Most auroral data are concerned with observations from single stations, whereas it would be highly desirable to know by means of some index the auroral condition right from the auroral zone to the lowest geomagnetic latitude at which the display is seen, so as to obtain a complete evaluation of the auroral activity. No suggestion can be made at this stage, and in the meantime New Zealand, Campbell Island, Tasmanian and Australian observations are to be dealt with separately. Brief mention was made of the apparently great expansion and contraction of the auroral zone in the Southern Hemisphere in sympathy with the solar cycle.

WEATHER FORECASTING TO-DAY.

By J. F. Gabites, N.Z. Meteorological Service.

The preparation of a weather forecast takes place in three distinct phases. First there is the assembling of the observational data, then the second phase of diagnosis when the present state of the atmosphere and its motions are analysed, and the third phase of prognosis when the atmospheric motions are projected forward through finite time intervals and the future characteristics of the air are assessed.

The First Phase—Observation.

The collection of data improved considerably during the war years, both through the extension of the observing networks, especially into the upper air, and through the provision of speedier, more efficient communications. Teletype and radio networks exclusively for meteorological purposes are now standard practice.

The observational requirements may be examined from the theoretical aspect. For a mathematically complete specification of the state of the atmosphere we would require a mass of observational data approximating to continuity in both space and time, to enable the construction of the scalar fields of pressure, temperature, density and humidity, the vector field of motion, and the time differentials of those fields.

In practice the meteorologist must content himself with a series of samplings at strategic intervals of space and time. The system is to take simultaneous observations at points sufficiently close to reveal the significant space variations of the elements, and repeated at sufficiently short time intervals to reveal significant time variations. Closer, more frequent, observations would merely load the communication systems unnecessarily.

The International Meteorological Organisation has recently recommended a suitable compromise on the basis of war-time experience. At low levels variations are rapid, and surface observations not more than 50 to 100 miles apart over land, or 300 miles apart over oceans, seem desirable. They should be available at least every three hours from nearby areas and every six hours from more remote regions.

Complete upper-air observations appear desirable from points not more than 200 miles apart over land, or 600 miles over the oceans, at six-hourly intervals.

The necessary horizontal extent of the observational network is related to the dimensions of the features to be shown, such as anticyclones and depressions, and to their speeds of movement. In temperate regions forecasts for periods of two or three days ahead appear to require data from at least a sixth of the earth's surface. To give an illustration, a depression developed just west of Perth on 11th May, 1947. Only 48 hours later it had travelled 3,000 miles and was passing just south of New Zealand, causing gales in the South Island.

The same example illustrates the natural handicap under which the forecaster works in New Zealand. Although reports are received from points up to 3,000 miles away in directions from west through north to north-east, New Zealand is completely unguarded in directions from west through south to east, with the exception of the reports from two isolated islands 500 miles off the coast, Campbell Island to the south and Chatham Island to the east. The depression from Western Australia did not again pass within 700 miles of a reporting station until it reached New Zealand; its progress and development meantime could be deduced from only the most indirect evidence.

Of the available land areas, Australia and New Zealand have a reasonable density of surface observations during daylight hours, but there are some conspicuous gaps in the Pacific Islands since the withdrawal of the military stations. At night, unfortunately, the networks are very meagre in New Zealand and the Islands. This deficiency is aggravated by the available observations made in darkness being inherently less informative than daylight observations. It is a major difficulty in a sparsely-populated country like New Zealand to find people in suitable locations who are willing and able to make regular reports during the night or early morning, punctually, 365 days per year. The community should be grateful to those light-house keepers, Post and Telegraph employees, radio operators and aerodrome caretakers who so conscientiously provide the basic information.

The war accelerated enormously the development of upper-air networks, but unfortunately peace has seen the closing of many stations. This is particularly true in the South Pacific, where at one time over thirty radiosonde stations were operating; but now only twelve remain. Only two of these are outside Australia.

Upper-wind observations benefited during the war by the use of radar instead of visual means for following pilot balloons. By this means winds could be measured to high levels regardless of cloud or weather. Again, in the South Pacific the war-time networks have not been maintained, and at the moment only two radar wind stations are still in operation.

The Second Phase—Diagnosis.

In the field of diagnosis very little that is really new has emerged from the war. Rather has there been an introduction into everyday forecasting of certain analytical techniques hitherto confined to research.

The methods of surface analysis in temperate regions have not changed appreciably. The forecaster still draws isobars and fronts on the surface weather map, and deduces the characteristics of the air masses mainly from the temperatures, humidities, cloud forms and hydrometeors.

The greater volume of upper-air data now available has increased the part played by upper-air charts of various sorts. Before the war, tephigrams and adiabatic charts were in regular use for studying the vertical variations of pressure, temperature and humidity, but analysis of their horizontal variations was little developed, and mainly confined to pressure charts for certain fixed levels, such as 5,000 and 10,000 feet. In Germany, however, there had been in routine use for some years pressure-contour charts, which, instead of showing the pressures at fixed heights, showed the heights of fixed-pressure surfaces such as 1,000, 800 and 500 millibars.

Early in the war Dr. Petterssen, a prominent Norwegian meteorologist, took charge of the Upper Air Section of the British Central Forecasting Office, and, after a series of comparative tests, introduced the pressure-contour charts there. United States meanwhile had become deeply committed in her vast training programme based on the fixed-level charts, and was not able to make a general change until late in 1945.

Construction of Contour Charts for at least the 700 and 500 millibar-pressure surfaces, corresponding to about 10,000 and 18,000 feet, is now a standard routine in most services. These charts possess all the virtues of the old fixed-level charts, and others besides. They can also be constructed much more speedily from the data normally available.

Tropical meteorology was in a very primitive state at the outbreak of war. The advances made since, however, suggest that this war may have done for the tropics what the 1914-18 war did for the temperate regions. During that war a close network of observing stations on the coast and in small vessels off-shore enabled the Norwegians to study the detailed structure of depressions and evolve their frontal theories. They established the life history of the depression from its birth as a wave on the surface of separation of two air masses of different density, to its death as an occluded cyclone. Complex structures may now be identified from relatively sparse data. No such synoptic models had been evolved for tropical disturbances. It was not until observation stations were established throughout the tiny islands of the South Pacific, that a comprehensive picture could be obtained, unobscured by continental influences or local diurnal effects.

Meteorologists in the forward areas were too busy to make much immediate contribution to the broad theoretical aspects. However, in 1943, C. E. Palmer (N.Z. Meteorological Service) was invited to take charge of the Institute of Tropical Meteorology being established at San Juan (Puerto Rico) as a joint project of the U.S.A.A.F., U.S.N. and U.S. Weather Bureau for research

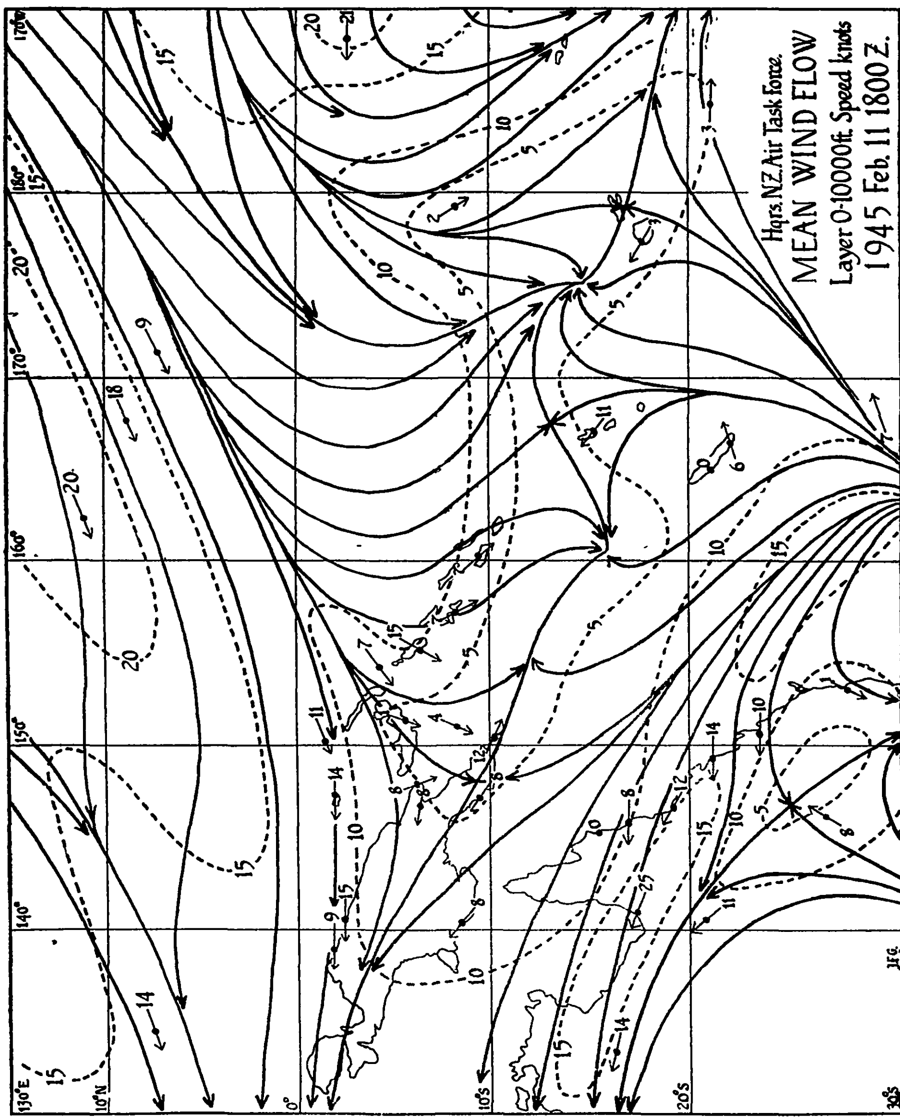

Fig. 1.—Example of routine wind flow analysis in tropics.

and the training of forecasters. Under his direction current knowledge was systematised, and particular weather patterns came to be associated with certain wave-like sinuosities in the air streams commonly occurring at pressure troughs. It was after his return to New Zealand that the more spectacular advances in technique were made.

New Zealand meteorologists experimented with a form of stream-flow analysis well known in oceanography but largely overlooked by meteorologists since it had been used early in the century by V. Bjerknes.

A major problem of the forecaster is that of detecting and predicting vertical motion, because it is ultimately ascent of moist air which produces cloud and precipitation. Vertical velocities of the order of one centimetre per second may be highly significant, but are far beyond the range of instrumental measurement by any known means. It was found for the tropics that, with a good network of upper winds and a careful analysis of the fields of motion in the lowest 8,000-10,000 feet of the atmosphere, the horizontal divergence or convergence could be estimated. This gave a measure of the ascent out of the layer or descent of air into the layer. Quick methods of computation were devised. Figs. 1 and 2 show an example of a routine analysis. The estimations are less accurate than those obtained by laborious field geometry, but the approximations appear justified by results.

Much research has still to be undertaken, but this promising diagnostic method has already revealed something of the structure of tropical disturbances and the normal synoptic models.

The Third Phase—Prognosis.

The methods of prognosis have not made any spectacular advance. This does not imply that the quality of the forecasting has not improved. The extension of the observational facilities, especially into the upper air, allowing the more complete and confident application of known principles, and the wealth of experience gained during the war when data were at a maximum, have increased the reliability of the forecasts. Perhaps the real advance lies in the better understanding of the processes taking place in the atmosphere. Capable brains have been delving deeper into the hydrodynamics of the baroclinic medium. A critical re-examination of many of the traditional equations has revealed that some terms hitherto dismissed as negligible are on the contrary of some significance.

The major problems are still those of predicting pressure changes, because pressure patterns, in the temperate regions at least, still give the best approximation to the horizontal flow of air, and of predicting vertical motion because cloud and rain are due to ascent of moist air.

The method of predicting the pressure field introduced by Petterssen in 1933 is based on the pressure and isallobaric (pressure change) fields. The movement, acceleration and intensification of pressure systems, may be extrapolated without any assumptions being made about the physical processes involved. The method has limited application in New Zealand owing to the impossibility of constructing accurate isallobaric fields over the surrounding sea areas and to the masking effects of the rugged topography on the fields.

Early in the war Professor Rossby at Chicago publicised a method of computing the pressure changes due to the horizontal transport or advection of air of a different density. Estimates were made from a hodograph of the wind vectors for successive levels aloft. While the method has its uses, it treats only one term of the total pressure change. The elusive convergence term often has the same order of magnitude.

In England Dr. Petterssen's team made a more rigorous exploration of the theory of pressure changes and devised another convenient method of computing the advective contribution from upper-air charts. They attempted to estimate the convergence term also from the difference between the observed winds at different levels and those computed from the upper-air charts. Departures from the geostrophic values would be due to convergence. The present accuracy of the observations proved insufficient for any reliable estimates.

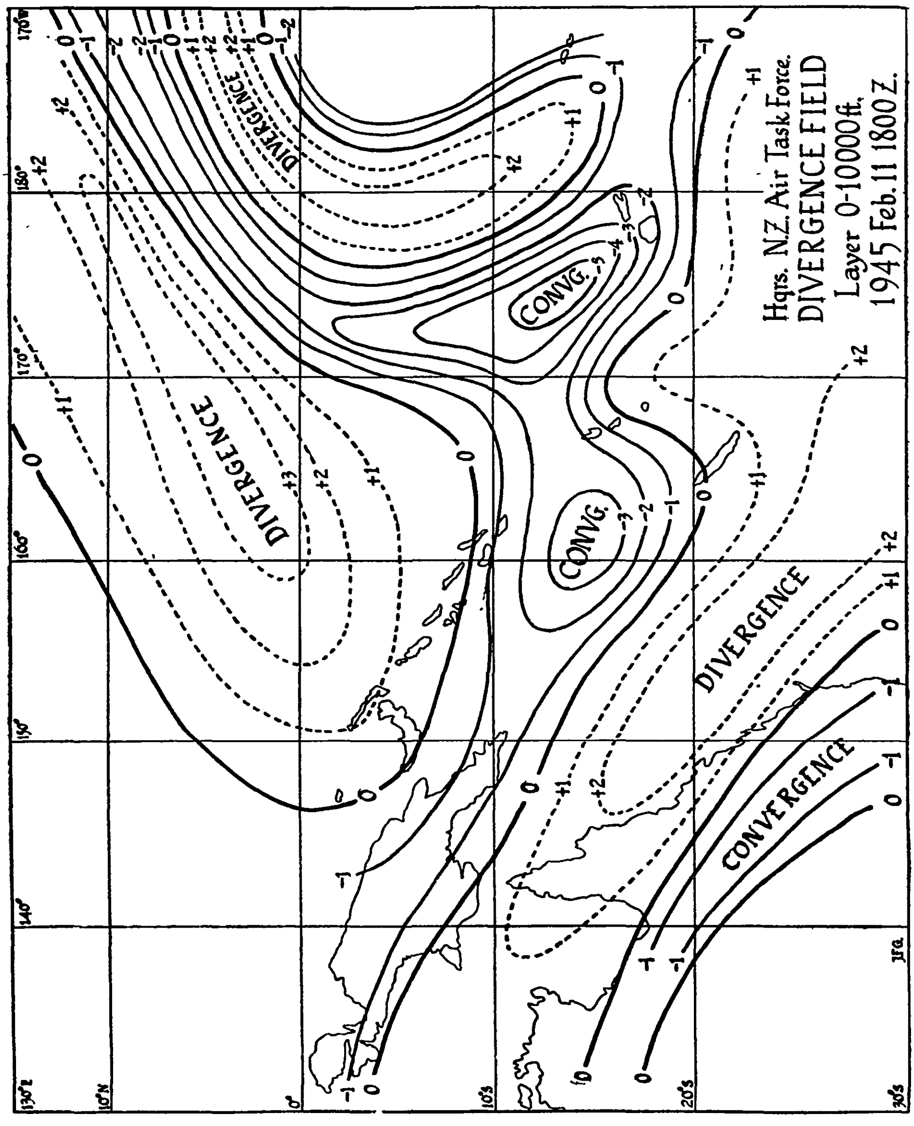

FIG. 2.—Divergence-convergence patterns in lowest 10,000 ft. of atmosphere, with relative intensities, estimated fiom wind flow patterns in Fig. 1. Horizontal convergence implies ascent ot aii out of layer and divergence, descent into layer.

Professor Rossby at Chicago made another attack based on the assumption of conservation of absolute voiticity in an air column. The absolute vorticity is the sum of the vorticity relative to the earth and that due to the rotation of the earth itself. Air moving to different latitudes must continually readjust its relative vorticity to compensate for variation of the earth's contribution. As a result it describes an oscillation between limiting latitudes. Slide rules or graphical means are available for the rapid computation of the future trajectories of selected particles of air on, for example, the 700 millibar surface. Thus the future flow patterns can be predicted. Unfortunately converg- ence appears again to render the estimates unreliable on at least a proportion of occasions.

Experience in England and United States during the war seems to indi- cate that the average error in the 24-hour prognosis of frontal positions by present methods is not likely to be reduced below about 100–150 miles, corres- ponding to errors of four or five hours in timing. These errors would be consistent with a 5 m.p.h. uncertainty in speed of movement. In New Zea- land we are less favourably placed. We are fortunate if we know a front's present position with that accuracy. The front which will be arriving over the country in 24 hours' time is probably 500 or even 1,000 miles out over the South Tasman at present, and we are lucky if ship reports chance to show its present position within 100-200 miles.

Even in regions with more favourable networks, incipient frontal waves may slip through undetected and develop into active depressions within 12 or 18 hours.

The longer the period of the forecast the greater the probable error in timing and intensity. Beyond 24-36 hours the weather is usually due to disturb- ances which have not yet formed. Forecasts of any great precision beyond 24 hours are usually possible only when a large, slow-moving anticyclone seems likely to dominate the situation for some time. Some regions are more favoured than others in the persistence of their anticyclones. New Zealand unfortu- nately lies in a region of fairly rapidly-moving anticyclones.

The importance to military operations of forecasts for periods longer than 24-48 hours led to investigations of several methods, especially in the U.S.A. Probably the most successful method there is the one originally tested at Massachusetts Institute of Technology and now used by the U.S. Weather Bureau in preparing its rather generalised 5-day forecasts. It is based on the principle that long-term trends, which are masked by the complexity of the day-to-day weather maps, may be revealed by charts of the five-day-mean values of the elements. These patterns tend to be related to the mean strength of flow of the westerly winds around the globe. For example, during periods when the westerlies are strong and the so-called "westerly zonal index" is high, disturbances tend to be widely spaced, fast moving and not very intense. In low-index periods the north-south movements of air are greater, and dis- turbances often deep and slow-moving. On the basis of these trends the U.S. Weather Bureau issues 5-day forecasts twice a week, indicating the nature of the anomalies in temperature and precipitation relative to the normal values.

In New Zealand use is made of the general principles, but a precise estimate of the zonal index itself is impossible owing to the complete absence of observations east and west of New Zealand in the critical latitudes. The index is necessarily based on indirect deductions.

In 1944 the application of the system to tropical forecasting was tested under the joint auspices of the U.S.A.A.F. and New Zealand Services. The result was negative owing to the obscurity of the relationship between tropical convection and pressure systems.

A method developed by Dr. Krick in California was tried, less successfully, in other regions during the war. He classifies the weather over a broad area into basic weather types, and assumes that a particular type will persist for a period of about six days, during which time the day-to-day patterns follow characteristic sequences. The identification of the dominant type at the outset enables forecasts to be prepared for periods up to six days. The system has not been successful in the New Zealand region.

To summarise, the recent advances have been in the direction of faster and more comprehensive collections of observational data rather than in im- proved techniques for forecasting. New Zealand, by its geographical isolation, is deprived of the full benefit of existing techniques. The most promising way of minimising its disadvantages appears to be in the improvement of available observation networks, with special emphasis on radar measurements of upper winds, and backed by adequate research into the fullest utilisation of the data.

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