A MATHEMATICIAN IN METEOROLOGY

By M. KWIZAK

Central Analysis Office

Meteorological Service of Canada

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Many times in the past seven years I have been asked to explain what a mathematician is doing in meteorology. It seems that a weatherman is regarded more as a soothsayer than a scientist. The fact that he goes through a process of objective analysis and diagnosis of the symptoms as revealed by reported weather data in order to arrive at a forecast is little understood.

In the spring of 1949 I completed my work in mathematics for a Master's Degree at the University of Saskatchewan. I was one of many veterans with a family who had gone back to school after the war, and it was important to find employment immediately upon finishing my studies. The most attractive opportunity which presented itself was to join the Civil Service of Canada as a meteorologist. The initial salary, the possibility of future advancement, the Civil Service pension fund, and the security were better than in the other positions available at the time. The position required shift work but the other advantages seemed to outweigh this disadvantage. My main concern in applying for the job was that I would not be able to use the specialized mathematical knowledge I had acquired. However, many day positions involving mathematical research have been available. These are filled by competition based on merit.

After joining the Meteorological Division I was given three months field training in weather observing and then proceeded to Toronto for training as a meteorologist on full salary. The course is given by the School of Graduate Studies, University of Toronto, in conjunction with the Research and Training staff of the Meteorological Division during the regular university term. It is open to Honour graduates in Mathematics and Physics or Engineering Physics, and leads to a Master's Degree. It provides the qualifications necessary for independent forecasting and research positions. A shorter course is also given by the Meteorological Division and is open to graduates in Arts and Engineering with somewhat lower qualifications in mathematics and physics. It is designed to train Meteorological Officers for instructional and forecast duties at R.C.A.F. stations.

A meteorologist now starts at $3900. per annum while on the M.A. course and will progress in about six years to a salary ranging from $6200. to $6700. Higher positions are available through competition in administration or research which yield salaries up to $8500.

During the M.A. course I was surprised at the amount of applied mathematics necessary in Dynamic Meteorology, Thermodynamics, Radiation, etcetera. A good knowledge of advanced calculus, differential equations and vector analysis is essential. Current publications in meteorology make full use of vector notation. Many of the physical quantities in meteorology are particularly adaptable to vector representation. The behaviour of the atmosphere is easily represented vectorially by the Newtonian equations of motion.

Upon completion of the M.A. course in meteorology in the spring of 1950 I was transferred to the weather office in Winnipeg where I was engaged in public and aviation weather forecasting. The first six months were spent in acquiring practical forecasting experience and training by working with an experienced meteorologist. The routine analysis of weather data and weather charts, the preparation of prognostic charts and forecasts for both aviation and public requirements, the investigation of typical and unusual weather situations, the issuing of weather warnings, etcetera all make up part of the meteorologist's duties. To keep in step with current advances in meteorology a meteorologist must read and integrate the latest techniques appearing in the scientific literature which frequently involve working through complicated mathematical equations.

After spending two years at Winnipeg I joined the staff of the Central Analysis Office in Montreal. This office was established in 1950 as a national weather centre and has counterparts in the United States, the United Kingdom, and other countries. The purpose is to provide accurate and consistent analysed weather charts to depict the three-dimensional structure of the atmosphere; to provide shortrange (1-2 days) prognostic charts of this structure; and to develop an extended forecast service which will permit the issuance of forecasts on general terms for a five day period. These charts serve in the provision of weather forecasts supplied by all military and civil forecast offices in Canada.

To meet the ambitious program the Central Analysis Office was organized around a nucleus of some of the highest skilled personnel available in physics, mathematics, and synoptic and dynamic meteorology. Emphasis was placed on both theoretical and practical knowledge.

The first couple of years involved mainly theoretical and empirical research. It was a period of preparation, organization, evaluation, and development of the techniques and methods to be used in practice. I made excellent use of my mathematical training in applying the theories of dynamic meteorology. After the preliminary developmental period the Central Analysis Office went into actual operation in the summer of 1953. The dissemination of all the analysed charts is accomplished by a facsimile network which extends from Vancouver to Newfoundland. The analysed charts are transmitted from our office and are received simultaneously at all the network stations across the country.

After almost three years at the Central Analysis Office I was a successful candidate to the operational development and evaluation section of the Central Analysis Office. This section is responsible for surveying theoretical work, then testing, developing, and streamlining any useful techniques for operational application. In view of the rapid advances taking place in dynamic meteorology this work provides full scope for the application of pure mathematics. The section is small at present but is expected to expand in the future.

The most exciting research currently going on in meteorology is in the field of numerical weather prediction. In spite of the tremendous advances in meteorology as a science in the last fifteen years it is anticipated that the development of numerical techniques will ultimately result in a great increase in the accuracy of weather forecasts. This will also depend on obtaining an accurate analysis of the atmospheric flow patterns which is restricted at present by the limited number of upper air observations over the oceans and northern regions of the continents.

During the last decade several groups of research workers have devoted an increasing amount of effort to the problem of translating basic dynamic principles into practically usable methods for quantitative objective forecasting of the changes in the large-scale flow patterns of the atmosphere. The advent of the electronic computer has aided in this development together with the fact that we now seem to know how to construct theoretical models of the atmosphere. Some of the really good mathematicians and meteorologists in the world are working on the problem. The first group of this type was at the Institute for Advanced Study in Princeton under J. Charney and J. VonNeumann. Another group of early research workers on this project was at the University of Stockholm in Sweden under the direction of B. Bolin, A. Eliassen, and C. W. Newton. A few of the others througout the world are J. Van Mieghem, E. T. Eady, C. C. McVittie, R. C. Sutcliffe, R. Fjortoft, and many more too numerous to mention.

In numerical weather prognosis one works with a certain system of partial differential equations of the atmosphere. The problem has been reduced to the integration of Poisson's and Helmhotz's equations. Numerical solutions are arrived at by using finite difference approximations. This is where the high-speed electronic computer comes in since it permits us to make computations which would otherwise be impossible in the time required. Furthermore, it will ease the burden of amassing, analyzing, and integrating vast amounts of weather data. The weather bureau in Washington, U.S.A. has been supplying numerical prognostic charts since the first of this year with encouraging results. One of the largest electronic computers on the continent is available to the numerical prediction unit for this purpose.

The research and training section at Head Office has commenced preliminary experimentation with numerical prediction methods on the electronic computer at the University of Toronto. At the Central Analysis Office we have been investigating theoretical models and hope to be doing some practical work when a computer is available. For this purpose I attended a course on electronic computers a short time ago.

At present the actual motion in the atmosphere is approximated by simplified models. Further success will undoubtedly follow as electronic techniques progress, and when the mathematician is more able to provide less restrictive solutions of the non-linear partial differential equations governing the behaviour of the atmosphere. As we gain more experience and knowledge this will ultimately result in more accurate weather forecasts.

I have emphasized the fields in which I have been working. There are also many opportunities for research in other specialized fields such as radiation, turbulence, cloud physics, and physics of the high atmosphere.

Meteorology is coming of age as a science in mathematics and physics.