The Bergen School of Meteorology[1]

The Cradle of modern weather-forecasting

By Ralph Jewell

With the weather a major factor in the process of survival and development, it is no surprise that fishermen and small farmers in Western Norway have been preoccupied with some sort of forecasting for century upon century. It was a surprise, however, that the coastal town of Bergen should become the cradle of meteorology as a twentieth-century science. It was as late as 60 years ago that a small group of researchers – the so-called Bergen School of Meteorology – developed a remarkable new kind of weather-forecasting practice. Their effort quickly became the most conspicuous of all the various initiatives which competed to become the guiding principle for the massive and urgent task of reconstructing international cooperation in meteorology after the First World War.

The Bergen group made an outstanding contribution to the understanding of a great problem, the anomalies and paradoxes of which had often divided meteorologists – the problem of middle-latitude atmospheric depressions. The emerging meteorology comprised practical innovations in forecasting procedures as well as a conceptual revision of the structure of cyclones.

«Polar Front Meteorology», as the Bergen School's methods and ideas were called during the Twenties, signalled the beginning of a new phase in the development of meteorology. It is a challenge to find a way of accounting for how meteorology was changed as a science, and how it was, through the work of the Bergen School, that the most thorough of all transformations in the history of meteorology took place.

When telegraphy opened up new possibilities for internationally coordinated effort in meteorology during the 1850's and 1860's many governments established official institutions for the scientific management of the new opportunities. Each participating state had its own pattern of initiatives and priorities, but the practical usefulness of anticipating storms was seen by all of them and thus the problem of the dynamics of travelling depressions («lows», or «cyclones») became established as the leading challenge for scientific meteorology.

There was a widespread optimism that with telegraphy and the daily synoptic representation of pressure and temperature which it allowed, the problem of cyclones considered as a problem for science could be solved.

But the fuller awareness of the unexpected complexities of the atmosphere's behaviour combined with the growing amount of routine work in official meteorological institutions apparently led to a growing pessimism, even apathy, towards the theoretical problem of the physical dynamics of cyclones.

Essence of the Bergen School's historical significance is that it supplied an extremely imaginative revision of the principles of meteorology and that after the Bergen School meteorology did not relapse

The author

Ralph Jewell was born in Cornwall, England 1940. He is presently Research Fellow of the Norwegian Research Council for Science and the Humanities on leave of absence from his post at the Department of Philosophy, University of Bergen, to which he was appointed in 1966.

Beginning his studies in the Natural Sciences, but provoked by philosophical and social problems about science, Ralph Jewell turned his attention to the humanistic study of science, graduating from the University of Leicester in 1964 in Philosophy, History of Science and Psychology.

The author is now preparing for publication a comprehensive account and analysis of the history of the Bergen School of Meteorology.

[1] Reprinted by permission of the Editor, *Research in Norway 1979*, Oslo 2, Norway, pp. 1–8. We regret that the weather maps in full color in the original had to be limited here to the most significant colors.

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The Bergen School had four leading figures: Vilhelm Bjerknes (1862–1951), who was the senior member and the key personality in every way, Jack Bjerknes (Vilhelm Bjerknes' son and twenty years old at the beginning of the Bergen School in 1917), Halvor Solberg and Tor Bergeron.

Although the most striking innovations of the Bergen School, both in working methods and theory, were mainly due to the three younger personalities, they were only possible within the context of Vilhelm Bjerknes' well-established research strategy and the inspiring leadership he always seemed to provide.

The Pre-Bergen School Meteorological Research Programme of Vilhelm Bjerknes

After showing great talent in physics in continuing the intellectually extremely ambitious programme of his father C. A. Bjerknes who sought to lay new foundations for understanding the properties of the all-pervading medium «ether», in performing excellent experimental and theoretical work as Hertz' assistant at Bonn, and in his first academic position as Lecturer, afterwards Professor, in Mechanics at the Technical University of Stockholm, Vilhelm Bjerknes became more and more occupied with exploring the research opportunities in meteorology and hydrography which had been dramatically opened up by his discovery of a theorem in 1897 concerning circulation in fluids. Attempting to make the step from a classical hydrodynamics of an idealised fluid, to a physical hydrodynamics of the actual fluid bodies of ocean and atmosphere, and supported by the characteristic «outdoor» connections of Scandinavian expedition-related research, he announced the original research programme from which the Bergen School's new meteorology ultimately sprang.

Bjerknes' great plan, of adopting the research criteria of physics for the scientific handling of the complex problems of meteorology and ultimately of weather forecasting, was stated clearly and firmly in 1904. As a scientific manifesto it was so attractive that it won support from the Carnegie Institution (support which lasted from 1906 to 1941), it attracted talented recruits to his project, and it helps to explain why it was Bjerknes who was called to a professorship to lead a new Geophysics Institute at the University of Leipzig where he began his tenure in January 1913. At Leipzig he continued his dynamical investigations under conditions which augured well in 1913 but which deteriorated after the onset of war in 1914. At Leipzig Bjerknes hoped to achieve a theoretical solution to the problem of the atmosphere's dynamics conceived as a problem of physics.

The new conditions at Bergen

Bjerknes' war-time difficulties while living and working in Germany during the war came to a head in the winter of 1916 – 1917. The food shortages and other restrictions which he had to face encouraged family and friends to arrange for him to return to Norway. At the same time ambitious developments were afoot in Bergen, where the oceanographer Bjørn Helland-Hansen was busy establishing a new Geophysics Institute within the framework of Bergen Museum.

On 17 March 1917, the council of Bergen Museum sent Bjerknes its invitation to a specially created second professorship at the Geophysics Institute. After making arrangements which satisfied him that his work in Leipzig would continue under favourable conditions, Bjerknes accepted this offer.

On 23 August 1917, Bjerknes wrote to his friend and confidant Svante Arrhenius about the developments in his research programme up to the departure from Leipzig:

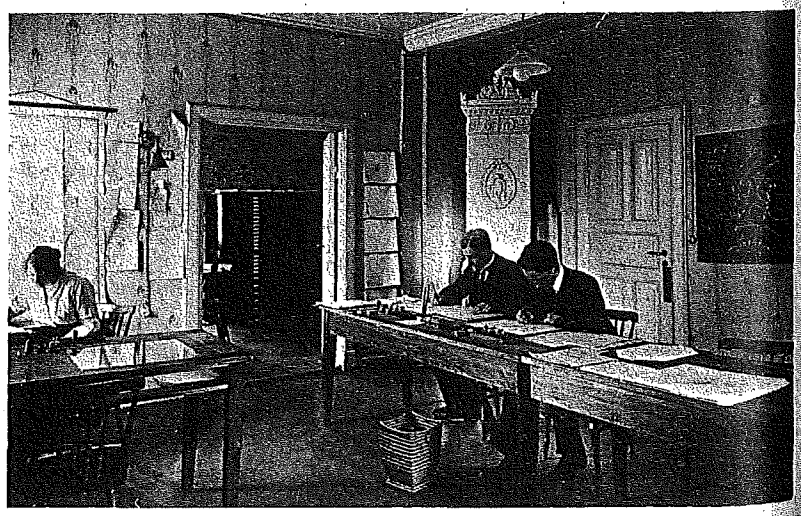
«Concerning scientific work the final year in Leipzig has been extremely fruitful. For the first time, we have made headway with meteorological prognosis based on dynamical principles. How much practical significance this might have, it is still too soon to say. But as theory, it looks promising.»

On 18 December, after his first autumn i Bergen, Bjerknes wrote to Arrhenius: « . . . we are really getting on with the prognosis problem, using dynamical principles. Up to a certain point it is going well, and strangely enough it is my old circulation-theorem which seems to offer most, so far at any rate. But other paths appear to be opening up too – competition is healthy after all. There is still a long way to go to anything practical, but in any case it feels satisfying when it turns out that atmospheric phenomena develop according to the laws of nature.» These «other paths» were the first hints towards new approaches in meteorology – approaches in the spirit of the Bergen School as opposed to Bjerknes' earlier programme.

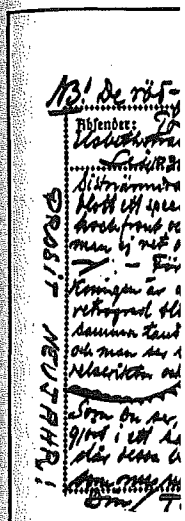
Several factors affected the emergence of new «strains» of enquiry within the Bergen-based Bjerknes-led group. The change from the established academic milieu of Leipzig to the much less formally academic situation in Bergen, the improved access to Scandinavian meteorological data and the influence of new colleagues such as the oceanographer Bjørn Helland-Hansen, all played some part in the subtle processes by which new circumstances evoked

Allégaten 33 – the home of the Bergen School. Situated on the edge of Bergen's finest public park on a rise of land near the town centre this house provided splendid accommodation for the Bjerknes family on the ground floor and for the working offices of the forecasting venture of the Bergen School upstairs on the floor above. The house was transferred to the Geophysics Institute by the local shipowner J. L. Mowinckel in 1919. The combination of the Bjerknes family living downstairs with the Bergen School working upstairs meant a lot to the young recruits for whom Vilhelm Bjerknes was a constant source of encouragement and inspiration, and for whom in many cases their time in Bergen was the first long stay away from familiar company and surroundings.

This picture was taken at Allégaten 33, Bergen in November 1919. Seated in the foreground at the table on the left is Tor Bergeron, at his left Carl Gustav Rossby and his left Svein Rosseland. The person standing, almost with his back to the camera, is Jack Bjerknes. Continuing clockwise around the group, Sverre Gåsland and Johan Larsen, both clerical assistants are seated at the back of the room. The young lady is Gunvor Færstad and her duties involved receiving meteorological observations by telephone and the subsequent entering of the data on the day's map sheets. Gunvor Færstad's neat writing allowed her to enter a great number of observations without too much confusion on the map sheet – a matter certain members of the Bergen School prized highly, and which is not without significance for what the weather map became in the milieu of the Bergen School.



Gunvor Færstad, Tor Bergeron and Jack Bjerknes at work on 14 November 1919. Two days earlier an exceptional fall of snow had occurred in Bergen and Bergeron was keen to find out the reason for it. Four days after this picture was taken he made what he took to be his first reliable drawing of the joining of the cold and warm fronts. This particular map, for November 18th, 1919, has recently been located by the author at Bergen. By depicting the phenomenon of occlusion it can be said to mark a turning point in the meteorology of the Bergen School.



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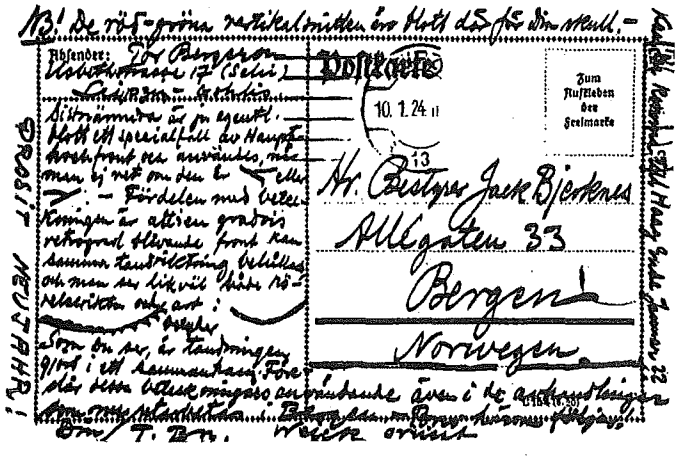
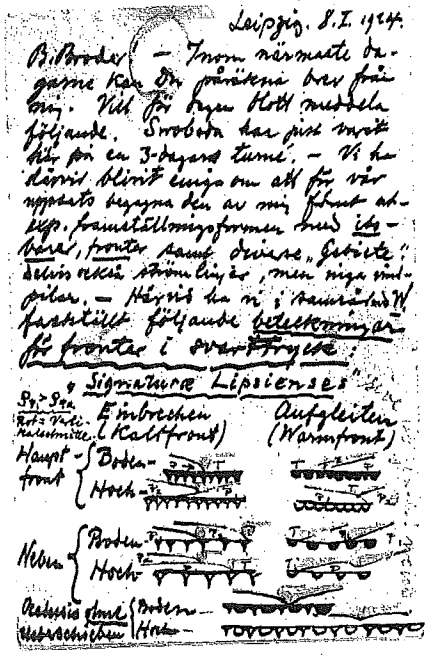


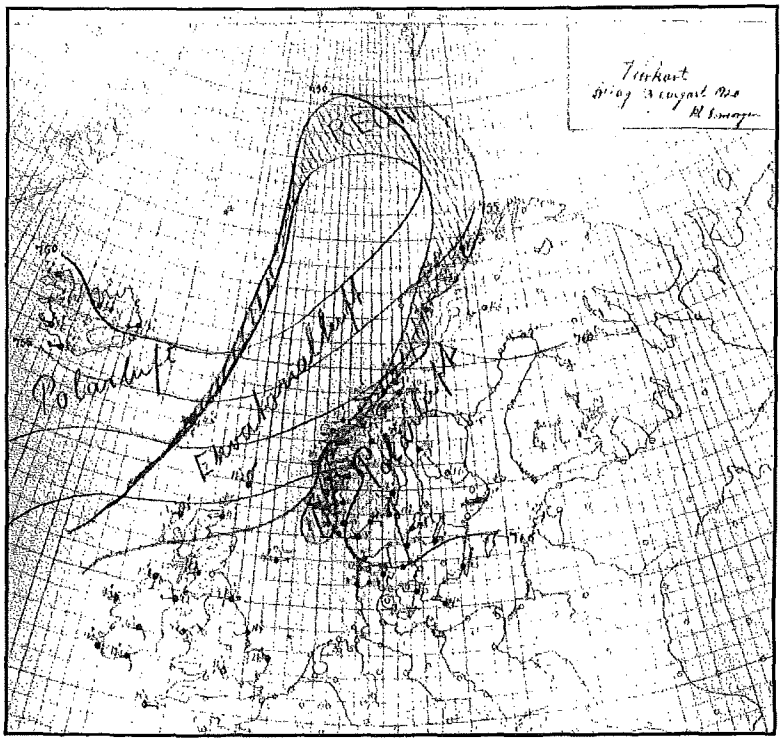


The key features of the weather maps of the Bergen School were the fronts. They were drawn in red and blue on the daily charts. Facing the difficulty of representing the three main kinds of fronts without the benefit of colour printing, Bergeron devised a scheme of indented black lines which is now thoroughly familiar to all. From Leipzig where he was temporarily continuing his investigations Bergeron sent this post card, dated 8 January, 1924, to his friend and colleague Jack Bjerknes, urging him to employ the notation in future Bergen School publications. This remarkable document offers a reminder of how simple some important origins can be.

quite new modulations of Bjerknes' basic research theme. It is clear that Bjerknes still saw his task as to provide a theoretical solution of the problem of the behaviour of the atmosphere appropriate to the needs of practical meteorology. But was it necessary actually to solve a theoretical problem of such enormous complexity *before any* practical use could result?

One factor was to have crucial significance for the extent to which Bjerknes' early programme gave way to characteristically «Bergen School» investigations. Norway faced a difficult food-supply situation following a disappointing harvest in 1917. During late autumn and the first weeks of 1918 the Government seemed to be willing to encourage any initiative aimed at increasing the productivity of Norwegian agriculture.

These were the circumstances which induced Bjerknes to tack from theory to practical forecast-



A typical Bergen School weather map showing rain («Regn» in Norwegian) in conjunction with the warm front drawn at that time as a blue line and a narrower band of rain belonging to the cold front drawn as a red line. This might strike meteorologists as slightly odd – it was not until later that the Bergen maps depicted warm fronts in red and cold fronts in blue.

ing *before* the theoretical solution was properly obtained. If these general conditions created the background for this momentous switch in Bjerknes' attitude towards involvement in practical meteorology, the immediate catalyst was apparently a newspaper article.

Meteorology in the interests of food production

On 13 February 1918 the Kristiania newspaper «Tidens Tegn» carried a report of a meteorological service in Sweden whereby farmers could obtain weather forecasts by telephone. «In the interest of our agriculture, can we have something similar in Norway?» the Director of the Norwegian Meteorological Institute, Th. Hesselberg, was asked in an interview following this report. Hesselberg's reply was that there were too many difficulties for such a scheme to be practical in Norway.

A key document in the history of the Bergen School came as a comment on this interview. Vilhelm Bjerknes wrote to Hesselberg on 18 February: «Helland-Hansen and I have been disturbed by reading your surrendering remarks in «Tidens Tegn» of Feb 13th. (. .) The situation is such that for the sake of the country meteorology is duty-bound to do its utmost, even if there are no telegrams from England. And a situation like the present one for getting meteorology the resources it properly deserves will never arise again.»

The connection with the problem of food-supply catalysed a chain reaction among Bjerknes and his contacts, both civil and military. Following a short talk between Bjerknes and the Prime Minister, Gunnar Knudsen, a government grant was made to finance a project whereby a scheme to offer weather forecasts for the benefit of agriculture could be realised.

On 4 June Bjerknes wrote again to Arrhenius. «Life is fateful. Now I have suddenly become a «practical» meteorologist. We shall try to do all we can in order to provide weather forecasts for farming. Previously this has only been tried in Eastern Norway. But now, at my suggestion, the Storting has granted 100,000 kr. for establishing a forecasting service for the whole of Western Norway from Kristiansand to Trondhjem.»

Jack Bjerknes' cyclone-model

On 18 September after Jack Bjerknes had spent a busy summer preparing daily weather forecasts based on a greatly increased number of reporting observer-stations established within the budget of the special government grant, Bjerknes wrote again to Arrhenius: «Jack really enjoys his work here (in Bergen). Steering-lines and squall-lines sweep past incessantly and provide him with the best material he could desire for his work.» By November 1918 Jack Bjerknes had completed a brilliant eight-page paper which gave a revolutionary view of the structure of cyclones. In this new conception steering-lines and squall-lines had pride of place. Later these names gave way to «warm front» and «cold front», which were to be the two linch-pins of the new meteorology.

On 2 November Jack Bjerknes and Halvor Solberg met Tor Bergeron in Stockholm. While the two «Bergen» adepts enthusiastically explained their new conceptions, Bergeron became aware of the great relevance these ideas had for his own work on comparing the transparency of the atmosphere in different weather conditions. Jack Bjerknes and Solberg also apparently saw the relevance of Bergeron's interest for their work too. Just as Vilhelm's 1904 programme attracted attention and support, so too the developing ideas of Jack and Solberg attracted great enthusiasm and Bergeron especially became fascinated. The roots of the Bergen School as a milieu of youthful improvising enthusiasts are found just here.

Bergeron's Early Contribution: Occlusion of fronts

Bergeron's first major contribution to the emerging Bergen School of Meteorology came in November 1919. Several times during his forecasting work Bergeron detected features on his maps which seemed anomalous according to the conception of cyclone-structure as expressed in Jack Bjerknes' paper. Whereas Jack Bjerknes' model allowed only the possibility of separation between the steering-line and squall-line at the southern part of the tongue of warm air, Bergeron suspected the squall-line to catch up with the steering-line in some cases, and that they might even join in some way.

On 18 November 1919 Bergeron expressed this suspicion in a confident drawing where these two lines actually did merge together. This drawing opened up the path to the idea of the process of the «occlusion» of cold and warm fronts, a conception which in the much later remark of Vilhelm Bjerknes came to belong to every meteorologist's ABC. With this process the way was clear for seeing that cyclones do not have one fixed structure, but that they have several, corresponding to the different stages of a complete life-cycle, involving the stages of birth, development and decay. With the discovery of occlusion the new Bergen ideas became resilient and robust in regard to their capacity to encounter challenge from empirical confrontations with weather systems, or from competing theory.

Solberg's discovery of cyclone «families»

The third major constituent of the emergent research platform of the Bergen School was the discovery made by Halvor Solberg during February and March 1920. By this time Jack Bjerknes' cyclone model was already attracting wide attention, and the important modifications leading towards the conception that cyclones had life-histories had been suggested by Bergeron.

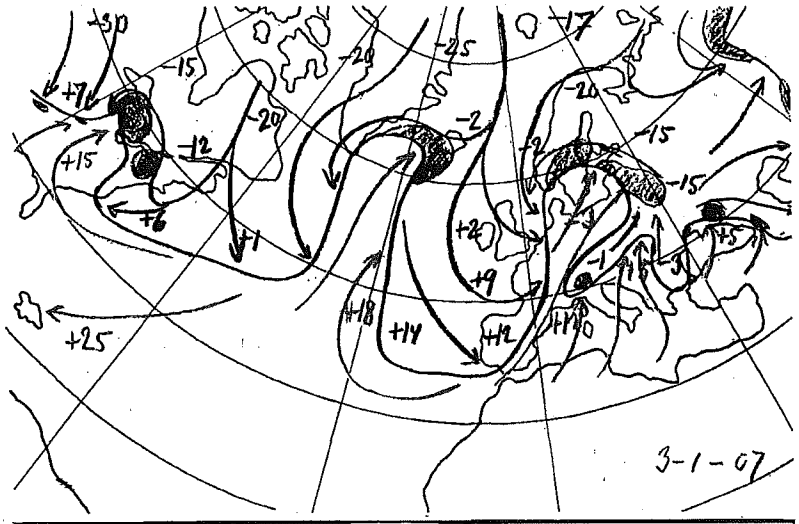
Solberg's own words reveal the great new vision of meteorological problems which he, Jack Bjerknes and Bergeron now shared. He wrote to his chief Th. Hesselberg, Director of the Meteorological Institute:

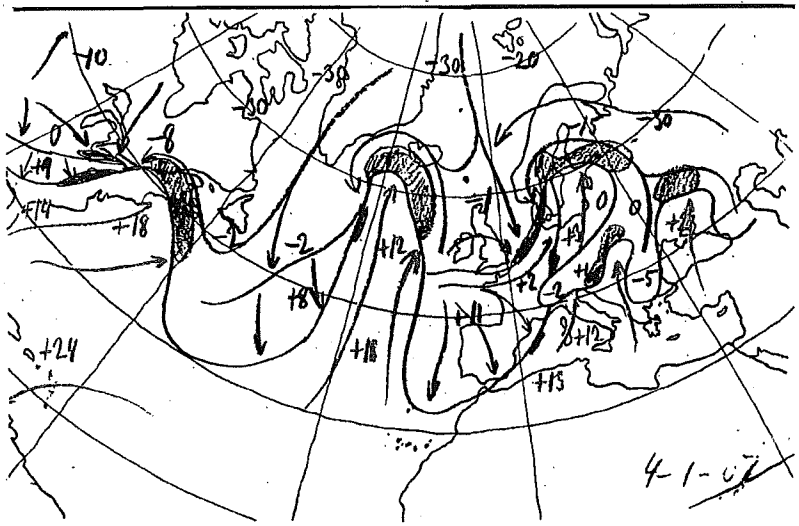
«In the course of our work we now have to make digressions first to one side and then to the other, so that forward progress is very uneven. (. . .) We have, in fact, plans to write a whole new meteorology, a «Meteorologie der reinen Vernunft», indeed a «der praktischen too if you will, . . . Our latest results, which are bound to have far-reaching consequences, directly invite us to do this.»

«During Jack's absence I reflected on the Hoffmeyer charts. I managed to find something which we had suspected for a long time, namely a line of discontinuity in temperature, wind etc. which stretched right across the map from one side to the other. There is no doubt at all that this line continues all around the Pole, even if the Hoffmeyer charts do not extend so far. To the North of the line we have «cold Polar air», to the South we have «warm Equatorial air». It is only along this line that rain falls, in most cases at least. It marks the front battle-line between two bodies of air and that is why it has such a contorted course, since now the warm and then the cold has dominance over the other.»

Cyclones were now seen as occurring in families, the life-stage reached by any particular cyclone arriving at the West Norwegian coast giving important clues about the state of the remaining members to be expected from the West in the same sequence, or family.

Vilhelm Bjerknes saw immediately that this discovery had great importance for the practical service of weather forecasting and that it was bound to attract great attention internationally. The younger members of the Bergen School experienced the situation as standing at the edge of a completely new and unexpected research frontier. With this conception the three main components of the Bergen School's new research programme were assembled into a





As the text makes clear Jack Bjerknes set the ball rolling with a remarkably clear conceptual picture of the motions going on within cyclonic disturbances of the atmosphere. Solberg was the first who ventured to continue drawing the two characteristic lines of cyclones so as to connect cyclones with each other along a fairly continuous circumpolar line of demarcation between warm and cold air, along which cyclones seemed to be strung «like pearls on a string». These two photographs show two of Solberg's original sketches based on observations collected and made available in the «Hoffmeyer» Charts for the year 1907. Drawn in March 1920 these sketches consolidate the idea of a (circum) polar front and open up the further concept of «cyclone families».

single, very powerful, integrated form.

The response of fishermen

The forecasts sent out by Bjerknes' group immediately became very popular among fishermen, whose daily life was often a succession of battles against winds and waves along a rocky coast. The Secretary of Rogaland County Fishermen's Organisation invited Vilhelm Bjerknes to address the 1920 Annual Meeting which was held in July 1920. The day after this meeting a local newspaper of Stavanger carried the story –:

«... the Secretary of the Organisation asked the Professor to do all in his power to make sure that the forecasts were sent out as early in the day as possible. Similarly, he requested the professor to extend the service so that also fishing hamlets without telephones could receive some kind of signalled forecasts as promptly as possible. Just last winter the forecasts have saved a great deal of equipment, perhaps even human lives, and we fishermen know full well that these forecasts are bound to have an importance for saving lives and equipment which could not have been thought of before, and that it is therefore of the most pressing urgency that they should be as fully developed as possible.»

Bjerknes' reception among the Rogaland fishermen was such a talking point that the Hordaland County Fishermen's Organisation from Hordaland, the district around Bergen, invited him to its annual meeting, and from this gathering a telegram was sent to the Norwegian Government:

«The Hordaland County Fishermen's Organisation gathered at its Annual Meeting at Manger today, submits its urgent appeal to the Government that the enterprise which has been led by Professor Bjerknes regarding weather forecasting must be supported with all the funds necessary for the continuation and the extension of this work which is of the greatest importance for the fishing industry.»

Some time after these very positive responses from the fishermen, Bjerknes made the remark that of all the forms of scientific recognition which he had received, none gladdened him more than these responses from this part of the community.

From projects to new theory

As early as 1918 the Vilhelm Bjerknes-led group became a focal point for several different social, commercial, political and intellectual forms of attention. The several ways in which this group attracted this attention and won prestige had important bearings on the kind of opportunities which arose, and also on the goals and objectives which the members individually or collectively attempted to reach. Seen in this way, the 1918 connection with the problems of farming and food production, the 1919 connection with fishing and the improvement of security at sea, the way in which international relations during the post-war years made Norway a favoured location for initiatives aimed at reconciling scientists from previously warring states, the special interest of the shipping companies of Bergen in a transatlantic weather service, are all matters of intrinsic, not merely extrinsic, interest, affecting as they do such basic features as the opportunities, goals and objectives of the research group in question.

By means of the documents collected, salvaged and processed by the author during the last few years in Bergen, it is now possible to show the direct connections between the practical projects of the Bergen School and the theoretical work which grew from them. It was the reflection on the methods and procedures which had been improvised to fulfil the demands of practical needs in specific projects which contained the spur to new theory in the case of the Bergen School. The pathway from specific projects to durable theory can be made fully clear for this particular episode in the history of science.

Vilhelm Bjerknes' theoretical concerns thus passed through a major intellectual and personal change, the full understanding of which only history can provide.●

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