THE PROBLEM OF EXTENDED FORECASTING IN AUSTRALIA

by S. Karelsky
(Research Section, Central Weather Bureau, Melbourne)

INTRODUCTION

The main goal of meteorology is weather forecasting. Two distinct methods of approach can be used for meteorological investigations, the "climatological" and the "dynamic" approach, though these are not mutually exclusive, and other methods have been evolved partaking in varying degrees of points from each of the main fields. For example, Bergeron's method of "Dynamic Climatology" (1932).

Pure climatological method seeks to find by the use of statistics, correlations between the various meteorological elements and their averages in time, in their periodic and non-periodic changes, without reference to the physical connections between them.

The purely dynamic approach, on the other hand, relies very much on these physical relationships. The process of forecasting by dynamic methods has been divided by V. Bjerknes (1909) into three main steps:-

(1) DIAGNOSIS or the investigation and analysis of the fields of meteorological elements (e.g. pressure) at the present moment of time, and the physical connections between the elements.

(2) EPIGNOSIS the investigation of the changes which have led from an earlier state of such a field to the present state (e.g. examination of isallobaric fields) seeking thus to find causes for the present situation. Most scientific investigations in synoptic meteorology are "epignostic".

(3) PROGNOSIS the construction of future fields of the elements, and the most difficult of the three steps. For the solution of this problem the forecaster must have a good diagnosis and epignosis, and must have at his disposal not only working rules, discovered, probably empirically, from investigations into dynamical processes (i.e. from Epignosis), but experience or knowledge of past developments similar to the current situation.

EXTENDED PERIOD FORECASTING

The experience of most meteorological services is that more or less successful forecasts for periods up to 24-36 hours ahead are possible based on prognostic rules, derived from modern dynamic methods, and that forecasts for more than two days ahead are occasionally successful when made by experienced analysts, without definite rules, but based rather on experience. The lack of rules for extended forecasts is due in part to the fact that very few investigations have been made into processes taking longer than 2 to 3 days.

Nevertheless many attempts have been made to develop methods of investigation (i.e. epignosis) and forecasting (prognosis) for periods up to ten days. Some of the methods of extended period forecasting developed in the Northern Hemisphere have been examined and described by Hogan and Maher (1946). The methods fall into four main types:-

(1) the "Climato-Dynamic" method of smoothed processes, that is of 5-10 day averages of different meteorological elements up to say 10,000 ft. These have been much used in the U.S.A. by Rossby, Willett, Namias and others, and in Germany by Baur, combined with the use of analogues.

(2) the pure "Climatological" method, the extrapolation into the future of curves of the elements by harmonic analysis, correlation, etc. This is used extensively by climatologists.

(3) the "Synoptic-Statistical" method devised by Multanovsky in Russia, and used there by him in both the Czarist and Soviet regimes.

(4) the method of "Analogies", used by Lamb in England and Elliot in the U.S.A.

On examination of these methods to determine the possibility of using them in the Southern Hemisphere in general and Australia in particular it has been found that

(1) The synoptic charts for at least half the hemisphere, with upper level observations, would be required.

(2) There are very marked differences between processes in the Northern and Southern Hemispheres, for example:-

(a) Most of the above methods were developed for latitudes between 40 and 75, while Australian latitudes are 0 - 40;

(b) Statistical averages of elements in this region yield little of value as processes here are mostly sinusoidal.

(c) There is a big difference in the distribution of land and sea in the two hemispheres and therefore in the distribution of sources of energy.

<u>MULTANOVSKY'S COLLECTIVE CHARTS</u>

The most promising approach to extend forecasting in Australia seemed to be the development of a method based on synoptic charts, and attempts were made to use the Multanovsky method. In its original form (in Russia) this consisted of plotting "collective charts", which showed the concentration into different areas, or along different axes, of the positions of anticyclonic centres, cyclonic centres, ridges and troughs for some definite phenomena (e.g. drought). Multanovsky's investigation showed that in the European sector of the Northern Hemisphere there are 5 different "axes" along which anticyclonic centres proceed, and since action can be the result of Anticyclonic processes along combinations of two axes, there could be at least 9 different types of anticyclonic action, each of which is preceded by a more or less definite distribution of anticyclonic and cyclonic centres on the chart for a definite period, and each connected with definite types of weather in different parts of Russia. Multanovsky looked for analogues in his collective charts, and also, by constructing collective charts for current periods, found some empirical rules for the movement of centres, in particular, establishing the idea of "natural Periods", which in his earlier definition are the times taken for areas of cyclonic centres to be replaced on the collective charts by areas of anticyclonic centres. From the collective charts for natural periods, forecasts for extended periods (4 to 7 days) were possible.

APPLICATION TO AUSTRALIA

In Australia, investigation soon showed that

(1) The above idea of "natural period" did not apply, owing to the fast west-east movement of centres.

(2) Anticyclonic "axes" are very different from the multiple axes found in Europe - here there is only one axis for each month, and always lying along a parallel.

The processes in Australia thus depend on the latitude of moving anticyclones. All processes were divided into three main types:-

Type 1 - movement of anticyclones to the north of the normal track, or with a northerly component.

Type 2 - normal, or a little to the south of normal, movement.

Type G - movement to the south of normal.

Furthermore movement of each type can be sub-divided according to whether there is present a quasistationary blocking High over New Zealand (sub-type b) or not (sub-type a). Thus there are at least 6 main types of development for each month, but not necessarily 72 types for the whole year, as some developments are common to several months.

It was found that if two cases are compared when an anticyclone moves along the same particular latitude, either with or without a blocking High over New Zealand, there is usually a similar distribution of cyclones in both cases. On the above reasoning the first "collective charts" for Australia were plotted, one each for the summer season (January) and winter (July). For the summer chart, all cases with similar movement of the col over Australia (it is difficult always to find the exact position of an Anticyclone in January) were investigated and the tracks of anticyclonic and cyclonic centres and cols plotted on the same chart, as well as the successive positions of a definite point in the pressure field in relation to an anticyclonic centre if the latter is indeterminate. Most processes in summer start with the formation of a col between longitudes 115 and 120, formed as a result of the approach of a new trough towards South-western Australia, combined with the existence of the thermal low over the North-West. The col then

moves eastwards with a very small north or south component, and the "natural period" of the col is defined as the interval between the appearance at about Long 115 of successive cols.

For the winter charts, owing to the absence of the heat low, there is no well defined col, butthe positions of anticyclones and cyclones can be determined over the continent with far more certainty. Winter processes (July) are considered to begin when a trough or cyclone appears about Long 130, and usually at the same time a new anticyclone or ridge, moving from the west, forms over the South-west coast of W.A. The "natural period" for winter processes is the interval between the appearance at about Long 130 of two successive troughs of cyclones.

The mean duration of natural periods for both January and July is about 4 days, the range of periods being from 3 to 7 days. In both cases the natural period is the full wave of a sinusoidal process, but with different phase.

Collective charts for other months were then constructed, and it was found that for April, May and June the full wave natural period is longer than for January or July, and for some processes a half wave only was taken as the natural period.

CLASSIFICATION OF TYPE SEQUENCE AND USE IN FORECASTING

The question then arose, "how can many similar processes be represented by sequences of charts?". There were several possible methods:-

(1) All cases of similar processes could be represented by one most typical sequence (used by Lamb and many others).

(2) All cases could be represented by ideal charts (Elliot and collaborators).

(3) All cases could be represented by sequences of collective charts as defined above.

(4) All similar cases could be represented by sequences of mean isobaric charts, which could be constructed by either of two methods:-

(a) Construction of mean pressure fields for each synchronous stage of a process by plotting and averaging the pressure in each 5 degree square.

(b) Construction of mean pressure field by finding the centres of gravity of areas with cyclonic centres, anticyclonic centres, ridges, troughs and cols. The contours of this chart should then be the most representative contours for the particular stage of the process.

The method 4(a) was chosen as offering the greatest possibilities, and for each month about five most representative cases of each type of process over a period of 5 to 7 years were selected, and mean pressure fields constructed for 3 stages of the process. A summary of the types for certain months has been given by Karelsky (1952) in the roneoed paper "The classification of Australian Weather Maps into type sequences".

Investigation then continued into methods of using the type sequences for forecasting the pressure fields 3 to 6 days ahead. It was found that in many cases successful forecasts could be made by similarity of type sequences alone. From the type sequences for the current or neighbouring months the type and positions most similar to the current and prognostic isobaric charts are chosen, and the forecast made either from the type sequence, or preferably by further choosing from the catalogue of actual chart sequences used in the construction of this type, the most similar process which has occurred during the past few years. Often however similarity alone is insufficient and often it is difficult to find a similar type. For such cases it would be helpful to investigate:-

(1) The change with time in the position of the boundary line between easterlies and westerlies on the M.S.L. charts.

(2) Deviations of the real processes from "normal" types.

(3) Deviations of isallobaric fields from "normal" fields.

(4) Processes on upper level charts during each type.

For practical use the weather forecast is more necessary than the forecast of pressure fields, and for this purpose the investigation of the distribution of temperature, rainfall and winds for each type is essential. From a brief

investigation of temperatures and rainfall for January it seems that in many cases these elements can be successfully forecast if the pressure field forecast is correct.

OTHER USES

The type sequences obtained for the different months are useful not only for weather forecasting. The mean types also yield:-

(1) The mean position and mean movement (velocity and acceleration) of lows, highs and cols.

(2) The mean positions and direction of movement of fronts.

(3) The mean areas most favourable for frontogenesis and cyclogenesis.

(4) The possibility of constructing the ideal general circulation of the atmosphere by dynamical rather than climatological methods. Earlier it was shown that Bergeron's "Dynamic Climatology" methods could not be successfully applied in the Southern Hemisphere, but a useful alternative method could be devised from the "ideal pressure sequences" instead of working with mean monthly pressure charts of a purely climatological character.

CONCLUSION

In conclusion, many theoretical and practical questions arise in connection with extended forecasting by dynamical methods, the most important being:-

(1) It is well known that the belt along which the dynamic highs of Australia move eastward, itself moves north and south with the Sun, and the movement clearly depends on the distribution of the sources of energy, but no quantitative investigations have been made. It would be interesting to seek an explanation of the extremely northern or southern tracks of anticyclones in individual years and months, and also to find a reason for the existence or absence of a blocking high over New Zealand.

(2) The structure of the moving highs. It would be interesting to know the properties of the air masses moving on the north and the south sides of the anticyclones, and the connection between their changing properties and the distribution of sources of energy.

(3) Incorrect forecasts (both short period and extended) are very often due to the new development of cyclones over Australia. It would be interesting to investigate the causes of new developments (a) in westerlies (i.e. at sea level) and (b) in easterlies.

(4) The conditions necessary for cold outbreaks of Antarctic air over the Australian continent.

REFERENCES

BERGERON, T.	1932	Richtlinien einer dynamischen Klimatologie, Met. Z.
BJERKNES, V. and collaborators	1910	Dynamic Meteorology and Hydrography, Washington (Carnegie Institution).
HOGAN, J. and MAHER, J.V.	1946	The Possibilities of short-range (5 day) Weather Forecasting in Australian and Adjacent areas, Melbourne (CMB roneoed paper).
KARELSKY, S.	1952	The Classification of Australian Weather Maps into Type Sequences, Melbourne (CMB roneoed paper).