Book review

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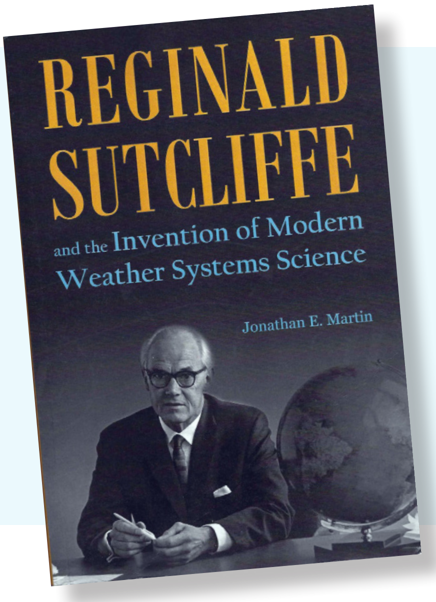

Jonathan E. Martin. 2021.

Reginald Sutcliffe and the Invention of Modern Weather Systems Science.

West Lafayette, Indiana: Purdue University Press.

484 pp. 34 illustrations.

US$39.99.

Atmospheric science is short on book-length biographies of its heroes compared to other fields in the physical sciences[1]. As such, Jonathan Martin's recent biography of renowned British meteorologist Reginald Sutcliffe is a welcome addition to the literature. Martin's study examines Sutcliffe's best-known intellectual contributions – his theory of development and his introduction of isobaric coordinates – as well as his activity with the British Meteorological Office, World Meteorological Organization, and the University of Reading. The author makes the case that Sutcliffe's contributions to meteorological theory constituted a revolutionary advance in the field.

Martin is a Professor in the Department of Atmospheric and Oceanic Sciences at the University of Wisconsin-Madison and is the author of the popular textbook *Mid-Latitude Atmospheric Dynamics*. Martin first acquired a taste for history of science as a graduate student at the University of Washington during the 1980s. Thirty years or so later, this interest has apparently only deepened as Martin decided to dedicate his first sabbatical to the task of completing a biography of Sutcliffe. The outcome of five years of investigation, the author's study draws on extensive primary and secondary sources, including detailed information obtained from Sutcliffe's relatives.

Reginald Sutcliffe was born in 1904 in Wrexham, Wales, but grew up in Cleckheaton, Yorkshire, England. His father, Ormerod, was a grocery store manager at the Cleckheaton Cooperative. Ormerod was an autodidact with wide intellectual interests. He was also a socialist, a supporter of the Labour Party, and was involved with the local Workers' Educational Association (WEA). Ormerod took evening classes in biology at the Cleckheaton Technical School, and later in life he was asked to serve as an instructor at the WEA. Naturally, Reginald's parents valued education and encouraged academic achievement amongst Reginald and his brothers.

1 Some international examples include Friedman's (1989) study of Vilhelm Bjerknes and the Bergen School of Meteorology; Hamblyn's (2002) portrait of Luke Howard, the author of modern cloud nomenclature; Guadalupe's (2014) biography of Cuban hurricane scientist Father Benito Viñes; and Gribbin's and Gribbin's (2016) study of Robert Fitzroy, Britain's first weather forecaster. More recent publications include Potter's (2020) study of Cleveland Abbe, America's first weather forecaster; and Fleming's (2020) biography of Joanne Simpson, a pioneering tropical meteorologist. To my knowledge, the only biography of a New Zealand meteorologist – and an incomplete one at that – is Isabel Kidson's (1941) study of her late husband Edward Kidson.

Sutcliffe won a County Minor Scholarship to Whitcliffe Mount School where he completed his secondary education. A talented student in mathematics and physics, he won a County Major Scholarship to the University of Leeds, where he gained a BSc with first class honours in mathematics in 1925. Impressed by his performance, the university encouraged Sutcliffe to pursue a PhD. He won the Alfred Law Scholarship, which funded his PhD studies in mathematics under the supervision of William Berwick. Upon graduating in 1927 he discovered that there were limited employment opportunities for mathematicians besides academia. However, he was advised that the British Meteorological Office sometimes employed mathematics graduates; his application there was successful and he began his meteorological career in 1927.

Sutcliffe trained as a forecaster – a "training" he described as learning through osmosis – and spent many years working at stations around Europe. A significant event in Sutcliffe's development as a meteorologist occurred in late 1928 when he arrived at his new post in Malta to be greeted by Tor Bergeron, a leading figure in the innovative Bergen School of Meteorology, who was attached to the office at the invitation of the British government. Bergeron was to spend a period of six months studying Mediterranean weather using the methods of frontal and air mass analysis that the Bergen School had pioneered. Sutcliffe keenly observed Bergeron's careful, systematic synoptic analysis featuring fronts, isobars, isallobars, and shaded air masses. Sutcliffe recalled this experience as "a revelation after the slapdash drawing of isobars which was all that was generally attempted in UK offices at the time" (p. 50). The lessons he drew from these interactions stood him in good stead for years to come: Sutcliffe later commented that he always "tried to employ the same thorough methods and always felt one step ahead of anything being done in the UK for the next 15 years" (p. 50)[2]. However, this fortuitous time with Bergeron had another long-lasting impact on Sutcliffe's career: his engagement with the Norwegian Cyclone Model (NCM) – a central feature of the Bergen School's scientific framework. Though initially an enthusiastic student of the NCM, Sutcliffe eventually came to the conclusion that it was theoretically deficient; this realisation pushed him to develop a dynamical theory of his own.

During this period, Sutcliffe carried out research in his spare time, some of which resulted in impactful publications. Although Sutcliffe acknowledged the success of the NCM as a description of the life cycle of extratropical cyclones and its utility in forecasting, by the late 1930s he had concluded that it failed to give a satisfactory theoretical account of the process of development. For Sutcliffe, any theory of development needed to explain how the atmosphere produces situations where there is an excess of upper-level divergence over low-level convergence, resulting in net removal of air from a column and decreasing surface pressure.

In two ground-breaking papers, Sutcliffe (1938; 1939a) combined mathematical rigour and sound physical reasoning to derive equations which expressed a dynamical theory of development. The key step in Sutcliffe's reasoning was his recognition that surface pressure changes happened due to the vertical distribution of divergence/convergence of the ageostrophic wind. When he assumed a constant Coriolis parameter, Sutcliffe showed that the contribution of the geostrophic wind to the overall divergence of the wind field is eliminated, leaving only the contribution from the ageostrophic wind. Because the acceleration is always 90 degrees to the left of the ageostrophic wind, the problem then became mapping the field of acceleration. Though clearly a capable theoretician, Sutcliffe was at heart a forecaster: another important feature of these works was Sutcliffe's articulation of a graphical method that would allow forecasters to utilise the physical insight obtained from his equations in the practical interpretation of operational analyses[3].

In 1939 he published *Meteorology for Aviators,* which was read widely by Royal Air Force (RAF) pilots during the Second World War. In the early phase of the war, Sutcliffe was mobilised into the RAF at the rank of Squadron Leader and was sent to France with the British Expeditionary Force to forecast for flying operations over the continent. As France fell under Nazi control, Sutcliffe was evacuated back to England. Later he was posted to Bomber Command to organise forecasting for raids over Europe. His participation in the bombing raids over Germany, albeit at a distance, left

2 Doolin (2020) examines the story of the emergence of Bergen School ideas in the Southern Hemisphere during the 1930s under the supervision of Edward Kidson, Director of the Meteorological Service of New Zealand. Norwegian meteorologist Jørgen Holmboe spent much of 1934 in New Zealand, providing Kidson with the kind of fruitful interactions Sutcliffe enjoyed with Bergeron in Malta. In fact, Bergeron was scheduled to come to New Zealand in 1938 for six months but had to cancel at the last minute due to a bout of ill health.

3 Interestingly, in the first of these two papers Sutcliffe deployed the term "quasi-geostrophic". In fact, this was the second time the term had been used; it appeared for the first time in an English-language publication in a paper Sutcliffe co-authored with Charles Durst (Durst & Sutcliffe 1938).

him with lifelong nightmares. After being appointed chief meteorologist of the Allied Expeditionary Air Force in late March 1944 Sutcliffe was involved in the historic forecasting effort for the Normandy landings on 6 June.

Despite the at-times extreme workload pressures of wartime forecasting, Sutcliffe somehow found the energy for more research. A notable innovation Sutcliffe introduced during the war years, in collaboration with the Belgian polymath Odon Godart, was the adoption of pressure instead of geometric height as the vertical coordinate. In two important memos, they showed how the use of isobaric coordinates simplified the equations for the geostrophic and thermal winds, and the continuity equation (Sutcliffe 1943; Sutcliffe & Godart 1943). For example, the use of isobaric coordinates for the geostrophic wind equation removed the dependency on density, meaning that a single geostrophic wind scale could be used at all levels. Sutcliffe and Godart also demonstrated a method for constructing upper-air charts using surface pressure analyses and upper-air temperatures, and for prognosing the evolution of upper-air charts by calculating the column-average geostrophic temperature advection.

After Germany's defeat, Sutcliffe was engaged in reorganising the German meteorological service. Upon his return to England, he resumed his work at the Meteorological Office. He quickly set to work finessing his ideas about development, leading to his famous "development theorem" (Sutcliffe 1947). In this paper he showed that the difference in divergence between the top and bottom of a column is related to the advection of the combined surface and upper-level vorticity by the thermal wind. The mathematical elegance of this result was matched by its immediate applicability in operational forecasting. In Martin's view, Sutcliffe's development theorem "represented a revolution in synoptic-dynamic meteorology" in which Sutcliffe had "achieved what no one before him had – he had placed understanding of the progression and development of midlatitude weather systems on an unshakably solid scientific foundation" (pp. 157-158)[4].

4 It would be interesting to trace the influence of Sutcliffe's ideas on activity in New Zealand. On the other side of the Tasman, Bill Gibbs, a post-war Director of the Bureau of Meteorology, singles out Sutcliffe (1947) as the most important paper he encountered in the period immediately after the end of the war (Taba & Gibbs 1988, p. 248). It seems highly likely that Sutcliffe's work had a similar impact in New Zealand, but to uncover this would require some digging into internal Meteorological Service publications from the period as de Lisle's (1986) history of the organisation apparently makes no mention of Sutcliffe's influence.

Sutcliffe eventually became Director of Research at the Meteorological Office and guided many projects to fruition, most notably the British effort in numerical weather prediction (NWP). Martin argues that the influence of Sutcliffe's development theorem on British meteorology was a factor in the different paths taken by British and American NWP efforts from around 1948. Sutcliffe's work biased British efforts towards baroclinic models from the start, whereas Jule Charney's group in the United States were initially focused on barotropic models. On this aspect, Martin is anxious to dispel the reputation Sutcliffe has apparently acquired of being an NWP sceptic. Sutcliffe's attitude towards NWP had several facets. Firstly, he felt that though NWP was likely to prove useful in forecasting in his lifetime, he doubted it would constitute the revolutionary advance that some anticipated at the time. Secondly, he lamented that the scientific problem he had been faced with as a young forecaster – however frustrating – would be rendered less satisfying for the analyst as NWP took much of the interpretative challenge out of the process. Finally, he felt that the advent of electronic computers had come at a time when meteorological theory was just starting to undergo a renaissance and consequently energy was directed away from theoretical work and into NWP. In Sutcliffe's words:

> Sometimes I think the electronic computer came too soon. If we'd followed on from Rossby's ideas, which came long before computers – the first idea on vorticity fields, and then the idea of the thermal winds that I produced, and similar things – the dynamicists would have altered weather forecasting quite radically, in quite a revolutionary way, without the high speed computer. Because the ideas didn't need a high speed computer (p. 357).

In the post-war period, Sutcliffe also became heavily involved in international meteorological collaboration, most notably with the World Meteorological Organization and International Association for Meteorology and Atmospheric Physics. He was the recipient of many scientific honours. Perhaps chief among these was his election as a Fellow of the Royal Society in 1957, an achievement which was widely seen as recognition that meteorology had been accepted by the wider scientific community as a real science.

Following his retirement from the Meteorological Office in 1965 he immediately founded the Department of Meteorology at University of Reading. Reading became the first university in Britain to offer an undergraduate course in meteorology. He retired from academia in 1970, but maintained an involvement in meteorological affairs until his death in 1991.

One of the many interesting features of Martin's study is that it is not only a scientific biography: it is also a work of science communication. The author brings to bear his considerable experience as an educator in atmospheric science to produce a narrative that communicates the scientific concepts in plain language as he simultaneously catalogues the events of Sutcliffe's life and scientific career. Beginning with explanations of elementary meteorological concepts, Martin builds towards the more advanced dynamical ideas Sutcliffe is best known for, fortifying the reader's understanding with simple yet illuminating illustrations of the physical processes under discussion. With this approach Martin has broadened the potential appeal of his book beyond the rather narrow confines of the disciplines of atmospheric science and history of science; this book should be accessible to an interested, non-specialist readership. Given Sutcliffe's long-standing involvement with popular and specialist scientific education, this feature makes Martin's study an especially fitting tribute to his subject.

Historians of science have in recent years approached scientific biography with a degree of wariness (e.g., Greene 2007; Nye 2006; Porter 2006). Some critics argue that biography as a literary device tends to overstate the role of individual activity in the history of science, in the process washing out the broader cultural, social, and intellectual context within which science necessarily takes place. The author, while not a professional historian, does an able job of situating Sutcliffe's life within this broader context thereby minimising some of the potential pitfalls of biography as a literary genre. For example, somewhat to my surprise, the book begins with a lengthy account of the labour movement's struggle for the democratisation of education in the highly class-stratified society of turn-of-the-century Britain. Sutcliffe, being from a working-class family, was a direct beneficiary of the partial success of this movement.

I have a few minor criticisms of this study. Some of the chapters were excessively long. The chapter on the war years came to 65 pages while the chapter on Sutcliffe's international activities amounted to a gruelling 78 pages! These each could have been split into two chapters. Furthermore, I felt at times a more judicious selection could have been made of Sutcliffe's statements in various publications. This was particularly evident in the chapter on Sutcliffe's international activity in which the author seems to have nearly exhaustively quoted from Sutcliffe's many contributions to various international symposia, congresses, committee meetings, etc. A smaller sample of quotations representative of Sutcliffe's opinions and their evolution over time would have made for more fluid reading – these long tracts of commentary are likely to be lost on a non-meteorologist, or even a non-historically-inclined meteorologist. Finally, although I mentioned earlier that this book is a commendable exercise in science communication, in addition to history of science, there are places where this effort falters. Perhaps unsurprisingly, this was most evident in the sections discussing Sutcliffe's main theoretical contributions. A non-meteorologist would, I think, struggle to follow some of these discussions and likely would just have to take Martin's word that Sutcliffe's contributions were uniquely insightful and useful. Martin makes a valiant attempt to explain these concepts and that he at times falls short has less to do with his particular presentation and more to do with the simple fact that science can be rather complicated sometimes.

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Martin's passion for his subject – both the science and the individual scientist he is profiling – leaps off the pages of this book. This biography was undoubtedly a labour of love. In the acknowledgments, Martin describes the research process as an "academic exercise fueled by personal interest [that transformed] into a life-changing intellectual and spiritual experience" (p. 372). Though one shouldn't expect to get through this rather substantial book in a weekend of leisurely reading, it is nevertheless certainly worth the effort to see this fascinating, meticulously crafted story through to the end.

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