 storm depended largely on reports from the S.S. *Maunganui*, which encountered the cyclone in its final stages. The authors were surprised to find it difficult to locate a front in the trough. Yet they concluded:

The series discussed will doubtless leave a feeling of incompleteness because of both the lack of observational material and the small changes produced in all the elements by the disturbances at any distance from their centres ... Nevertheless, any one who considers the series would, we believe, find so much evidence for the presence of a frontal zone with waves developing and moving along it that he must conclude that the whole phenomena should be capable of explanation on those lines were sufficient information available (Kidson and Holmboe 1935b, p. 20).

This is a demonstration of adjusting the data to fit the theory. The confidence they had in the applicability of the NCM to low latitudes is further illustrated by the fact that Holmboe insisted on the omission of several scenarios for lack of observational data (Kidson 1934b). In a letter, Kidson (1934a) had asked Bjerknes whether the "inter-tropic front" was of a similar

nature to those found in the extratropical regions; Bjerknes (1934) answered in the affirmative. However, about tropical cyclones, he conceded he had “no experience, and therefore the classical statement about their symmetry has passed on into [*Physikalische Hydrodynamik*]¹ without criticism” (Bjerknes 1934, p. 2).

In subsequent papers by Meteorological Service staff, this practice of analyzing tropical disturbances using Norwegian methods appeared. Barnett (1938) analyzed a tropical cyclone which underwent extratropical transition and moved across New Zealand. The influence of Kidson and Holmboe in the analysis is clear, with their names appearing in Barnett’s acknowledgments. On his return journey from Europe in 1935, Kidson, traveling on the S.S. *Tainui*, encountered a tropical cyclone in the Caribbean. Using a combination of the ship’s log and United States Weather Bureau charts, Kidson (1937a) analyzed the storm using Norwegian methods. This elicited a lukewarm response from Weightman (1938) and Stone (1938), who doubted that Norwegian methods were applicable to tropical cyclones.

¹ Bjerknes et al. (1933).

Summarizing this period of research, Palmer relates:

The history of research in tropical meteorology during the past twenty years could be summed up as an account of struggle; the struggle to free the science from the domination of concepts derived from the study of weather in high latitudes. The domination itself is a recent thing, a consequent of the overwhelming success of the air-mass theory in the area of its origin ... The great difficulty of applying air-mass techniques to hurricanes and the success of the easterly-wave analysis in the Caribbean after [1940] finally freed the science from the extra-tropical bondage (Palmer 1952, p. 153).

Nonetheless, there were prominent figures defending the applicability of Norwegian methods to the tropical regions well into the post-War period. For example, Bergeron (1954) was advocating Bergen School theories in the study of tropical cyclones, albeit in a more nuanced form than during the inter-war years.

It is worth comparing the New Zealand experience of applying Norwegian methods to that of other countries. In the United States, the adoption of Norwegian methods took many years. Early advocates of Bergen School theories, such as Meisinger (1920a,b) and Weightman (1925), were met with indifference or even outright opposition from Weather Bureau colleagues. However, increasing demand from the aviation industry for more accurate forecasts, and inquests into the deadly crashes of Navy airships *Shenandoah* and *Akron* in bad weather, led President Roosevelt to establish a special committee of the Science Advisory Board, chaired by Nobel Laureate Robert A. Millikan. The Board’s report strongly recommended that Norwegian methods be adopted, while emphasizing that the transition be made cautiously so as not to jeopardize existing services (Millikan et al. 1933). They estimated that the transition would take five years. Still, by 1938 the recommendations of the Board had not been fully implemented. The death of Weather Bureau Chief Willis R. Gregg, in late 1938, led to pressure from the Air Transport Association for a reformer to be appointed to the position. Francis Reichelderfer, an ally of Carl-Gustaf Rossby and early practitioner of Norwegian methods, as officer in charge of the Navy’s aerology section, was appointed to head the Bureau. Finally, in 1938 Norwegian methods became official (Newton and Newton 1999).

Closer to home, in Australia, the Bureau of Meteorology had taken an interest in Norwegian methods in the 1930s. Scientists working with radio direction finders in 1934 had recognized a connection between thunderstorms located by their equipment and the passage of cold fronts across southern Australia (Munro et al. 1935). In 1935, Kidson presented the results of his efforts to incorporate Norwegian methods into forecasting practice in New Zealand at

a conference in Melbourne in January and published a series of analyses of the region in an Australian journal (Day 2007, p. 161; Kidson 1935). The Australian government also requested copies of the Kidson and Holmboe paper for use by the Royal Australian Navy (Kidson 1934c). However, Norwegian methods were not finally adopted in daily forecasting in Australia until the Second World War (Gibbs 1945, 1997). Kidson's departure from Australia may have contributed to this lag:

With the loss of Edward Kidson in 1927 to become Director of the New Zealand Meteorological Office and the retirement of [Henry A.] Hunt in 1931, the Bureau lost its scientific leadership and fell into a period of scientific stagnation (Zillman 2001, p. 29).

Like the United States, developments in meteorology in New Zealand during the 1930s occurred against a backdrop of a growing aviation industry. Although Kidson had provided forecasts for trans-Tasman exploratory flights from the late 1920s, this had occurred on an ad hoc basis. An organized aviation meteorological service did not arise in New Zealand until commercial trans-Tasman, trans-Pacific, and domestic flying routes began to be established from the mid-1930s onward. However, while this meant a welcome expansion of funding for the Meteorological Service, Kidson's response to this changing environment was not merely reactive (de Lisle 1986, 55–56). Kidson was an astute politician who was able to navigate a changing economic and political setting, in which meteorology was increasingly important, to advance his long-standing research program—an approach which echoes Vilhelm Bjerknes' efforts to seek state sponsorship for atmospheric science in Norway (Friedman 1989, 1999). As Henry observes, Kidson in his communications with government officials deployed a “trope of duty” to the safety of aviators, to use “the rise of aviation as a lever to lobby for greater funding for the agency” (Henry 2009, p. 26).

Kidson had been a student of Bergen School theories since the early 1920s but lacked adequate institutional and academic support as the Meteorological Service was a small, poorly resourced organization and there was no presence of meteorologists at New Zealand universities. Although the Meteorological Service was expanding during the 1930s, by mid-1939 it only had 21 scientific staff. Indeed, the pool of experienced forecasters was so small that “those with two or three years experience became ‘old hands’” (de Lisle 1986, p. 61). Kidson's early efforts to apply Norwegian methods to the region were hampered both by a dearth of observations and by inexperience with the methods in practice. Despite these challenges, Kidson's previous research and established international networks, meant that the Meteorological Service was in a strong position to take full advantage of Holmboe's visit and the sudden influx of funding for aviation meteorological services to make a quick transition to routinely using Norwegian methods—in contrast to the American and Australian experiences. This fact was not lost on Kidson, who reported to the Secretary of the DSIR that whereas, with Holmboe's visit, New Zealand had made a “rapid advance,” the Americans were likely to “take many years” to achieve the same result (Kidson 1934c).

“A pool of scientifically minded meteorologists ... could save the situation”: Return visit to Bergen in 1935

In a memorandum to the Secretary of the DSIR, Kidson requested to attend the Conference of Empire Meteorologists, to be held in London during August 1935, and the IMO Conference of Directors of Meteorological Services, scheduled for the following month in Warsaw, Poland. He also requested support to travel to Bergen, arguing that a “further visit to Norway would help to consolidate the progress made [in New Zealand]” (Kidson 1934c, p. 2).

Unlike the disappointment of the 1929 Empire Conference, this time Kidson's request was approved. Much of the discussion during both conferences revolved around aviation meteorology problems. The rapid expansion of commercial aviation demanded greater coordination between meteorological services, as well as a dramatic increase in the scope and quality of forecasts. The latter aspect, Sir George Simpson, Director of the London Meteorological Office, emphasized would necessitate much greater investment in fundamental meteorological research. This message obviously resonated with Kidson since much of his report to Parliament in 1936 is absorbed with discussion of the importance of research, even for a small country like New Zealand (Meteorological Branch 1936). Underscoring this point, he contrasted the conditions he found in Britain with those in Norway. In London he observed that

[t]he officers concerned have their time fully taken up by routine work. They are stationed in the cramped quarters of an office building in the centre of the city, and a large amount of time is consumed in going to and from work. There is little opportunity for meeting and exchanging views or leisured thought (Meteorological Branch 1936, p. 94).

The situation might be remedied, Kidson argued, if more positions were available in the universities for meteorologists; he noted that at that time there was only one such position in Britain, the Chair of Meteorology at Imperial College, occupied by Professor D. Brunt. These comments did not go unrecognized by other conference attendees. As Bjerknes related in a letter to Kidson:

[Sir George] Simpson told me about your intervention which was certainly in his mind when he invited me. I hope I had some little success with some of the forecasters, but it is difficult to create anything approaching a university atmosphere in a factory like the Air Ministry. A pool of scientifically minded meteorologists free from routine work could save the situation. Such a pool actually exists, but during the present period of extension it is engulfed in routine work too (Bjerknes 1936, p. 1).

In Bergen, on the other hand, Kidson observed:

[C]onditions are in marked contrast to those in London ... There are a number of forecasting officers at Bergen, each of whom, in turn, becomes responsible for the forecasts during a certain period. While on this duty he has to concentrate severely and work long hours, but in between times he has considerable leisure ... The Meteorological Institute ... is located in the building of the Geophysical Institute, which has a fine open situation overlooking the harbour and surrounding country ... In the forecast room at Bergen visiting scientists are welcomed. A discussion is held at midday on the morning weather charts and forecast, and there are frequent informal meetings at which more general discussions are held. There is an atmosphere of enthusiasm and confidence, and continual progress is being made (Meteorological Branch 1936, p. 94).

After the conference in Warsaw, Kidson traveled to Bergen for another brief visit. There he met Barnett, who had preceded him. A room was allocated to the two of them, and they were at all times allowed to enter the forecast room. The forecasters discussed each of the five charts produced during the day and allowed Barnett to draw the afternoon chart himself. They were also shown a rough chart for the following day, based on calculations alone, and shown how upper-air charts were used to delineate air masses, check the deductions made from surface charts, etc. Short lectures were arranged every day on subjects of mutual interest, including

on recent research, some of which was unpublished. Summarizing the visit in his report to Parliament in 1936, Kidson remarked: “It was again found that the Bergen meteorologists were much in advance of those of other countries in their treatment of synoptic meteorology” (Meteorological Branch 1936, p. 97).

Visit of Tor Bergeron to New Zealand

In April 1937, Kidson informed the Secretary of the DSIR that he had cabled Bjerknes to enquire into the availability of one of his meteorologists to serve as an instructor to new staff at the Meteorological Service. Bjerknes replied that Tor Bergeron was interested or alternatively a junior meteorologist or graduate might be trained for the job within a year (Kidson 1937b). A subsequent memorandum to the Secretary made clear the reason for Kidson’s cable: in the context of growing demand from the aviation industry for forecast services, training new staff had become a problem of acute concern (Kidson 1937d). In summarizing for his DSIR superiors Bergeron’s distinguished career, with emphasis on his experience teaching Soviet, German, and Swedish meteorologists, Kidson remarked:

There could be no better person found in the world for teaching the most recent methods and developments ... It is a compliment to us that he is prepared to come to Wellington ... He would, I am sure, do much to arouse public interest in scientific Meteorology in this country, and other services in the region could not fail to respond to the stimulus of his infectious eagerness (Kidson 1937b, p. 2).

Several months later Kidson received a letter from Bergeron detailing his motivations for coming to New Zealand:

I cannot refrain from saying that I fully realize what a great stimulus and benefit to my own work a stay at your Institute would mean to me ... As you know, I am since many years working with the enigma of the Southern Hemisphere circulation and have formed some definite ideas about it, which I feel that some day ‘must’ get confirmed on the spot (quoted in Kidson 1937c, p. 1).

He had, however, run into some difficulties as the Swedish and Norwegian authorities had been doing all they could to dissuade their meteorologists from leaving. Indeed, Bjerknes had complained to Kidson in a letter that “the service is to be extended at home, and we hardly know where to take our new men from,” a problem underscored by the recent departures of Holmboe and Sverdrup for the United States (Bjerknes 1936, p. 1). Bergeron wrote to Kidson that his interest in Southern Hemisphere meteorology “is one reason why I, in spite of all the difficulties, still reflect on the matter” (quoted in Kidson 1937c, p. 1).

In a memorandum to the Secretary of the DSIR, Kidson reflected on Bergeron’s remarks:

It is quite clear that he would throw himself into the work with the greatest energy were he to come here and we should benefit not only from the very valuable course of instruction he would give the members of the staff but also from the original investigations both while here and subsequently (Kidson 1937c, p. 1).

Kidson estimated the cost of such a visit would be low since “apparently, [Bergeron does not] wish to make money out of the trip” (Kidson 1937c, p. 1). He proposed the government offer a salary of £600, including £250 for the maintenance of Bergeron’s home (as his family did not intend to travel with him) and £200 for ship fares, for a period of six months from 1 April 1938. This was ultimately approved by Cabinet and the High

Commissioner in London was instructed to cable Bergeron to formally offer him the position (Department of Scientific and Industrial Research 1937). Shortly after, a reply was received from Bergeron saying he accepted the offer pending written approval from his employer (Kidson 1937e). However, Kidson received a further cable from Bergeron in early 1938, advising that he would not be able to visit New Zealand that year after coming down with rheumatic fever, an illness he had suffered from before. Kidson sought permission for the visit to be postponed to the following year and wrote to Bergeron asking if he would be willing to come then instead (Kidson 1938; Liljequist 1981). Whether he received a reply is unclear; in any event, no doubt to Kidson's disappointment, the Bergeron visit did not eventuate.

Conclusions

The application of Bergen School theories and analysis methods to Australasia by Edward Kidson marked a turning point in the history of meteorology in the Southern Hemisphere. The old methods of “isobaric geometry,” to borrow Bergeron's (1959) apt phrase, were replaced with modern, physically based methods.

This transition could not have been achieved without, on the one hand, the enthusiastic, prescient leadership of Kidson and, on the other, the guidance of Bjerknes, Petterssen, and Holmboe. Kidson's project of modernization had to surmount many obstacles: the geographic isolation of New Zealand and Australia; limited resources available for meteorological operations and research, made worse by the Great Depression; and a lack of university support for meteorological research and training. Like many countries during the 1930s, New Zealand experienced a rapid growth of the aviation industry, which helped to finance a corresponding expansion of forecasting services. However, whereas in countries like the United States advocates of Norwegian methods ran up against the resistance of institutions that had become set in their ways, in New Zealand Kidson was ready when the time was ripe to implement reforms, and so was able to leverage the growth of funding for aviation meteorology to advance his research interests. Indeed, it is difficult to avoid the conclusion that Kidson would happily have made the transition much earlier—perhaps as early as the 1920s—were it not for factors beyond his control. Kidson deserves, therefore, to be compared to American figures such as Meisner, Weightman, and Reichelderfer who had similar foresight while facing rather different obstacles in popularizing Norwegian methods.

The other crucial factor was the visit of Holmboe to New Zealand in 1934. Reflecting on Bergeron's legacy to synoptic meteorology, Schwerdtfeger observes:

[H]is line of work differed remarkably from that of the other members [of the Bergen School]. In his own way, he decisively helped his Norwegian colleagues to win worldwide recognition for the so-called polar front theory, not by theorizing a bit more, but rather by showing how and where the observed facts of the real weather could fit into the idealized conceptual picture (Schwerdtfeger 1981, p. 501).

Kidson very nearly managed to acquire the services of Bergeron himself. Nevertheless, Holmboe—who Kidson observes was “a great admirer of Bergeron from whom he had learnt much of his meteorology”—very ably demonstrated the “how and where” of the weather according to the Bergen School to New Zealand meteorologists, resulting in a swift transition to Norwegian methods in Meteorological Service daily practice (Kidson 1937b, p. 2).

In a letter to Kidson, Bjerknes signed off: “I hope you will be [at the 1939 Washington assembly of the International Union of Geodesy and Geophysics] too. With best regards from all of your friends [in Norway]” (Bjerknes 1936, p. 2). Sadly, Kidson was unable to make the meeting: he died suddenly of a heart attack on 12 June 1939, aged 57.

By the time of his death, Kidson had taken the Meteorological Service from a tiny, sclerotic organization to a relatively well-staffed service, versed in the most modern methods, capable of providing acceptable forecasts to aviators. His achievements were recognized internationally. For example, Sir George Simpson assessed that the Meteorological Service “compares favourably from a scientific point of view with the meteorological service of any other country” (Simpson 1939, p. 103). Clearly inspired by the example of Bergen, Kidson sought to cultivate a collegial working environment where a free flow of information existed between research and operations:

Even in a small and isolated country such as New Zealand, a service is bound to stagnate and become inefficient unless the staff display a true interest in meteorology for its own sake and a desire to carry out original investigations (Meteorological Branch 1936, p. 93).

This is a philosophy that is surely just as true today as it was in Kidson’s time.

Acknowledgments. I am especially grateful to Linda Stopforth, librarian at the Meteorological Service of New Zealand, who encouraged me to pursue this project in the first place, and was very helpful in sourcing material for me—if she couldn’t find it herself, she reliably pointed me in the right direction. I would also like to thank Sonja Barfoed and Dr. Lily Gao, librarians at the Commonwealth Scientific and Industrial Research Organisation and Bureau of Meteorology in Australia, respectively, as well as the staff of the J. C. Beaglehole Room at Victoria University of Wellington, Archives New Zealand, National Library of New Zealand, and the Alexander Turnbull Library. Finally, I am much obliged to Chris Webster, Mark Schwarz, Tui McInnes, and the two anonymous reviewers for their valuable comments on the manuscript. This research was supported by the Meteorological Service of New Zealand Limited.

References

- Anduaga, A., 2019: History of typhoon science. Oxford Research Encyclopedia of Climate Science, accessed 31 March 2020, <https://oxfordre.com/climatescience/view/10.1093/acrefore/9780190228620.001.0001/acrefore-9780190228620-e-721>.
- Barnett, M. A. F., 1938: The cyclonic storms in northern New Zealand on the 2nd February and the 26th March, 1936. Meteorological Office Note 22, 34 pp.
- Bergeron, T., 1941: A new era in teaching synoptic meteorology. *Geogr. Ann.*, **23**, 251–275, <https://doi.org/10.2307/519944>.
- , 1954: Review of modern meteorology—12. The problem of tropical hurricanes. *Quart. J. Roy. Meteor. Soc.*, **80**, 131–164, <https://doi.org/10.1002/qj.49708034402>.
- , 1959: Methods in scientific weather analysis and forecasting: An outline in the history of ideas and hints at a program. *The Atmosphere and the Sea in Motion: Scientific Contributions to the Rossby Memorial Volume*, B. Bolin, Ed., The Rockefeller Institute Press, 440–474.
- Bjerknes, J., 1919: On the structure of moving cyclones. *Mon. Wea. Rev.*, **47**, 95–99, [https://doi.org/10.1175/1520-0493\(1919\)47<95:OTSOMC>2.0.CO;2](https://doi.org/10.1175/1520-0493(1919)47<95:OTSOMC>2.0.CO;2).
- , 1934: Letter from J. Bjerknes to E. Kidson, Meteorological Service, Wellington, New Zealand, 7 June 1934. Meteorological Office: Request from Mr. Andrew Thomson that typical westerly weather charts for New Zealand—Australasian area be forwarded for analysis by Bergeron Bjerknes, Bergen. ABLO W4117 6/ 5/11/57, Archives New Zealand, Department of Internal Affairs Te Tari Taiwhenua, 2 pp.
- , 1936: Letter from J. Bjerknes to E. Kidson, Meteorological Service, Wellington, New Zealand, 5 October 1936. Meteorological Office: Request from Mr. Andrew Thomson that typical westerly weather charts for New Zealand—Australasian area be forwarded for analysis by Bergeron Bjerknes, Bergen. ABLO W4117 6/ 5/11/57, Archives New Zealand, Department of Internal Affairs Te Tari Taiwhenua, 2 pp.
- , and H. Solberg, 1922: Life cycle of cyclones and the polar front theory of atmospheric circulation. *Geophys. Publ.*, **3**, 3–18.
- Bjerknes, V., J. Bjerknes, H. Solberg, and T. Bergeron, 1933: *Physikalische Hydrodynamik: Mit Anwendung auf die Dynamische Meteorologie*. Springer, 797 pp.
- Brodie, J. W., 1998: Kidson, Edward. Te Ara—The Encyclopedia of New Zealand, accessed 10 February 2020, <https://teara.govt.nz/en/biographies/4k12/kidson-edward>.
- Cushman, G. T., 2005: Bergen south: The Americanization of the meteorology profession in Latin America during World War II. *From Beaufort to Bjerknes and Beyond: Critical Perspectives on Observing, Analysing, and Predicting Weather and Climate*, S. Emeis and C. Lüdecke, Eds., Erwin Rauner Verlag, 197–213.

- Day, D., 2007: *The Weather Watchers: 100 Years of the Bureau of Meteorology*. Melbourne University Press, 530 pp.
- de Lisle, J. F., 1986: *Sails to Satellites: A History of Meteorology in New Zealand*. New Zealand Meteorological Service, 186 pp.
- Department of Scientific and Industrial Research, 1931: Memorandum for the Director, Meteorological Office, Wellington, 9 January 1931. Meteorological Office: Request from Mr. Andrew Thomson that typical westerly weather charts for New Zealand—Australasian area be forwarded for analysis by Bergeron Bjerknes, Bergen. ABLO W4117 6/ 5/11/57, Archives New Zealand, Department of Internal Affairs Te Tari Taiwhenua, 1 pp.
- , 1937: Memorandum for Mr. Sleight, 11 November 1937. Visit of Dr. Tor Bergeron. ADPG 17167 MET1 4/ 8/21, Archives New Zealand, Department of Internal Affairs Te Tari Taiwhenua, 1 pp.
- Evening Post*, 1934a: N.Z. Royal Society: Pleasant tea party. *Evening Post*, Vol. CXVII, Issue 118, 21 May, p. 13, <https://paperspast.natlib.govt.nz/newspapers/EP19340521.2.140.7>.
- , 1934b: Tararua ski party. *Evening Post*, Vol. CXVIII, Issue 20, 24 July, p. 16, <https://paperspast.natlib.govt.nz/newspapers/EP19340724.2.158>.
- Evening Star*, 1935: Caught in ice: Ellsworth expedition rumour; Ship held in Weddell Sea; Alarming report reaches Dunedin. *Evening Star*, Issue 21930, 17 January, p. 8, <https://paperspast.natlib.govt.nz/newspapers/ESD19350117.2.81>.
- Fleming, J. R., 2016: *Inventing Atmospheric Science: Bjerknes, Rossby, Wexler, and the Foundations of Modern Meteorology*. MIT Press, 306 pp.
- Friedman, R. M., 1989: *Appropriating the Weather: Vilhelm Bjerknes and the Construction of a Modern Meteorology*. Cornell University Press, 251 pp.
- , 1999: Constituting the polar front, 1919–1920. *The Life Cycles of Extra-tropical Cyclones*, M. Shapiro and S. Gronas, Eds., American Meteorological Society, 29–39.
- Gibbs, W. J., 1945: Recent developments in weather analysis in Australia. *Aust. Geogr.*, **5**, 47–51, <https://doi.org/10.1080/00049184508702250>.
- , 1997: A mini-history of meteorology in Australia. *Windows on Meteorology: Australian Perspective*, E. K. Webb, Ed., CSIRO Publishing, 81–104.
- Harper, K. C., 2012: *Weather by the Numbers: The Genesis of Modern Meteorology*. MIT Press, 320 pp.
- Henry, M., 2009: Trans-Tasman meteorology and the production of a Tasman Airspace, 1920–1940. *Environ. Nat. N. Z.*, **4**, 14–36.
- , 2014: Australasian Airspace: Meteorology and the practical geopolitics of Australasian Airspace, 1935–1940. *Climate, Science, and Colonization: Histories from Australia and New Zealand*, J. Beattie, Ed., Palgrave Macmillan, 233–249.
- , 2015: ‘Inspired divination’: Mapping the boundaries of meteorological credibility in New Zealand, 1920–1939. *J. Hist. Geogr.*, **50**, 66–75, <https://doi.org/10.1016/j.jhg.2015.07.003>.
- , 2017: Assembling the weather: Expertise, authority and the negotiation of trans-Tasman aviation forecasts. *Hist. Meteor.*, **8**, 179–201.
- Holzer, R. E., L. Knopoff, and L. B. Slichter, 2011: Clarence E. Palmer, Geophysics and Planetary Physics: Los Angeles. Calisphere, University of California, accessed 29 March 2020, <https://texts.cdlib.org/view?docId=hb9k4009c7&doc.view=frames&chunk.id=div00040&toc.depth=1&toc.id=>.
- Howkins, A., 2008: Political meteorology: Weather, climate and the contest for Antarctic sovereignty, 1939–1959. *Hist. Meteor.*, **4**, 27–40.
- Jewell, R., 1981: The Bergen School of Meteorology: The cradle of modern weather-forecasting. *Bull. Amer. Meteor. Soc.*, **62**, 824–830, <https://doi.org/10.1175/1520-0477-62.6.821>.
- Kidson, E., 1923: The theory of the polar front. *Rep. Australas. Assoc. Adv. Sci.*, **16**, 140–153.
- , 1925: Some periods in Australian weather. Commonwealth Bureau of Meteorology Bulletin No. 17, 28 pp.
- , ca. 1928a: Meteorology. British Antarctic Expedition, 1907–1909, Reports on the Scientific Investigations, 188 pp.
- , 1928b: Memorandum for the Secretary, Department of Scientific and Industrial Research, Wellington, 12 July 1928. Meteorological Office: Empire Conference London 1929 and Organisation Meteorologique Internationale Conference Copenhagen 1929. ABLO W4117 7/ 9/4/1, Archives New Zealand, Department of Internal Affairs Te Tari Taiwhenua, 2 pp.
- , 1929: *Forecasting Weather in New Zealand*. Department of Scientific and Industrial Research, Meteorological Branch, 8 pp.
- , 1930: The flood rains of 11th March, 1924, in Hawke’s Bay. *N. Z. J. Sci. Technol.*, **12**, 53–60.
- , 1931a: Letter from Edward Kidson to Andrew Thomson, c/o New Zealand High Commissioner, London, England, 27 January 1931. Meteorological Office: Request from Mr. Andrew Thomson that typical westerly weather charts for New Zealand—Australasian area be forwarded for analysis by Bergeron Bjerknes, Bergen. ABLO W4117 6/ 5/11/57, Archives New Zealand, Department of Internal Affairs Te Tari Taiwhenua, 1 pp.
- , 1931b: Memorandum for the Secretary, Department of Scientific and Industrial Research, Wellington, 21 December 1931. Meteorological Office: Empire Meteorological Conference 1935. ABLO W4117 7/ 9/4/1, Archives New Zealand, Department of Internal Affairs Te Tari Taiwhenua, 4 pp.
- , 1932a: Some problems of modern meteorology, No. 8: Problems of Antarctic meteorology. *Quart. J. Roy. Meteor. Soc.*, **58**, 219–228, <https://doi.org/10.1002/qj.49705824503>.
- , 1932b: The Canterbury ‘Northwester’. *N. Z. J. Sci. Technol.*, **14**, 65–75.
- , 1933a: Letter from E. Kidson to J. Bjerknes, Det Geofysiske Institut, Bergen, Norway, 4 July 1933. Meteorological Office: Request from Mr. Andrew Thomson that typical westerly weather charts for New Zealand—Australasian area be forwarded for analysis by Bergeron Bjerknes, Bergen. ABLO W4117 6/ 5/11/57, Archives New Zealand, Department of Internal Affairs Te Tari Taiwhenua, 2 pp.
- , 1933b: The Wairarapa floods of August 1932. *N. Z. J. Sci. Technol.*, **14**, 220–227.
- , 1933c: Some New Zealand weather charts. *Gerlands Beitr. Geophys.*, **40**, 206–255.
- , 1934a: Letter from E. Kidson to J. Bjerknes, Det Geofysiske Institut, Bergen, Norway, 19 January 1934. Meteorological Office: Request from Mr. Andrew Thomson that typical westerly weather charts for New Zealand—Australasian area be forwarded for analysis by Bergeron Bjerknes, Bergen. ABLO W4117 6/ 5/11/57, Archives New Zealand, Department of Internal Affairs Te Tari Taiwhenua, 3 pp.
- , 1934b: Letter from E. Kidson to J. Bjerknes, Det Geofysiske Institut, Bergen, Norway, 26 July 1934. Meteorological Office: Request from Mr. Andrew Thomson that typical westerly weather charts for New Zealand—Australasian area be forwarded for analysis by Bergeron Bjerknes, Bergen. ABLO W4117 6/ 5/11/57, Archives New Zealand, Department of Internal Affairs Te Tari Taiwhenua, 2 pp.
- , 1934c: Memorandum for the Secretary, Department of Scientific and Industrial Research, Wellington, 24 May 1934. Meteorological Office: Empire Meteorological Conference 1935. ABLO W4117 7/ 9/4/1 Archives New Zealand, Department of Internal Affairs Te Tari Taiwhenua, 2 pp.
- , 1935: The analysis of weather charts. *Aust. Geogr.*, **2**, 3–17, <https://doi.org/10.1080/00049183508702121>.
- , 1937a: The cyclone series in the Caribbean Sea, October 17–24, 1935. *Quart. J. Roy. Meteor. Soc.*, **63**, 339–354, <https://doi.org/10.1002/qj.49706327106>.
- , 1937b: Memorandum for the Secretary, Department of Scientific and Industrial Research, Wellington, 26 April 1937. Visit of Dr. Tor Bergeron. ADPG 17167 MET1 4/ 8/21, Archives New Zealand, Department of Internal Affairs Te Tari Taiwhenua, 2 pp.
- , 1937c: Memorandum for the Secretary, Department of Scientific and Industrial Research, Wellington, 22 September 1937. Visit of Dr. Tor Bergeron. ADPG 17167 MET1 4/ 8/21, Archives New Zealand, Department of Internal Affairs Te Tari Taiwhenua, 2 pp.
- , 1937d: Memorandum for the Secretary, Department of Scientific and Industrial Research, Wellington, 29 September 1937. Visit of Dr. Tor Bergeron. ADPG 17167 MET1 4/ 8/21, Archives New Zealand, Department of Internal Affairs Te Tari Taiwhenua, 1 pp.
- , 1937e: Memorandum for the Secretary, Department of Scientific and Industrial Research, Wellington, 22 November 1937. Visit of Dr. Tor Bergeron.

- ADPG 17167 MET1 4/ 8/21, Archives New Zealand, Department of Internal Affairs Te Tari Taiwhenua, 1 pp.
- , 1938: Memorandum for the Secretary, Department of Scientific and Industrial Research, Wellington, 7 February 1938. Visit of Dr. Tor Bergeron. ADPG 17167 MET1 4/ 8/21, Archives New Zealand, Department of Internal Affairs Te Tari Taiwhenua, 1 pp.
- , 1947: Daily weather charts extending from Australia and New Zealand to the Antarctic continent. Australasian Antarctic Expedition 1911-14, Scientific Rep. Series B, Vol. VII, 31 pp. and 365 charts.
- , and J. Holmboe, 1935a: *Frontal Methods of Weather Analysis Applied to the Australia-New Zealand Area: Part I. Discussion*. Department of Scientific and Industrial Research, Meteorological Branch, 20 pp.
- , and —, 1935b: *Frontal Methods of Weather Analysis Applied to the Australia-New Zealand Area: Part II. Weather Charts*. Department of Scientific and Industrial Research, Meteorological Branch, 16 pp.
- Lammert, I., 1932: Frontologische Untersuchungen in Australien. *Beitr. Phys. Atmos.*, **19**, 203–219.
- Liljequist, G. H., 1981: Tor Bergeron: A biography. *Weather and Weather Maps: A Volume Dedicated to the Memory of Tor Bergeron*, G. H. Liljequist, Ed., Birkhäuser, 409–442.
- Meisinger, C. L., 1920a: The precipitation of sleet and the formation of glaze in the eastern United States, January 20 to 25, 1920, with remarks on forecasting. *Mon. Wea. Rev.*, **48**, 73–80, [https://doi.org/10.1175/1520-0493\(1920\)48<73b:TPOSAT>2.0.CO;2](https://doi.org/10.1175/1520-0493(1920)48<73b:TPOSAT>2.0.CO;2).
- , 1920b: The great cyclone of mid-February, 1919. *Mon. Wea. Rev.*, **48**, 582–586, [https://doi.org/10.1175/1520-0493\(1920\)48<582:TGCOM>2.0.CO;2](https://doi.org/10.1175/1520-0493(1920)48<582:TGCOM>2.0.CO;2).
- Meteorological Branch, 1932: Department of Scientific and Industrial Research (Report of the), Appendix to the Journals of the House of Representatives. Session I-II, H-34, 45–47, <https://paperspast.natlib.govt.nz/parliamentary/AJHR1932-I-II.2.3.2.33>.
- , 1933: Department of Scientific and Industrial Research (7th Annual Report of the), Appendix to the Journals of the House of Representatives. Session I, H-34, 68–72, <https://paperspast.natlib.govt.nz/parliamentary/AJHR1933-I.2.3.2.30>.
- , 1934: Department of Scientific and Industrial Research (8th Annual Report of the), Appendix to the Journals of the House of Representatives. Session I, H-34, 57–60, <https://paperspast.natlib.govt.nz/parliamentary/AJHR1934-I.2.3.2.40>.
- , 1935: Department of Scientific and Industrial Research (9th Annual report of the), Appendix to the Journals of the House of Representatives. Session I, H-34, 98–100, <https://paperspast.natlib.govt.nz/parliamentary/AJHR1935-I.2.3.2.31>.
- , 1936: Department of Scientific and Industrial Research (10th Annual Report of the), Appendix to the Journals of the House of Representatives. Session I, H-34, 90–98, <https://paperspast.natlib.govt.nz/parliamentary/AJHR1936-I.2.3.2.35>.
- Millikan, R. A., I. Bowman, K. T. Compton, and C. D. Reed, 1933: Preliminary report of the special committee on the Weather Bureau of the Science Advisory Board. *Bull. Amer. Meteor. Soc.*, **14**, 273–281, <https://doi.org/10.1175/1520-0477-14.12.273>.
- Munro, G. H., H. C. Webster, and A. J. Higgs, 1935: Simultaneous observations of atmospheric with cathode ray direction-finders at Toowoomba and Canberra. Council for Scientific and Industrial Research Bulletin No. 89, Radio Research Board Rep. 8, 9–42.
- Namias, J., 1981: The early influence of the Bergen School on synoptic meteorology in the United States. *Pure Appl. Geophys.*, **119**, 491–500, <https://doi.org/10.1007/BF00878154>.
- , 1983: The history of polar front and air mass concepts in America—An eyewitness account. *Bull. Amer. Meteor. Soc.*, **64**, 735–755, [https://doi.org/10.1175/1520-0477\(1983\)064<0730:AHOPIA>2.0.CO;2](https://doi.org/10.1175/1520-0477(1983)064<0730:AHOPIA>2.0.CO;2).
- Newton, C. W., and H. R. Newton, 1999: The Bergen School concepts come to America. *The Life Cycles of Extratropical Cyclones*, M. Shapiro and S. Granas, Eds., American Meteorological Society, 41–59.
- Palmer, C. E., 1942: Synoptic analysis over the southern oceans. New Zealand Meteorological Office Professional Note 1, 38 pp.
- , 1951: Tropical meteorology. *Compendium of Meteorology*, T. F. Malone, Ed., American Meteorological Society, 859–880.
- , 1952: Reviews of modern meteorology—5. Tropical meteorology. *Quart. J. Roy. Meteor. Soc.*, **78**, 126–164, <https://doi.org/10.1002/qj.49707833603>.
- Schwerdtfeger, W., 1981: Comments on Tor Bergeron's contributions to synoptic meteorology. *Weather and Weather Maps: A Volume Dedicated to the Memory of Tor Bergeron*, G. H. Liljequist, Ed., Birkhäuser, 501–509.
- Simmonds, I., and K. Keay, 2000: Mean Southern Hemisphere extratropical cyclone behavior in the 40-year NCEP–NCAR reanalysis. *J. Climate*, **13**, 873–885, [https://doi.org/10.1175/1520-0442\(2000\)013<0873:MSHECB>2.0.CO;2](https://doi.org/10.1175/1520-0442(2000)013<0873:MSHECB>2.0.CO;2).
- Simpson, G. C., 1939: Dr. Edward Kidson, O.B.E. *Nature*, **144**, 103, <https://doi.org/10.1038/144103a0>.
- Sinclair, M. R., 1995: A climatology of cyclogenesis for the Southern Hemisphere. *Mon. Wea. Rev.*, **123**, 1601–1619, [https://doi.org/10.1175/1520-0493\(1995\)123<1601:ACOCFT>2.0.CO;2](https://doi.org/10.1175/1520-0493(1995)123<1601:ACOCFT>2.0.CO;2).
- , 1997: Objective identification of cyclones and their circulation intensity, and climatology. *Wea. Forecasting*, **12**, 595–612, [https://doi.org/10.1175/1520-0434\(1997\)012<0595:OIOCAT>2.0.CO;2](https://doi.org/10.1175/1520-0434(1997)012<0595:OIOCAT>2.0.CO;2).
- Stone, R. G., 1938: Remarks on Kidson's and Weightman's "The cyclone series in the Caribbean Sea, Oct. 17–24, 1935." *Bull. Amer. Meteor. Soc.*, **19**, 256–259, <https://doi.org/10.1175/1520-0477-19.6.256>.
- Sturman, A. P., and N. J. Tapper, 2006: *The Weather and Climate of Australia and New Zealand*. Oxford University Press, 541 pp.
- , H. A. McGowan, and R. A. Spronken-Smith, 1999: Mesoscale and local climates in New Zealand. *Prog. Phys. Geogr.*, **23**, 611–635, <https://doi.org/10.1191/030913399677305474>.
- Taljaard, J. J., 1972: Synoptic meteorology of the Southern Hemisphere. *Meteorology of the Southern Hemisphere*, C. W. Newton, Ed., American Meteorological Society, 139–213.
- Thomas, M., 2004: Dr. Andrew Thomson (1893–1974). Canadian Oceanographic and Meteorological Society, accessed 20 February 2020, www.cmos.ca/site/biography_a_thomson.
- Thomson, A., 1930: Letter from A. Thomson to High Commissioner for New Zealand, London, England, 24 December 1930. Meteorological Office: Request from Mr. Andrew Thomson that typical westerly weather charts for New Zealand—Australasian area be forwarded for analysis by Bergeron Bjerknes, Bergen. ABLO W4117 6/ 5/11/57, Archives New Zealand, Department of Internal Affairs Te Tari Taiwhenua, 2 pp.
- , 1931: Letter from Andrew Thomson to High Commissioner for New Zealand, London, England, 4 January 1931. Meteorological Office: Request from Mr. Andrew Thomson that typical westerly weather charts for New Zealand – Australasian area be forwarded for analysis by Bergeron Bjerknes, Bergen. ABLO W4117 6/ 5/11/57, Archives New Zealand, Department of Internal Affairs Te Tari Taiwhenua, 5 pp.
- Weightman, R. H., 1925: Some observations on the cyclonic precipitation of February 22–23, 1925, in the central and eastern United States. *Mon. Wea. Rev.*, **53**, 379–384, [https://doi.org/10.1175/1520-0493\(1925\)53<379:SOOTC P>2.0.CO;2](https://doi.org/10.1175/1520-0493(1925)53<379:SOOTC P>2.0.CO;2).
- , 1938: The cyclone series in the Caribbean Sea, October 17–24, 1935. *Quart. J. Roy. Meteor. Soc.*, **64**, 117–119, <https://doi.org/10.1002/qj.49706427313>.
- Zillman, J. W., 2001: A hundred years of science and service—Australian meteorology through the twentieth century. *Year Book Australia 2001*, Australian Bureau of Statistics, 22–50.