Weather Forecasting—An International Task

By R. A. Hornstein

FEW matters which concern mankind are of more universal interest than the weather. It is perhaps the only commodity which can still move across modern civilization's complex system of borders and barriers without let or hindrance. Its current condition, and even more its future developments, are of vital importance, either directly or indirectly, to every man, woman and child inhabiting the globe. It is readily understandable, therefore, that the body of men who have chosen meteorology as their profession is looming ever larger in the scientific and economic field. Nor is it strange, in view of their necessarily international outlook, that these men should be inwardly compelled to work harmoniously with their colleagues in every land.

This fact was very apparent in the summer of 1947 when the ten Technical Commissions of the International Meteorological Organization convened in Toronto. This was the first meeting of the Organization since 1939, and the first in its 75-year history which had been held in the Western Hemisphere. Delegates from 44 countries met to reorganize international meteorology and to bridge the gap of the war years.

Indeed the war did introduce many difficulties, the full appreciation of which were, at the time, greatly obscured to the layman by the indiscriminate publication of sensational "promise" articles, most of which hinted at tremendous progress being achieved under the critical impetus of war-time necessity. However, progress in practical meteorology has not yet been achieved in the spectacular fashion displayed by some war-stimulated sciences. World War I undoubtedly contributed greatly to advances in medical surgery; World War II ominously fostered the practical application of the theories of the nuclear phycsiists. But meteorology, as applied to weather forecasting, is still primarily an empirical problem—a problem, the solution of which appears at the present time to be dependent on the accumulation and international exchange of vast quantities of factual data gathered from all portions of the atmosphere. However, because of the military importance of weather foreknowledge, both in strategic and in tactical plannings, the free international exchange of raw materials was inhibited by the war. The result of this blockade was that meteorologists in all sections of the world were trying to fit together a jigsaw puzzle, all the pieces of which were not available.

Preparing the Forecast

At this point it might be well to outline briefly the methods used in preparing weather forecasts. Basically there are three major steps in the process:

(1) Scattered across the face of the earth are thousands of weather reporting stations. At each of these stations trained weather observers prepare a comprehensive statement, at fixed intervals, of the current weather situation. This involves careful computation of the atmospheric pressure, temperature and moisture content, precipitation amounts and wind velocity, and observations of the state of the weather, cloud forms, visibility and other essential data. These observations are then encoded in a shorthand type of notation in order that they may be distributed rapidly.

(2) The need for the rapid accumulation in central forecasting offices of observations, from hundreds of thousands of square miles, brings into play every means of modern communication: teletype, telephone, radio, telegraph and radio-teletype. Utilizing these facilities at their highest degree of efficiency

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permits an office such as the Halifax Dominion Public Weather Office to receive reports from upwards of six hundred stations within an hour of the time the observers have completed their observations. As these reports flow into the forecasting office they are entered on large working charts depicting an area of nearly one-half of the Northern Hemisphere. Within an hour and a half of the time of observation, the chart has sufficient data on it to permit the forecaster to commence his analysis.

(3) In analysing the weather chart, the forecaster determines the locations, intensities and motions of pressure systems; he identifies air masses and indicates their boundaries; in short, he performs a diagnosis of the weather situation over a quarter of the earth; to aid in obtaining a three-dimensional picture he studies auxiliary charts of the stream lines at selected levels above the earth's surface and thermodynamic charts of cross-sectional slices through the atmosphere; to gain the important fourth dimensional aspect he studies the charts drawn at earlier six-hourly intervals. Then the process of prognosis is undertaken. In which direction and how quickly will each centre of action move? Which cyclones will become more active and which less active—and to what extent will these changes occur? To what degree will the varying surfaces over which the air will move modify the characteristics of the atmosphere, particularly as to stability of the air mass? As answers to these and dozens of other questions are determined, the next day's weather chart takes form, based, not on actual weather reports as to-day's chart is, but on the calculations, the experience and the knowledge of local peculiarities which are the tools of the forecasting meteorologist. A description of the weather changes accompanying the transformation of the weather scene as portrayed on the diagnostic chart to that depicted on the prognostic chart is then embodied in the forecast soon to be broadcast from radio stations and to be published in the newspapers.

In view of the fact that the weather at any given locality is interrelated with that in distant regions, it is immediately apparent that gaps in the weather reporting network create distinct handicaps to the practical meteorologists, and equally to the theoretical meteorologists who are endeavouring to evolve new methods of analysing the physical processes of the atmosphere. Hence the disrupting influence of wartime secrecy is evident. Similarly, the uninhabited portions of the earth present huge blind spots. One of these exists in the ice-covered wastelands of the Canadian Arctic. Public funds are now being provided to establish reporting stations in this strategically vital area in the conflict between man and the weather.

The air above the North Atlantic Ocean is rapidly becoming one of the busiest highways of modern times. Detailed weather information is essential to permit safe and efficient operation over that region. International co-operation has reached a high peak of achievement in the establishment of floating weather stations in an effort to fill blank spaces on the meteorologists' working charts. Belgium, Canada, France, the Netherlands, Norway, Sweden, the United Kingdom and the United States will jointly operate a network of thirteen such stations each equipped to provide regular and frequent observations of atmospheric conditions at the earth's surface and upwards approximately ten miles into the surrounding air envelope.

In obtaining the mass of information specified in the foregoing, many modern devices of recent development are employed. Radiosonde equipment is one of these; it consists basically of a hydrogen-filled balloon carrying aloft an instrument with elements responsive to variations in pressure, temperature and humidity; these elements are switched in turn into a radio transmitting circuit, thereby permitting the radio broadcast

of the information which is received by a ground-based receiver. The data so obtained broaden the three-dimensional horizons of the meteorologist, as do the observations made by means of radar which permit the measurement of winds up to great heights.

Accuracy of Forecasts

Naturally the question arises as to whether there has been an advance in the standard of forecasting commensurate with the vast increase in the information available to the forecaster. If statistics could be produced comparing the percentage frequency of successes ten years ago and at the present time, the answer would be self-evident. Unfortunately, the verification of weather forecasts is an extremely complex task involving as it does several weather elements, each in itself subject to objective scrutiny, but whose individual importance varies markedly with the consumer involved. An airline operator would be concerned with successes in forecasting ceiling and visibility; a road contractor with rain; a yachting club with wind; a manufacturer with relative humidity; a heating engineer with temperature, etc. Obviously, therefore, the assessment of the accuracy of a given forecast is a difficult task. Undoubtedly, however, advances in observational networks and techniques have been accompanied by more reliable forecasts.

Certainly, a number of war-time and post-war endeavours testify to the forecasters' ability to anticipate weather changes. Recent progress in the analysis of the upper air, for example, has permitted the preparation of detailed short range forecasts of the winds at great heights. These forecasts during war-time enabled military aircraft to carry out long range missions with a high degree of success. Similarly, the meteorological protection of transoceanic flights is a most important task whose success can be measured in the small percentage of losses occurring on routes which are subject to dangerous flight conditions.

Turning to the ordinary forecasting of weather twenty-four to forty-eight hours ahead, which is of interest to the great majority of the public, it is not easy to prove that there has been a marked improvement. Every practising forecaster feels that the regular receipt of this new information will result in an increase of efficiency. But there has not been time to explore the potentialities fully, much less to have already made use of them in daily forecasting. From this it may be seen that there is a wide open field for intensive research, and that a higher standard will be available only when a better understanding of the uses of the new tools has been achieved.

As matters now stand, a forecast for six hours ahead can be made in great detail and to a very high order of accuracy; with twelve-hour forecasts the percentage of serious errors is still very small, although greater than for the shorter period; twenty-four-hour forecasts are correct to an extent which makes them essential in many lines of endeavour. Beyond that period the accuracy of the forecasts falls off more rapidly, and three- to five-day forecasts are still very general in expression. These can only be used for specialized purposes, and by carefully bearing in mind their limitations.

Sources of Errors

Forecasts which go wide of the mark do so primarily because of either errors in timing the movements of action centres, or inaccurate estimations of the development of action centres—or for both of these reasons occurring simultaneously. It is only on rare occasions that the forecaster completely fails to anticipate a change; however, he does underestimate or overestimate the rate of change. More exasperating to him, perhaps, are those occasions when two different lines of development appear equally possible and he decides upon the one which fails to materialize. Thus it may be seen that current forecasting

procedures, although involving certain mathematical manipulations, depend in the final analysis upon the forecaster's judgment of anticipated future weather developments. His construction of a prognostic chart is based upon a very careful consideration of the current diagnostic chart, and a historical sequence of similar charts, but the process of filling in the features of the prognostic chart is not entirely a mathematical computation, but is partially a matter of judgment. The day when human fallibility is completely eliminated will come only when the determination of future weather has been reduced to a mathematical process. When that becomes practicable, forecasting will have made a giant stride forward.

Role of Mathematics

Although it has been said that if expert mathematicians were to devote their talents to the problem of the weather we should soon obtain perfect forecasts, it should be realized that every weather service has excellent mathematicians on its staff—each Canadian forecaster is an honour science graduate, and most of them have majored in mathematics and physics. One fact which must be faced is that we still have a very imperfect knowledge of the state of the atmosphere at this very moment, much less of its future state. Huge voids in the weather reporting network still exist. Before mathematical formulae and techniques can be applied to day-to-day forecasting problems, we must have much more precise data concerning the horizontal and vertical distribution of the several weather variables; from this starting point we should soon be able to determine accurately the laws governing the movements and processes which take place in the atmosphere. Having satisfied these two conditions, the mathematical computations required to produce the forecast still must be capable of solution in less time than the time interval for which the forecast is valid.

Lines of Progress

These three conditions may well be solved; technically, little appears to be impossible in modern society if funds and international co-operation are freely made available. However, it is still impossible to estimate whether precise perfect mathematical forecasts will be achieved in ten or in one hundred years.

Meanwhile, progress will be made by improving present methods through research on the application of the increasing amount of available data to the problems of daily forecasting. Also, it is likely that as we improve forecasts for one or two days in advance, we shall also make headway with the problem of issuing forecasts for periods of five to ten days in advance. However, in weather forecasting the further afield we go in the matter of time the further we must range in space. Consequently, long period forecasts will only be feasible when all countries are eager and willing to work together for the common good. Even in days as foreboding as these, meteorologists are confidently looking forward to the high level of international friendliness which will facilitate their task and, of course, enable all men to enjoy the benefits of scientific planning based on accurate weather forecasts.

Research Helps Develop Industries in Nova Scotia

By H. D. Smith

THIS article is concerned with the part research is playing in the development of industries in Nova Scotia, but it will deal primarily with the functions which the recently established Nova Scotia Research Foundation has to perform in the program carried out by various governmental and private

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