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Vilhelm Bjerknes in Memoriam

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It is with great humility that I stand here today in order to attempt an evaluation of the contributions to the advance of meteorology and oceanography which my late teacher and friend, Vilhelm Bjerknes, made during his long and active life. He laid an ambitious plan for his work, he followed his plan with great consistency — and he lived to see many of his ideas bear fruit.

To Bjerknes the prediction of the weather soon became the central problem towards which he directed his attention. In his entrance lecture at the University of Leipzig, which in 1913 had called him to the chair of professor of geophysics and director of the new Geophysical Institute, he formulated his programme by saying:

"From the observed state of the atmosphere at one moment we must compute the state at a later moment. The problem of the exact computation of a future state, which long ago has been solved in astronomy, must now be tackled in all seriousness in meteorology.

"The problem is of immense dimensions. It can be solved only as result of a long development. One single research worker cannot get far, no matter how great his efforts are. However, I am convinced that in spite of all this it is not too early to point at this problem as the goal of the research. One does not always select a goal in the hope of reaching it soon. To steer towards a distant goal determines the course. In this case the far-away goal will give us an indispensable plan for our work."

Fifteen years earlier the name of Bjerknes had been unknown in meteorology. During his early years he had mainly been working in the field of classical hydrodynamics and had brought part of the remarkable work of his father, C. A. Bjerknes, to a conclusion. At this time he had frequently felt that the assumptions defining an ideal fluid placed too great limitation upon the character of the problems to which the results could be applied. In his search for an expansion he discovered in 1898 his famous theorem of circulation that later on became the core of what he called physical hydrodynamics. Unknown to Bjerknes the same theorem had been discovered already in 1886 by Silberstein who had published his findings but had failed to draw any further conclusions. The very great merit of Bjerknes is that he immediately realised the importance of the theorem to the dynamics of the atmosphere and the ocean, and drew attention to the applications in his first paper on the subject. In this first paper he did not consider circulation relative to the earth, but this matter was taken up a few years later, in 1902.

From the very beginning Bjerknes' papers

aroused great interest among meteorologists and oceanographers. One reason why Bjerknes' work became rapidly known was that by a happy coincidence his ideas, which opened up new possibilities for dealing with the three-dimensional problems of the atmosphere, were advanced just at the time when the exploration of the free atmosphere started. Around year 1900 this fascinating field, for which Köppen proposed the name aerology, was suddenly being developed. In the 1890-s systematic meteorological observations from manned balloons had been organized in Germany by R. Assmann. From 1892 paper balloons with recording instruments had been sent up by the French meteorologists, Hermite, Besançon and Teisserenc de Bort, and in 1894 A. Lawrence Rotch had started using kites at the Blue Hill observatory, Mass. In 1901 Assmann introduced the rubber balloon, which Teisserenc de Bort immediately took into use, and in the following year, 1902, he and Assmann announced independently the discovery of the stratosphere.

In the midst of all this activity Bjerknes' ideas of tackling the problem of the computation of the future weather as a three-dimensional problem naturally aroused great hopes. The meteorologists who had turned with enthusiasm to the study of the free atmosphere foresaw the possibility that the observations gathered by their efforts might revolutionize the forecasting procedure.

In oceanography the situation was similarly favourable. Around 1900 the accuracy of oceanographic observations was greatly improved and the technique of deep sea measurements perfected. Numerous observations were being collected, and now Bjerknes' theoretical contribution promised to render the needed tools for the rational use of the observations.

Still another fortunate circumstance contributed to the furthering of Bjerknes' work. In this case I do not refer to a coincidence, but to a development for which Bjerknes himself has a great deal of the credit because he understood how to impart his own enthusiasm to others. In 1904 he visited the at that time recently established Carnegie Institution of Washington where he gave a number of lectures which created such an interest that from 1906 and until shortly before his death Bjerknes received an annual grant from the Carnegie Institution in order to continue the development of his theories and apply them to the atmosphere and the ocean.

I believe it will be difficult to point at any modest grant which has rendered greater returns than the one given Bjerknes. There are two reasons for this. One is that thanks to the grant Bjerknes could employ the assistants he needed in his work. He did need assistants, because his own work centered completely around the further development of the theoretical tools. He has to my knowledge never attempted to draw a weather map, nor has he ever discussed actual meteorological observations. In the course of the years many of his assistants worked with the data, they tried to interpret the observed conditions, and, step by step, to gain better understanding of the physical processes in the atmosphere or the ocean. Bjerknes gave them complete freedom in their work. He was no hard taskmaster, but he laid the course. He was himself a very independent thinker, who in his writings rarely quoted results obtained by other authors. His papers are characterized by their elegant mathematics and clear style, because he never published a paper before he had corrected every ambiguous sentence and removed every superfluous word. He expected the same clarity from his assistants, and to some degree he wanted his assistants to be as independent in their research as he himself was. There were instances when he was openly displeased by finding his assistants spending too much time studying meteorological literature. In all events, Bjerknes' assistants helped to advance his ideas, partly when they were working with him, and partly in later years, when many of them had students who worked under their direction. In this manner the Bjerknes influence has spread like rings in the water, reaching to ever greater distances.

The other reason for the importance of the grant from the Carnegie Institution was that his grant was given during years when it was difficult for a young man to start on a scientific career. Bjerknes was free to offer assistantships to any interested student and could select among the more promising ones. Several of the young men who for some periods became his "Carnegie assistants" did not continue in meteorology or oceanography,

but most of them did, and could later on, as already mentioned, bring Bjerknes' view points to their own students.

I have dealt to such an extent with Bjerknes' assistants and his relation to them, partly because Bjerknes' attitude to them was characteristic of him, and partly because speaking of Bjerknes' influence on the development of meteorology and oceanography the contributions of his assistants cannot be overlooked, although Bjerknes was the dominating leader. He laid out the course, and his thinking exerted the greatest influence upon those who came in contact with him.

After Bjerknes turned to the application of hydrodynamics to the problems of geophysics his activity falls in four different periods. The first was the period from 1898 to 1912 when he was in Stockholm until 1907 and in Oslo from 1907 until 1912. During these years the first two volumes of the broadly planned work 'Dynamic Meteorology and Hydrography", the "Static" and the "Kinematic", were published by the Carnegie Institution, and during these years the impact of Bjerknes' thoughts started to become apparent in the meteorological and oceanographic literature. Thus, in a paper of 1909 Bjerknes lists a dozen papers in which his theorem of circulation has been applied.

He conducted an intensive campaign for the use of rational units in aerological research, and after he had urged his case at several meetings of the International Aerological Commission this body recommended in 1912 to the Directors' Conference that in the aerological publications pressure should be reported in millibar and that geopotential should be used as the vertical co-ordinate.

The second phase is covered by the years in Leipzig, from 1913 to 1917. Bjerknes accepted the offer from Leipzig for two reasons. In the first place because he could expect to obtain more students and, therefore, might hope to develop a school in meteorology; in the second place because facilities were promised him for the working up of the aerological data that were being accumulated on agreed-upon

international days. Bjerknes would use these for a three-dimensional analysis of the state of the free atmosphere partly to develop methods for representing the state of the atmosphere by means of a series of charts, partly to gain experience as to the extent to which that particular material was suited for a study of the changes in the state of the free atmosphere. His stay in Leipzig became much shorter than he had anticipated, and the results were less because only one and one half year after his appointment the first world war started, he lost his German students and also the needed assistance for preparing the aerological charts. As an interesting side-light on the role of meteorology during the first war, as contrasted to its part during the last war, I may mention that no demands for participation in meteorological research related to military problems were made on Bjerknes or on his two or three Norwegian assistants, who continued their strictly academic work and were paid by the grant from the Carnegie Institution in Washington even after the United States had entered the war.

The Leipzig period was terminated in 1917 when Bjerknes was asked to return to Norway and to accept the chair of professor of theoretical meteorology at the Geophysical Institute which recently had been established in Bergen. There he entered the most exciting period in his life, the period in which the importance of the fronts was recognized by his young collaborators, when the structure of the cyclones was discovered and the term polar front was coined. The credit for the actual discovery of the structure of the cyclones and of the polar front goes to his collaborators, but Bjerknes himself had long been interested in the lines of convergence and divergence which appear on charts on which the wind direction is shown by means of stream lines. He had early conceived the idea that a cyclone starts as a wave-like disturbance at a discontinuity surface, and one of his most important papers from the Leipzig period represents his first attempt at approaching that problem, the paper "Über Wellenbewegung in kompressiblen, schweren Flüssigkeiten".

In Bergen he had, however, to neglect his theoretical work because he and his assistants started immediately the organisation of a unique weather forecasting service, basing it on inadequate observations, but using the newly gained insight in the importance of the fronts. This development exercised a considerable influence on Bjerknes' approach to the whole problem of forecasting, as evident from an address he gave at the meeting of Scandinavian geophysicists in Gothenburg in August 1918. He started by saying:

"It is possible that different roads may lead to the solution of the problem of a satisfactory and practical method for weather forecasting. It is conceivable that among these there may be convenient roads which may lead around the strict requirement as to complete understanding of the events whose development shall be predicted. Personally I am not interested in such roads. I am only interested in the road that leads straight through the inexorable demand of complete understanding."

But then he went on to say:

"If we formulate the task (of predicting) as a mathematical problem, we may have no hope of finding a solution in a foreseeable future. But if we transfer it into a more practical form we find that we may advance simply by following consistently the road that the meteorologists started on when they first made the synoptic charts the basis of the study of the weather processes and by means of these found Bar's law and so on. We do not need to doubt that along this road we may reach results which will give us increased understanding and thus will influence the meteorological practice."

In his Leipzig address in 1913 he had stressed the direct application of the laws of hydrodynamics to given initial conditions. Now, after having been more in contact with the practical aspects of forecasting, he recognized the value of the step-wise approach, but he never relaxed his demand for complete understanding of the physical processes. He held his banner high and under this banner meteorologists and oceanographers from all parts of the world gathered.

During the Leipzig and Bergen periods the applications to meteorology came into the foreground, and Bjerknes himself and his direct collaborators gave little thought to oceanography. Still, his influence on oceanography has been equally great because for nearly fifty years Bjerknes' demand as to

striving towards understanding of the physics of the events has directed the progress.

The fourth and last period in Bjerknes' life started in 1926, when he returned to the University of Oslo as professor of mechanics and applied mathematics. He retired in 1932, but remained active until shortly before his death. During these years he returned to his theoretical work. For a long time the third volume, "Dynamics", of his great work, "Dynamic Meteorology and Hydrography" had been in preparation. Drafts had been written to parts of the volume, but had been discarded because new ideas were advanced. Many of these appeared in the "Physikalische Hydrodynamik" which was published in 1933 by himself and three of his collaborators, but the work with the "Dynamics" continued.

I said that Bjerknes lived long enough to see many results of his life's work. He saw aerology being developed to a degree which even in his most optimistic moments he had hardly considered possible, he saw the three-dimensional analysis of the atmosphere be made part of the routine work in forecasting, he experienced an expansion beyond expectation of meteorological research and, best of all, he saw that most of this research was carried out along the lines he had advocated, aiming towards interpretation of events in terms of physics. Shortly before his death he had also the great satisfaction of seeing the manuscript of the "Dynamics" completed by himself and some of his early collaborators.

I cannot close a brief appreciation of Bjerknes' activities without mentioning his very broad cultural interests. In Norway he was an untiring advocate for an expansion of the facilities of the university both in order to train better teachers and in order to create better conditions for scientific research. Along these lines he did not achieve as much as in his special field, but during the last years of his life he had at least the satisfaction that in Norway the possibilities for young men to use their abilities were increased greatly as compared to the years when he himself was nearly the only professor at the university who, thanks to the Carnegie grant, could offer a student an opportunity to attempt entering upon a scientific career.

He was fortunate in retaining his clear mind to the last. Less than eight months ago he took active part in scientific meetings, and on his 89th birthday, only three weeks before his death, he was weak and had to stay in bed, but he insisted on seeing the many of the friends who called upon him to pay their respects.

I am tempted to close with a poor translation from the old Norse "Haavamaal" in which much of the wisdom of our forebears is condensed:

"Cattle dies, man dies,
you yourself shall die.
Your name never dies."