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LONG-RANGE WEATHER FORECASTING

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Abstract. This article describes long-range forecasting, examples in Japan being mainly quoted.

The article stresses the approach with which the author is most familiar, namely that used in the Japan Meteorological Agency; it employs statistical, synoptic, and physical techniques which contain implicitly many of the considerations used in long-range forecasting in many countries.

After World War II, with an increase in quantity of upper-air data over the Northern Hemisphere, many studies of long-range forecasting were made in relation to the general circulation of the atmosphere. For the past several years the studies of long-range forecasting in Japan have been especially concentrated on the development of the techniques of seasonal weather forecasting.

The relevant approaches to long-range forecasting are now being developed from synoptic and dynamical viewpoints in many countries, by the use of data in both the troposphere and the stratosphere over the globe and electronic computers.

1. Introduction

In recent years, *short-range* weather forecasting methods have been improved considerably by direct numerical solution of the equations governing atmospheric motions, by the advent of high speed electronic computers, and by the development of sophisticated numerical models. In addition to short-range forecasts, two categories are usually recognized at present: *extended* and *long-range*. The extended forecast gives prediction of weather changes on a day-by-day basis over a period of say, 5 to 10 days. It is now well recognized that recently developed numerical prediction models have a potential value for extended forecasting. These models, however, have not been developed to the stage where they might produce forecasts of departures from normal weather over a month or a season.

Long-range forecasts, which are defined in this article as 1-month, 3-month, and seasonal weather forecasts, are at present one of the most important aspects of applied meteorology and climatology. These forecasts become increasingly important with agricultural, industrial, and commercial growth, and their utilization increases in each country. Especially, the importance of long-range forecasts to civilian economy is highlighted by long term losses suffered by adverse trends in weather, such as famine due to droughts or floods due to persistent heavy rain.

Although numerous efforts have been made to develop long-range forecasting techniques in many countries around the world, there is no universally adopted methodology and many of the requirements relating to long-range forecasts cannot be fully satisfied at present. It should be noted here that the object of long-range forecasting is not to predict the weather changes on a day-by-day basis over a long time period, but to predict the departures from climatic normals, using a variety of methods which will provide some clue, better at least than sheer climatological probability, to the nature of the weather expected several months ahead.

The purpose of this article is to describe, in general, the nature of long-range forecasts, the basic methods used to forecast mean temperature and total precipitation, and the various methods of long-range forecasts currently used. Examples in Japan are quoted.

2. Historical Review

A brief review of development to date of long-range forecasting techniques, and an introduction to their origins, is given.

Teisserenc de Bort (1883) first pointed out the existence of macroscale, time-averaged pressure patterns and developed the concept of *centers of action*. These are statistical aggregates of daily sea level pressure cells, such as the Bermuda high, Aleutian low, etc., which are closely related to long term prevailing weather conditions of certain strength and position. After a number of investigations on the development of weather types had been made it became clear that long term weather anomalies were linked to the behavior of centers of action and that it would be necessary to forecast their behavior in order to predict the weather.

During the early stages of practical long-range forecasting, pure statistical methods, such as simultaneous and lag correlation, were applied to the prediction of the behavior of centers of action. Walker (1910) studied the relationship between the SW monsoon precipitation in India and the sea level pressure over different parts of the world. Thus, Walker's North Atlantic, North Pacific, and Southern Oscillation became common knowledge to the world meteorological community. However, his study did not provide the key to predict the behavior of the three centers of action over periods of a month or more.

Multanovsky (1933) developed the concepts of *natural synoptic period* and *natural synoptic season*. During the natural synoptic period a series of disturbances, such as cyclones and anticyclones, tracks through prescribed areas. During the natural synoptic season the natural periods would be fairly constant in length.

Baur (1936) introduced the term *grosswetterlage*, which is defined as the mean pressure distribution (at sea level) for a time interval during which the essential characteristics of the atmospheric circulation over a large region remain unchanged. He proved, statistically, the existence of large-scale meteorological systems which steer the cyclones and anticyclones toward preferred directions. He also suggested that the cyclones and anticyclones might be steered by currents in the stratosphere. Multanovsky and Baur, and their followers, established many useful catalogs of circulation and weather types in the practice of long-range forecasting.

Rossby and Collaborators (1939) formulated a theory of planetary flow pattern in the atmosphere, which established a relation between the variations in the intensity of the zonal circulation of the atmosphere and the displacement of the semi-permanent centers of action. This work casts considerable light on the objective prediction of centers of action through the concept of vorticity redistribution.

During World War II, in the United States, sufficient upper air data became available for the systematic study of the relation between the behavior of centers of action and that of long waves in the upper westerlies. An effort was made to show that mean patterns had physical meaning and represented a class of planetary waves. Moreover, it was demonstrated that these mean circulation patterns led to fairly unique patterns of temperature and precipitation. Namias (1953) reviewed the 30-day forecasting experiments over the past 10-yr period in the United States.

After the War, with an increase in upper-air data, 5-day and monthly mean charts in the troposphere over the Northern Hemisphere have been constructed in many countries, and a remarkable development in long-range forecasting techniques has been made, mainly in the field of synoptic methods. Since the International Geophysical Year of 1957 special efforts have been devoted to the study of stratospheric phenomena relating to long-range forecasting, especially to seasonal weather forecasting.

In recent years, Namias (1968) made a historical review of long-range forecasting over the past century, which is a good reference on this subject.

3. Some Features of the General Circulation in the Troposphere

As stated previously, at present there is no universally employed distinct methodology of long-range forecasting. Although methods vary in weighting factors, they all have points in common and use the general atmospheric circulation as a foundation. What lines of attack should we pursue in order to improve our tools? It is obvious that a better understanding of the behavior of large-scale patterns in the general circulation is very important for more effective long-range forecasting. Fortunately, many theoretical and observational studies of the general circulation have increased our understanding of the causes of maintenance and fluctuation of the large-scale circulation patterns in the atmosphere. It has become evident that the grosswetterlage, including a prolonged, abnormal weather situation, is greatly affected by the behavior of the large-scale motion in the general circulation of the atmosphere. Accordingly, the ultimate purpose of long-range forecasting is to make a prediction of the variation of the long term general circulation.

The characteristic features of the general circulation in the troposphere are described in order to understand the so-called physical-synoptic approaches concerning long-range forecasting techniques.

3.1. CIRCULATION PATTERN IN THE TROPOSPHERE

At present in routine long-range forecasting it is customary to prepare pressure contour charts for any given level in the troposphere, e.g., 70 kPa (700 mbar) or 50 kPa (500 mbar), because these are less complicated in appearance than surface maps as a result of the diminished effects of land masses. Here, a pressure contour chart for any given level denotes a weather chart on which are drawn the contours of a specified, constant isobaric pressure surface, say 50 kPa.

Figures 1 and 2 illustrate the monthly mean, 50 kPa contour charts for the Northern Hemisphere in January and July. The contours are labeled in geopotential metres (gpm). Some features may be noted here. The vortex in winter splits off into two cells,

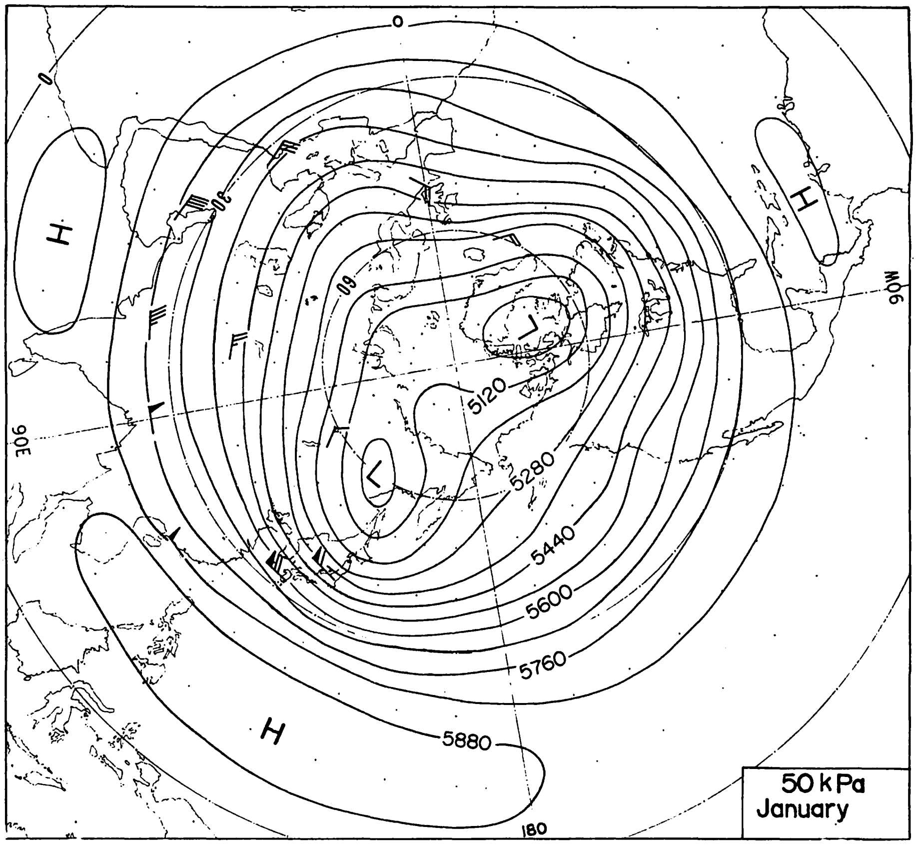


Fig. 1. Monthly mean 50 kPa (500 mbar) contour charts for January, in geopotential metres, (gpm). (After Wada, 1969.)

with a main center over the eastern Canadian Arctic and a secondary one over eastern Siberia. The former corresponds to the Iceland low and the latter to the Aleutian low on sea level maps, respectively. The sub-tropical high pressure cells are well developed over the Atlantic and Pacific in July, whereas in January the sub-tropical high pressure belt has a pronounced east-west axis along about 10°N latitude. The two major troughs at about 70° W and 150° E are thought to be induced by the combined influence on upper-air pressure and winds of large orographic barriers, like the Rocky Mountains, and heat sources such as warm ocean currents (in winter) or land masses (in summer). Wind speed is greatest where the contours are closely packed. Inspection of both charts reveals the existence of a broad westerly flow and a meandering flow, encircling the globe at mid-latitudes. Generally, the mean zonal westerlies in the temperate zone reach their maximum speed at an altitude of 10 km in winter.

The charts also show that the westerly current is not purely zonal but contains waves. In general, there are usually 3 to 7 long waves (Rossby waves) around the

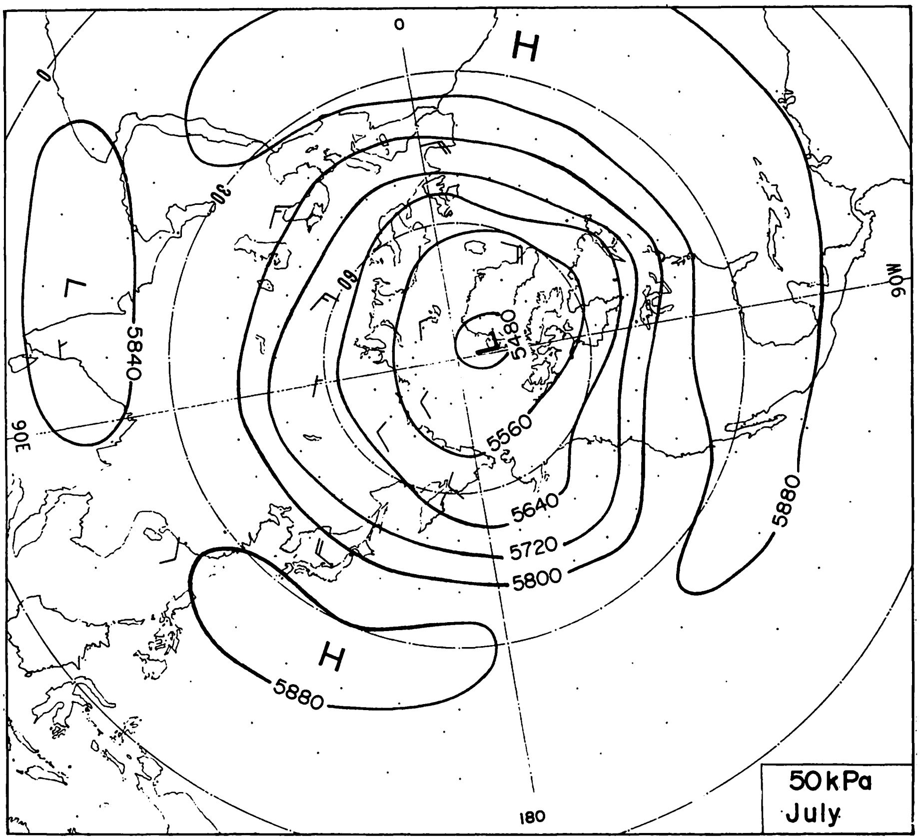


Fig. 2. Same as Figure 1, but for July. (After Wada, 1969.)

Earth in the westerlies, with a rather stable number of 3 or 4 being common on a monthly mean 50 kPa contour chart. In some cases, 1 to 2 long waves, which are usually seen in the stratosphere, are called *ultra-long waves* (very long waves).

3.2. ZONAL INDEX

The strength of the westerlies in the atmosphere is expressed in terms of *zonal index*. From the 50 kPa height it is possible to calculate indices expressing the strength of the zonal circulation in various wind belts. For example, the zonal index expresses the strength of the mid-latitude westerlies (computed between latitudes 35° and 55° N); the subtropical index (35° to 20° N), the strength of the east-west component of the trades or the components aloft; and the polar index (70° to 55° N), the speed of the west wind aloft. To simplify calculation of the zonal index, it is defined here as the height difference between 40° and 60° N at the 50 kPa level over the Northern Hemisphere.

Generally, strong zonal westerlies are representative of a high index, and marked meandering or cellular patterns occur with a low index. A roughly cyclic variation in the zonal index is called the *index cycle*, the period of which generally varies from 3 to 8 weeks. The index cycle is a fluctuation of the general circulation between high and low zonal index situations. An extremely high- or low-index situation rarely persists for over a month, resulting in abnormal weather throughout the world.

At present, one of the most important problems in long-range forecasting is to predict the future stage of the index cycle over the hemisphere, although the cause of the variation in index cycle is still uncertain.

3.3. POLAR VORTEX

The principal low in high latitudes or in the arctic region as revealed on the mean Northern Hemisphere 50 kPa charts is called the *polar vortex*. The month-to-month variations of the polar vortex in location are very complicated, but normally in mid-winter the center is located over low latitudes near North America; it moves northward until it approaches the North Pole in May and then retrogrades southward along the same course.

In general, the behavior of the polar vortex plays a leading role in the features of

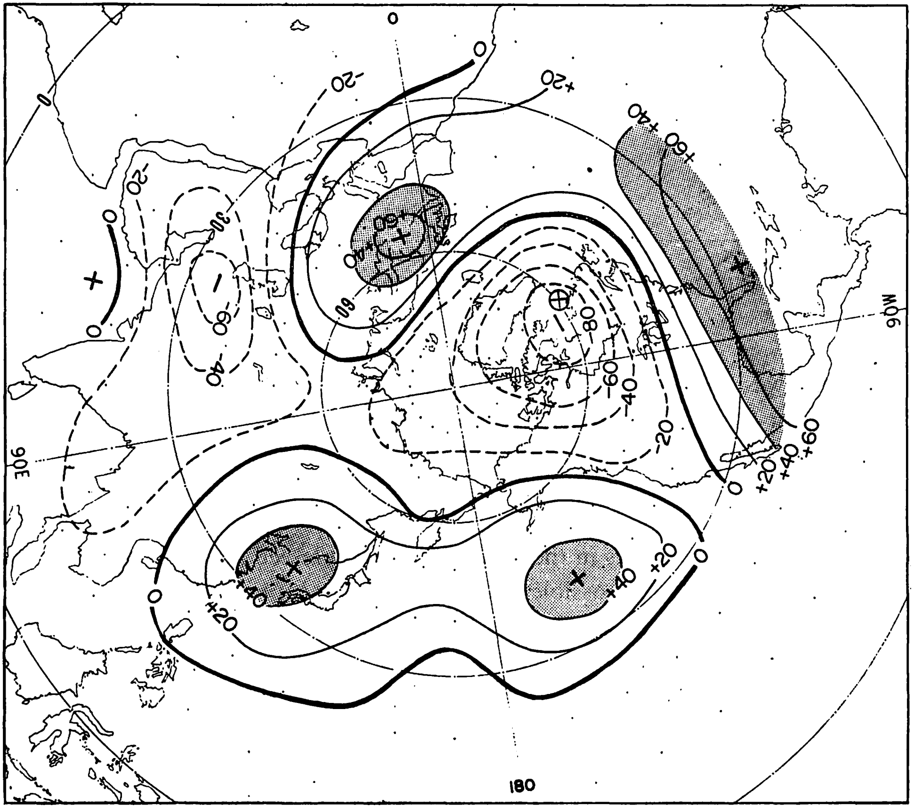


Fig. 3. Probability, in percent, of departures from normal of sign of the 50 kPa height for winter, with negative centers at 60° N, 60° W. (After JMA, 1962.)

mean surface temperature distribution in mid-latitudes. Furthermore, the polar vortex sometimes plays an important role in the combination of the pressure pattern over the Northern Hemisphere, as indicated by the following example.

Figure 3 shows the influence, on the circulation elsewhere, of an Icelandic negative, mid-tropospheric, height anomaly, particularly in Europe, the Florida peninsula, Central Asia, and Japan to the North Pacific area. The figure also indicates a similar pattern when the polar vortex is located in its normal position, the Davis Strait, in winter. In order to use the combination of pressure patterns in practice as a guide in the preparation of the Northern Hemisphere prognostic charts, a catalog of correlation fields between the monthly mean 50 kPa height at selected grid points and other points over the entire Northern Hemisphere is constructed for every season.

The polar vortex is one of the great centers of actions in the atmosphere over the hemisphere.

3.4. CLASSIFICATION OF THE CIRCULATION PATTERN

The circumpolar current of temperate latitudes usually is not symmetric about the Earth's axis of rotation. This asymmetry, which varies with time, is frequently so large that the zonal index no longer represents the true features of the current. Various classifications of the circulation pattern in the atmosphere have been proposed by many authors. For example, Girs (1960) made a study of the circulation pattern over the Northern Hemisphere and offered three basic circulation types, W, E, and C. W corresponds to a high index pattern, and the others to low index patterns.

In recent years, Wada and Kitahara (1971) made a detailed classification of the circulation pattern over the Northern Hemisphere. The entire Northern Hemisphere is divided into four quadrants, as shown in Figure 4, and the zonal index anomalies on the mean 50 kPa charts are calculated both for each quadrant and for the Northern Hemisphere. The patterns are classified into three types: two basic types *Z* (high index pattern), *M* (low index pattern), and sub-type *S* (mixed type). Types *Z* and *M* are defined as patterns in which three or more quadrants of the Northern Hemisphere have, respectively, either positive or negative values of zonal index anomalies, and

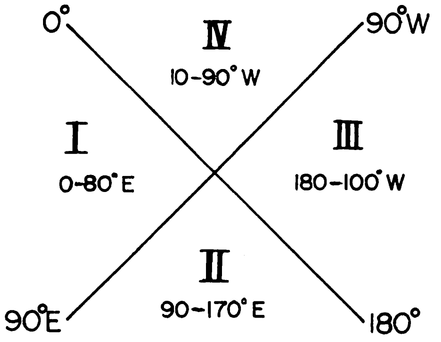


Fig. 4. Definition of quadrants used for the classification of circulation patterns over the Northern Hemisphere. (After Wada and Kitahara, 1971.)

type *S* as one in which two quadrants have positive and the others negative values. These three circulation types are further classified into 16 sub-divisions in all, with 10 basic types and 6 sub-types.

Following the definitions of classification, the monthly and 5-day mean 50 kPa height patterns over the Northern Hemisphere are classified objectively for the period 1946–1970, and model patterns for the classified types are constructed by making use of the composite maps of 5-day mean 50 kPa height anomalies.

Thus, the tropospheric circulation patterns over the Northern Hemisphere are classified by zonal index anomalies in each quadrant, resulting in a marked feature in the pattern for each classified type. Then, even if one only knows the classified type, one will be able to easily presume the outline of the circulation pattern over the Northern Hemisphere.

Furthermore, if there exist some regularities in the time series of classified patterns one may also be able to apply them to long-range forecasts in practice.

3.5. SEASONAL CHANGE OF THE GENERAL CIRCULATION

In general, the seasonal changes of the general circulation in the troposphere are very complicated. The upper westerlies vary in strength and extent according to the season. In summer their mean velocity is only half that of winter. Moreover, the westerly belt expands far into the tropics in winter, while in summer, subtropical high-pressure cells are situated near 30° latitudes at about 10 km altitude. It is understandable that seasonal processes in the general circulation are not continual and that they proceed in different ways during different years.

There exist, however, certain features in the seasonal change of the circulation. First of all, it seems probable that the complex changes in mid-tropospheric circulation may be obtained from the normal month-to-month changes in zonal index, 50 kPa height, or temperature.

It is known that the change of the zonal index from winter to spring shows a considerable peculiarity from year to year, and there is a remarkable irregularity in March in a long-term mean value; the zonal index gradually decreases with the passing of mid-winter, the decrease stagnates from the end of February through March and then in April it begins to diminish again. What significance is shown by the features in March from a synoptic viewpoint? The stagnation of zonal index in March has a close relation to the final warming in the stratosphere, as will be stated later.

Generally speaking, there is some tendency for a seasonal change in height of the troposphere over the Northern Hemisphere. With the passing of winter there is an increase of height around the pole, which reaches a maximum over the Pacific Ocean in summer. This process is reversed from summer to winter. However, the annual height changes in the troposphere over the Northern Hemisphere do not occur uniformly but show certain peculiarities. As an example, Figure 5 shows the normal changes of the 50 kPa height from March to April over the Northern Hemisphere. There are seen three marked positive regions in the figure: the Okhotsk Sea, Baffin Island, and Eastern Europe. This pattern is quite similar to that of June-July 1954,

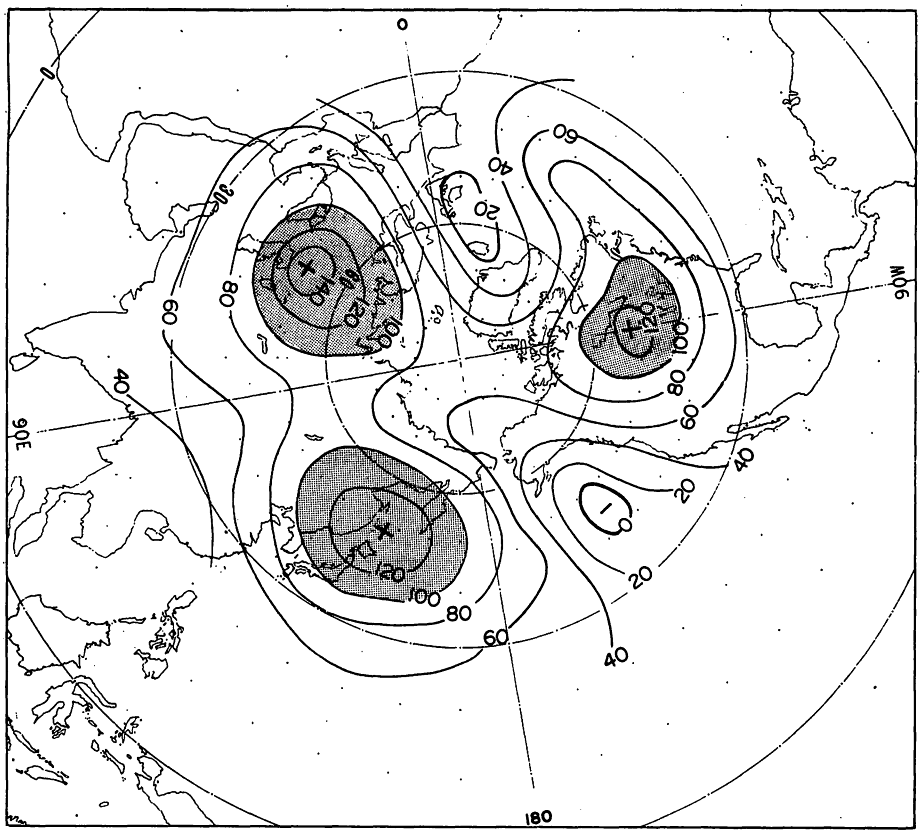


Fig. 5. Monthly mean normal 50 kPa height change from March to April (gpm). (After Wada, 1969.)

when abnormal weather persisted over many regions of the world, showing a large-scale *blocking* action in the troposphere. The blocking action leads, for an appreciable length of time, to meridional deviations of the normal-zonal, middle-latitude current of the general circulation, the zonal current being thus interrupted.

This fact gives a clue for summer weather forecasting; worldwide abnormal summer weather in mid-latitudes may be brought about by a time lag of seasonal change of height patterns in the general circulation, resulting in a large-scale blocking which should occur normally from March to April.

Wada (1971) pointed out some peculiarities in the seasonal change of temperature in the troposphere. There is a small decrease in the upper tropospheric temperature over the Tibetan Plateau from March to April, in striking contrast to the marked increase of temperature over high latitudes for the same period. However, a remarkable increase in temperature occurs over the Tibetan Plateau from April to May, and continues into August. This peculiarity gives some suggestion on the structure of the so-called Tibetan High, which has a great influence upon the weather in the *Baiu* season (rainy season from June to July) in Japan.

4. Some Features of the General Circulation in the Stratosphere

The stratosphere is defined as the regime of the atmosphere situated between the tropopause (10 km) and the stratopause (50 km), in which temperature generally increases with height. In the stratosphere the circulation patterns are less complicated in appearance than in the troposphere, and there only ultra-long waves are significant throughout the year. If the variations of circulation patterns in the stratosphere had a close relation with the grosswetterlage on the Earth through those in the troposphere then their relation would be a powerful tool for long-range forecasting.

4.1. CIRCULATION PATTERNS IN THE STRATOSPHERE

The flow at 3 kPa (at about 23 km) is mainly treated here because it offers the most nearly quiescent region of the atmosphere, with a persistent wind minimum which represents an effective decoupling of the tropospheric and stratospheric circulation systems.

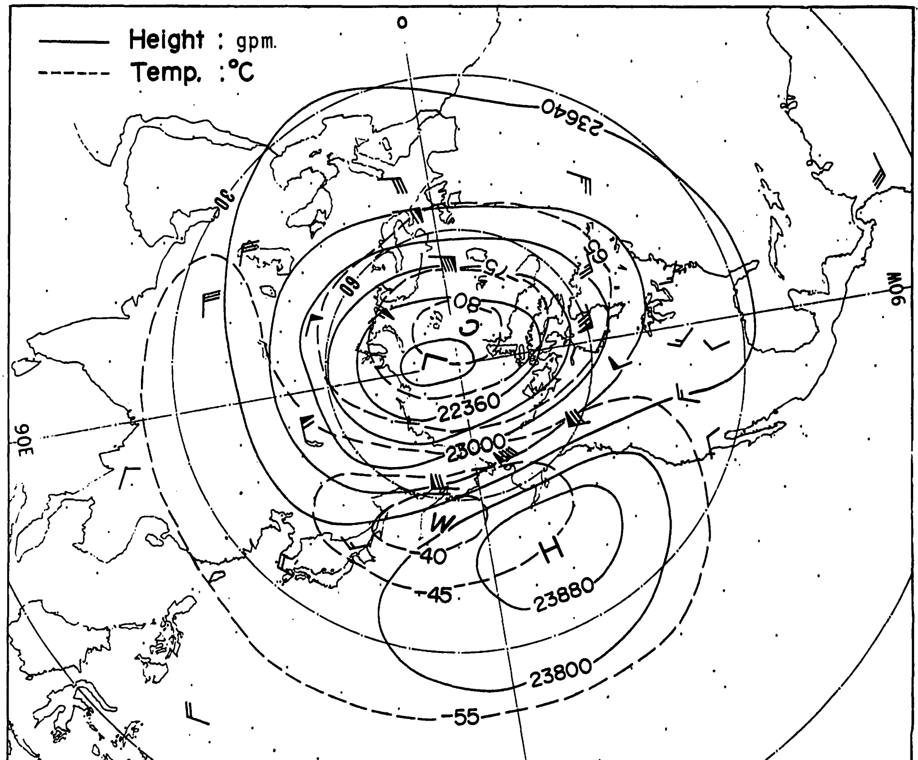


Fig. 6. Monthly mean 3 kPa chart for January 1967 (in gpm and °C). W and C show the centers of warm and cold cores, respectively. (After Freien Universität, Berlin, 1967.)

Figure 6 shows the monthly mean 3 kPa chart of the Northern Hemisphere for January, 1967. A well defined valley (L) of low pressure centers near the pole and is elongated in a particularly interesting fashion, resulting in almost complete coverage of the continental areas of the Northern Hemisphere by the cyclonic circulation. This low is called the *polar night vortex*. A high pressure system, considerably smaller than the polar night vortex, is observed over the comparatively large Pacific region. This high is called the *Aleutian high.*

It should be noted here that the Aleutian high in the stratosphere exists right above the Aleutian low at sea-level, and that the Iceland low at sea-level extends up to the stratosphere with a vertical conjugate through the mid-troposphere to the stratosphere.

From April to May the circulation pattern at the 3 kPa surface indicates a complete breakdown of the polar night vortex which has dominated the Northern Hemisphere winter.

In July the circulation pattern shows a stabilized situation in which a high-pressure warm-air core has developed over the polar regions and undisturbed easterlies cover the whole hemisphere, with a simple circular pattern. Quite similar patterns persist during the summer season.

The autumn chart for the Northern Hemisphere shows an asymmetry which is reminiscent of the 50 kPa-mean chart. The polar night vortex is usually established in September and is centered around the pole, with a cold center.

Thus, the seasonal changes of the general circulation in the stratosphere are not so complicated as in the troposphere. However, there are some dramatic events in the stratosphere which are never seen in the troposphere.

4.2. SUDDEN WARMINGS AND 26-MONTH OSCILLATION

One of the events in the stratosphere is a *sudden warming*, defined as a dynamic event in the stratospheric circulation. It is characterized principally by a temperature increase in the polar regions immediately above the stratonull level, greater than 50 °C over an interval 10 days or less, and accompanied by a disruption of the usual westerly zonal circumpolar flow of the stratospheric winter circulation. (The stratonull represents the level at which the meridional temperature gradient is most nearly zero in the lower stratosphere).

Sudden warming usually occurs with an elongation or a large displacement of the polar night vortex, which sometimes is accompanied by a large-scale blocking in the troposphere. Furthermore, in the Northern Hemisphere there occur two or three cases of sudden warming in mid-winter before the final warming from winter to spring. The timing of final warming, with a stagnation of zonal index in the troposphere, is extremely different from year to year, which sheds some light on the study of summer weather forecasting.

The other event is the *26-month oscillation* of the tropical stratosphere. In the tropical regions of the stratosphere the zonal wind alternates between easterly and westerly with an average period of about 26 months. The periodicity of 26 months in the stratosphere seems to be well established, though varing slightly in length of period. On the other hand, a biennial cycle has been found in many climatic series of meteorological elements in the world. It is quite interesting for long-range forecasters that these similar rhythms raise the question of whether these rhythms pertain to the 26-month oscillation in the tropical stratosphere.

5. One-Month Forecasting

The basic problems of long-range forecasting and the methods of routine practice of one-month forecasting are described in this section.

5.1. BASIC PROBLEMS

5.1.1. *Normal Values and Forecast Category*

The purpose of a long-range forecast is to give an estimate of the departures from normals of atmospheric circulation and weather. For this reason it is necessary to have available climatological normals for all elements considered, weather as well as circulation. The normals of surface meteorological elements are calculated for a 30-yr interval (1941–1970) based on the World Meteorological Organization (WMO) recommendation. However, the definitive normals for upper-air elements are not yet computed because the interval of observation is less than 30 yr.

In Japan the expected mean temperature and total precipitation are categorized into 5 categories: much above normal, above normal, near normal, below normal, and much below normal. The limits for the categories have been chosen so that they occur with unequal frequency; much above (or below) normal, 0.1, above (or below) normal, 0.2, near normal, 0.4. The category boundaries therefore vary a little from month to month and from one part of the country to another.

5.1.2. *Forecast Areas*

Long-range forecasts may be aimed at specific locations such as cities, geographical regions, countries, or even the entire Northern Hemisphere, depending on the user's requirements. It is quite natural, however, to settle the forecast areas for long-range forecasts in each country under the consideration of climatic conditions. From this viewpoint, a country should be divided into several areas with climatologically similar characteristics for monthly mean temperature and total precipitation by using statistical methods. Under a homogeneous climate for example, Japan is divided into 3 main divisions for long-range forecasts, with 12 subdivisions.

5.1.3. *50 kPa-Height Pattern and Grosswetterlage*

The fundamental part of the one-month prognosis is the mean and anomaly contour patterns of the 50 kPa surface, for those largely determines the prediction of prevailing temperature, total precipitation, and general weather. Hence, it is very important to study the relationship between the mean 50 kPa height, or its anomaly pattern in the broad areas, the mean temperature anomaly, and total precipitation in the country. Some examples in Japan are introduced here.

Basic flow patterns at a 5-day mean 50 kPa height in the Far East are divided into three types: trough, zonal, and blocking. Figures 7 and 8 show a trough type for temperature and precipitation, respectively. To the east of the trough type where a SW wind flows, surface temperatures are higher and precipitation is heavier than normal. But within the trough, cool weather and little precipitation are expected.

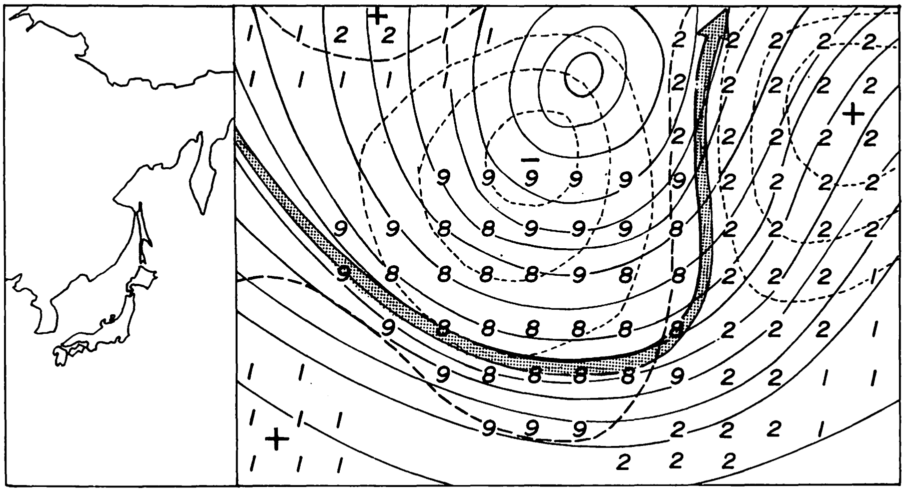


Fig. 7. A model pattern of the relation between the 5-day mean, 50 kPa height of trough type over the Far East and the 5-day mean, surface temperature anomaly over Japan (after JMA, 1962). 8, much below normal; 9, below normal; 0, near normal; 1, above normal; and 2, much above normal.

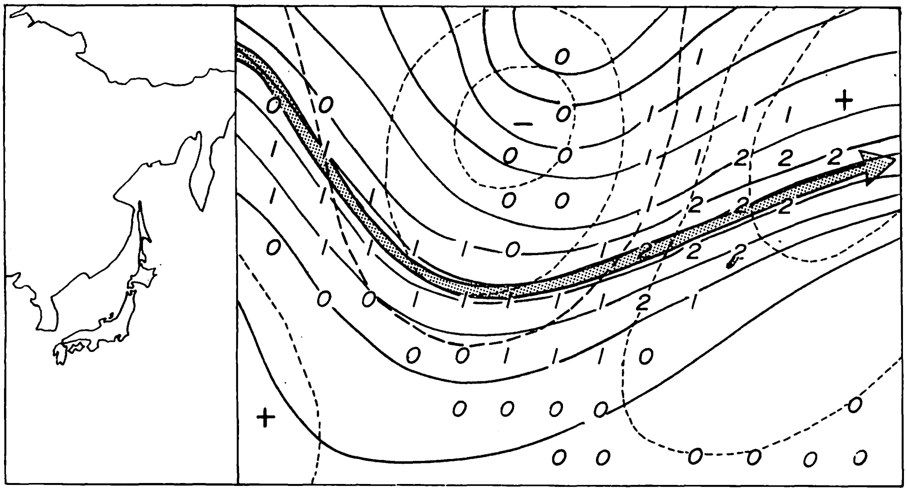


Fig. 8. A model pattern of the relation between the 5-day mean 50 kPa height (solid line) and its anomaly (broken line) of trough type over the Far East and the 5-day total precipitation over Japan (after JMA, 1962). 0, near normal; 1, above normal; 2, much above normal; others, below normal.

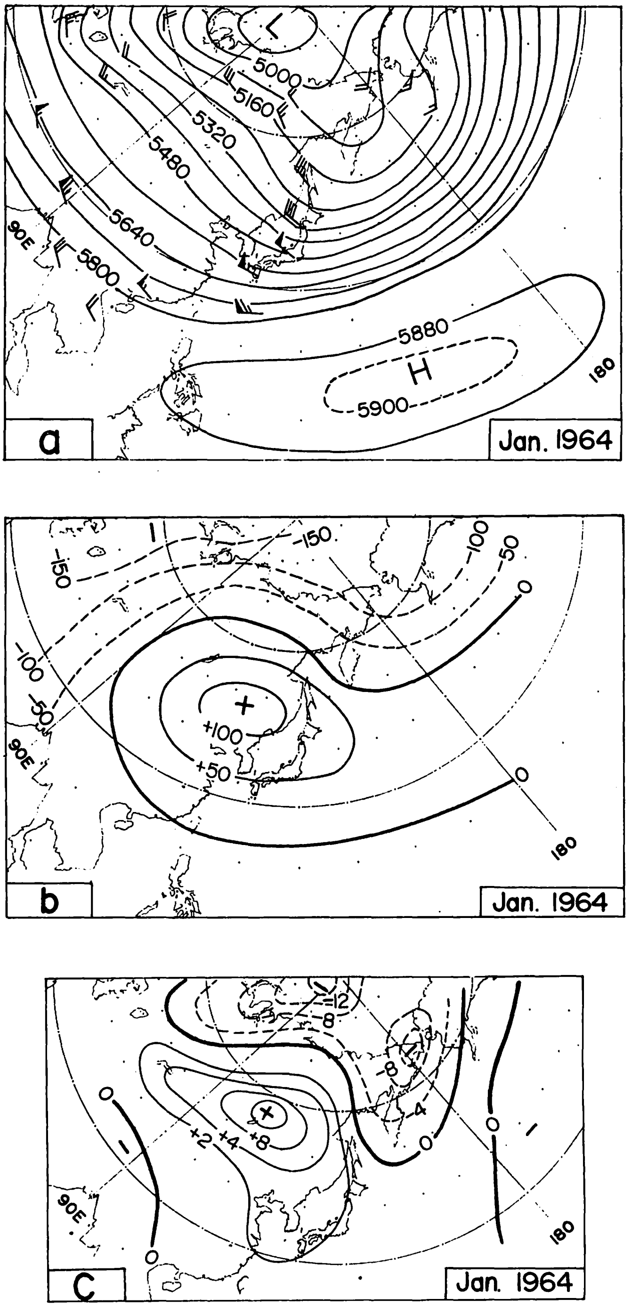


Fig. 9. (a) Monthly mean 50 kPa height distribution for January 1964 (gpm): (After Wada, 1969). (b) Monthly mean 50 kPa height anomaly distribution for January 1964 (gpm). (c) Monthly mean surface temperature anomaly distribution for January 1964 (°C).

An example of a monthly-mean 50 kPa chart and the grosswetterlage around Japan is shown in Figure 9. The mean planetary flow at 50 kPa for January 1964 indicates that a meridional flow prevailed over the Far East with an *S*-type pattern over the Northern Hemisphere; the circulation over the Pacific consisted of broad cyclonic flow with a deeper than normal trough over Kamchatka. At the same time, the subtropical high in the southern part of the Pacific was stronger than usual. As a result, a fast westerly flow prevailed over the North Pacific (Figure 9a).

The height anomaly pattern shows an extensive positive departure, as much as 100 m above normal, centered over the northeastern part of China (Figure 9b), while a large temperature departure, as much as 10 °C above normal, was observed around Lake Baikal (Figure 9c).

Under this flow pattern, a pronounced warming trend continued in Japan during January, with much precipitation over the Pacific side and light precipitation over the Japan Sea side. It should be noted in Figure 9 that the anomaly pattern of height is remarkably similar to that of temperature, although there is some discrepancy in their positions of centers.

5.2. TECHNIQUES OF ONE-MONTH FORECASTING

The approaches of one-month forecasting techniques may be considered most conveniently in three categories: (1) purely statistical, without physical interpretation, (2) physical-synoptic, involving the interpretation and understanding of the normal internal mechanics of the operation of the general circulation, and (3) hydro-dynamical, applying numerical prediction of the general circulation. The practical methods in each category are described, with some examples.

5.2.1. *Correlation Method*

It has long been recognized that a great deal of coherence exists in meteorological data, not only in space but in time as well. In general, the relation between two variables can be expressed by a linear correlation coefficient. As an example, the linear correlation coefficients between monthly, mean-surface temperatures at some selected stations in the world and monthly, mean-zonal indices at the 50 kPa level are calculated for January and July, as shown in Table I. It is found from Table I that in many cases the monthly mean temperatures have a significant relation to the zonal index for the Northern Hemisphere, with a better relation to the zonal index for the quadrant where the respective station is located. Especially, it is noticed that the correlation coefficients for January in Lyon, Kew, and Moscow, which are located at high latitudes, have significant positive values not only for the indices of each quadrant but for those of the Northern Hemisphere generally. This result lends support to the use of the zonal index in classifying the circulation pattern over the Northern Hemisphere.

Figure 10 indicates the simultaneous correlation field between the monthly mean temperature at Tokyo and the monthly mean Northern Hemisphere 50 kPa height for February. This pattern means that there is a close relation between the temperature at Tokyo and the 50 kPa height situation over the Northern Hemisphere. When the

TABLE I

Correlation coefficients between monthly mean temperature and monthly mean 50 kPa zonal index over each quadrant and the Northern Hemisphere for January and July (1946–1968)

Station	Month	0–80° E	90–170° E	180–100° W	90–10° W	Over N.H.
Helwan	Jan.	**0.46**	−0.29	−0.09	−0.22	−0.15
29°52′N, 31°20′E	Jul.	**0.43**	0.13	−0.26	−0.01	0.15
Tokyo	Jan.	0.19	0.27	−0.01	0.18	0.25
35°41′N, 139°46′E	Jul.	0.03	**0.69**	0.22	0.24	**0.49**
New York	Jan.	−0.34	−0.05	0.32	0.26	0.16
40°42′N, 74°01′W	Jul.	**−0.51**	0.24	**0.41**	0.16	0.09
Lyon	Jan.	**0.51**	**0.40**	0.16	0.12	**0.41**
45°44′N, 4°55′E	Jul.	−0.26	0.29	**0.61**	0.30	0.34
Kew	Jan.	0.38	**0.57**	0.22	**0.45**	**0.66**
51°28′N, 0°19′W	Jul.	**−0.44**	0.19	**0.54**	0.28	0.19
Moscow	Jan.	**0.48**	**0.42**	0.18	0.12	**0.42**
55°49′N, 37°33′E	Jul.	**−0.66**	0.00	0.06	0.35	−0.12
Oslo	Jan.	−0.06	0.27	0.25	**0.55**	**0.49**
59°56′N, 10°44′E	Jul.	−0.35	0.33	0.22	0.17	0.14

polar vortex exists at higher latitudes over Central Asia, i.e., when the high index pattern predominates over the Eastern Hemisphere, the temperature at Tokyo is very high because of a significant negative correlation, as shown in Figure 10, and vice versa.

The correlation method is very convenient, not only for monthly mean temperature forecasts but for monthly total precipitation forecasts. In Japan, lag correlation field maps between monthly mean temperature or total precipitation at 10 representative stations and the 50 kPa height over the Northern Hemisphere are constructed for time-lag series, 1 month to 11 months, and also linear regression equations are constructed for monthly mean temperatures and total precipitation at the representative stations, using significant high correlation coefficients on the lag correlation field maps over the Northern Hemisphere.

In addition to simple correlation, partial and multiple correlations are also applicable to long-range forecasting. In particular, a technique which has shown considerable and practical value in long-range forecasting is the screening method. A machine computation screens for the point (or element) of highest correlation. It then removes the effects of this correlation, finds the highest remaining correlation, and so on. This method is used to produce a multiple regression equation which expresses a predictand as a function of predictors. (When one knows X and would like to forecast Y, X is called the *predictor* and Y the *predictand.*) The techniques have been generalized so that it is possible to test up to several hundred predictors, by advanced computer techniques.

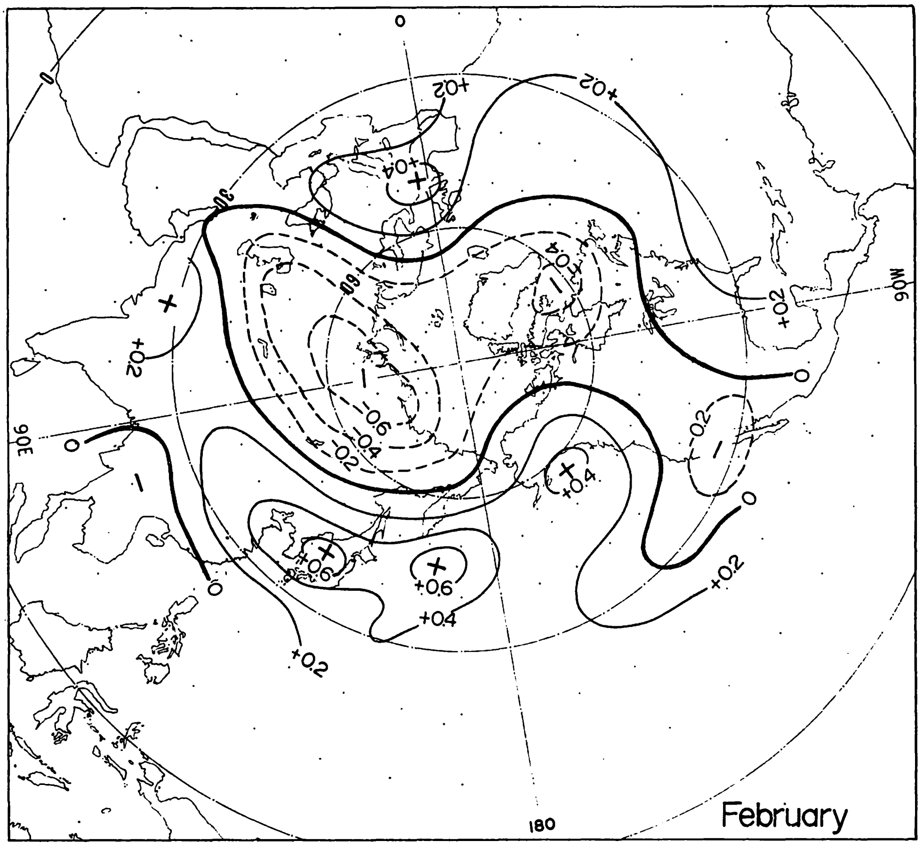


Fig. 10. Simultaneous correlation field between monthly, mean temperature at Tokyo and monthly, mean Northern Hemisphere 50 kPa height for February (1946–1965). (After Wada, 1969.)

An application of simple correlation methods to long-range forecasting was originated by Walker. However, such simple statistical methods have almost always produced disappointing results. This is due to the essential instability of the relationships between predictor and predictand in the long term. In other words, relationships that may hold at a high level of significance during a period of years, or even of decades, may become completely insignificant or even reverse themselves during another such period.

It is recognized today that searching for correlations without good physical reason to guide one is a hazardous undertaking, easily leading to discoveries which later turn out to be accidental coincidences of no prediction value.

5.2.2. *Periodicity Method*

The study of periodic variations in the weather has attracted many meteorologists and some major efforts have been made to find them. Thus far, however, no period has become firmly established other than the two obvious ones, the day and the year.

However, most meteorological variables show some periodic variations, which are sometimes referred to as *rhythms*, related to the basic period of a year.

In general, the periodic component can be estimated in advance from past values of the variable concerned, by using harmonic analysis, and the prognostic values can be extrapolated to the future. For the purpose of a one-month forecast it is known that there are 4 to 6 day, 10 to 12 day, and 20 to 30 day periods in meteorological elements. Especially, the 20 to 30 day period is found in the index cycle during wintertime, which occurs accompanied by the invasion of a cold air mass from the arctic region into middle latitudes.

This method is very useful when a dominant period continues for a long time. However, a weak point in this method is that there is no physical basis to decide whether a periodicity which appears can be extrapolated to the future.

5.2.3. *Analog Method*

Finding analogous situations to the current one in a space or time series is one of the practical long-range forecasting techniques. If there is available a data bank giving a most detailed description of past weather situations in a way which facilities comparison, it may be possible to select a past situation which in certain respects shows the closest agreement with the current one.

At present, the selection techniques are embodied by advanced computer techniques. In Japan, the most recent monthly mean 50 kPa height anomaly over the Northern Hemisphere is considered towards the end of each month by a forecaster who selects a group of analogs subjectively by comparison with the charts for the same calender month since 1946. A method of measuring the similarity between two charts is a measure of agreement in sign of height anomalies at each grid point (216 points). The agreement is expressed in percent and is calculated for both the entire Northern Hemisphere and the Far East area.

As an example, Table II shows the result of selected analogous months to the current chart of the 50 kPa height anomaly over the Northern Hemisphere for April 1972. As an example the circulation in 1946 shows a Z-type pattern, and the best analogy to the current circulation in April 1972. The agreement is 68% in sign of height anomalies over the Northern Hemisphere and 94% along 80° N. The 50 kPa patterns for 1946, 1948, 1967, 1962, and 1970 have high percentages of analogy; their patterns are quite similar to the one for April 1972, although the patterns are not presented here. These lists are then compared with the actual chart of April 1972 and differences between them are reconsidered. This examination may result in some years being thrown out and often results in some years being put in a different order of preference. Moreover, the most recent chart sequences of the 5-day mean 50 kPa height anomaly over the Northern Hemisphere are also compared to those of the past period since 1946, so that it is possible to select subjectively the 5-day mean 50 kPa height pattern sequences in past months which most nearly resemble those of the period just completed.

This method of selecting analogs is used effectively in the monthly routine; it often

TABLE II

Classified patterns and analogy, in percent, of 50 kPa height anomalies in April for past years with respect to April 1972, for the Northern Hemisphere. Z_{123}, for example, means that the zonal index anomalies in quadrants 1, 2, and 3 are positive, M_{123} that they are negative, and S_{23} that they are positive in quadrants 2 and 3

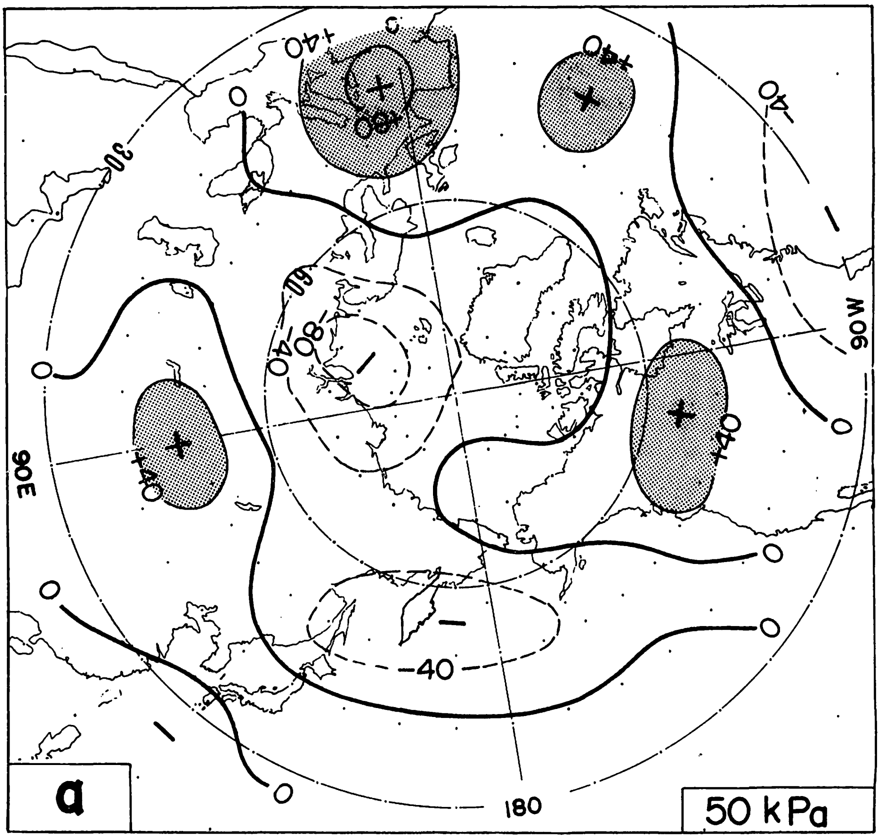
	1946	1948	1967	1962	1970	1964	1950	1965	1969	1963	1968	1949	1959	1954	1971
Classified pattern	Z	M_{123}	S_{24}	Z_{234}	Z_{123}	Z	S_{23}	S_{24}	Z_{124}	M_{134}	Z_{123}	Z_{134}	Z_{124}	M_{123}	Z_{123}
Percent	68	68	66	61	61	58	58	58	56	55	55	53	52	51	50
Mean SQ	51.1	64.0	58.6	48.5	49.4	64.1	60.5	54.3	58.2	54.4	53.3	60.7	54.1	61.0	56.2
80 N	94	94	94	92	72	86	61	72	61	67	56	94	22	19	22
70 N	83	72	67	67	100	94	50	81	72	61	78	72	75	19	61
60 N	74	67	53	61	65	56	35	42	58	8	71	81	35	61	44
50 N	58	56	75	78	61	39	61	62	50	72	36	47	67	67	50
40 N	82	68	75	53	75	60	61	64	72	75	58	29	58	42	75
30 N	50	64	61	32	35	44	69	49	43	42	31	37	58	65	31
20 N	44	74	35	71	26	59	71	47	38	88	79	29	41	53	68

	1956	1955	1958	1961	1947	1960	1957	1953	1951	1952	1966
Classified pattern	Z_{123}	S_{23}	M_{134}	Z_{123}	S_{14}	Z_{234}	M_{134}	M	M	Z	M_{134}
Percent	49	48	48	48	47	46	44	43	41	39	38
Mean SQ	67.9	63.1	64.5	63.8	74.6	58.9	63.7	85.8	75.2	66.6	79.1
80 N	6	42	72	28	47	25	39	58	28	44	28
70 N	75	56	78	89	39	44	44	17	22	67	42
60 N	50	53	24	35	69	47	22	44	39	35	28
50 N	54	28	44	61	42	61	33	60	47	14	40
40 N	42	57	78	56	56	49	69	40	31	54	49
30 N	67	57	36	37	32	47	53	31	61	33	47
20 N	35	47	18	38	38	24	50	53	41	41	18

gives forecasters information of unusual grosswetterlage in advance. However, it should be kept in mind that an analogous method is applied to long-range forecast under the hypothesis that if the present state of the circulation in the troposphere is any indication of the future, then cases which are similar in their large-scale pressure patterns should tend to evolve in the same way.

5.2.4. *Synoptic Method*

The large-scale pattern on the mean charts changes relatively slowly and determines the trend in the general types, whether stable or unstable, usually warm or cold. Thus, it is quite possible to make a one-month forecast from a synoptic viewpoint. For the one-month forecasts the 50 kPa fields of height and height tendency make it possible to compute kinematic displacements of singular features on the charts such as troughs and ridges, thereby assisting in preparing prognostic contour charts. In this case, suitable mean distributions, for example 5-day mean heights, are used, and it is



Figs. 11a–c. Model patterns of 50 kPa height anomalies over the Northern Hemisphere for heavy snowfall in Japan. (After Wada, 1969.) (a) Pattern for 25 days preceding heavy snowfall (*Z*-type). (b) For preceding 15 days (*M*-type). (c) For same day.

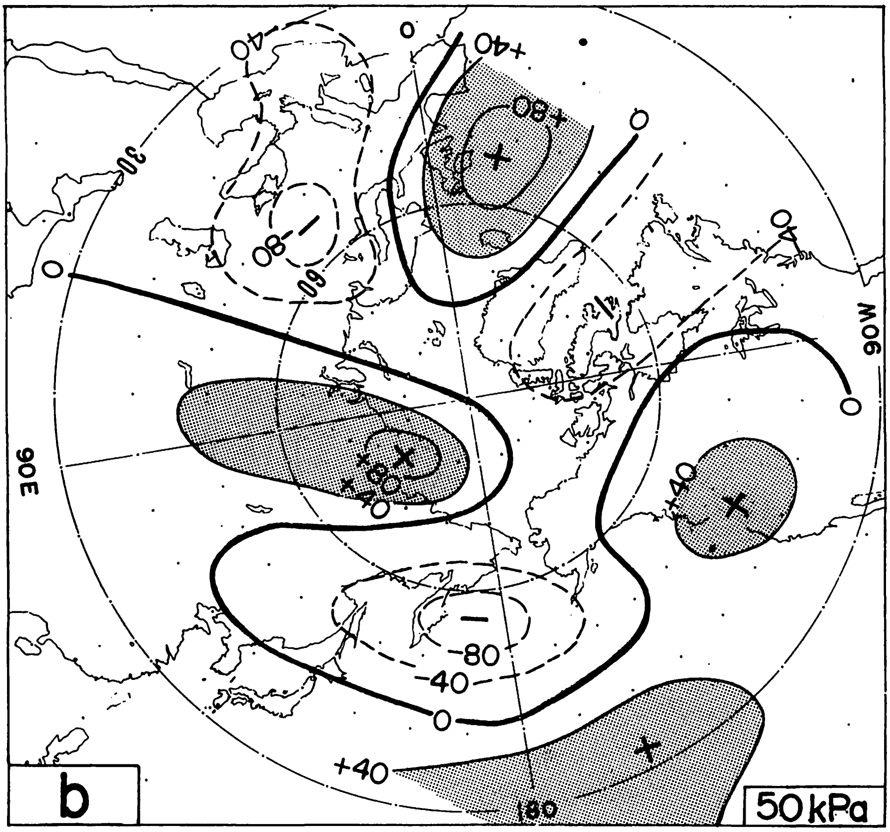


Fig. 11b.

assumed that the troughs and ridges shift in a nearly normal manner. In general, the troughs and ridges may be traced with consistency as they form, develop, move, and decay on the 5-day mean 50 kPa charts. However, a simple tracing of shifting troughs or ridges is not always effective for one-month forecasting.

On the other hand, it is quite effective to construct a model pattern for abnormal weather. As an example, the model patterns of 50 kPa height anomalies for heavy snowfall in Japan which is caused by cold air intrusion are introduced in Figure 11, where composite maps of 5-day mean height anomalies over the Northern Hemisphere are shown for the preceding days, based on heavy snowfall months in the past. In (a) the polar vortex with a negative anomaly is located over the Kara Sea. This pattern shows a high index one (*Z*-type). (b) The pattern shows a low index one (*M*-type), resulting in blocking highs over the north of the Atlantic Ocean and Taimyr peninsula. An extensive cold air mass, expressed by a negative anomaly, dislocates to the Far East and centers over Kamchatka. (c) The pattern shows a remarkable blocking situation over the Northern Hemisphere. As a result, the cold air mass invades Japan, resulting in a cold wave over Japan and heavy snowfalls along the Japan Sea side.

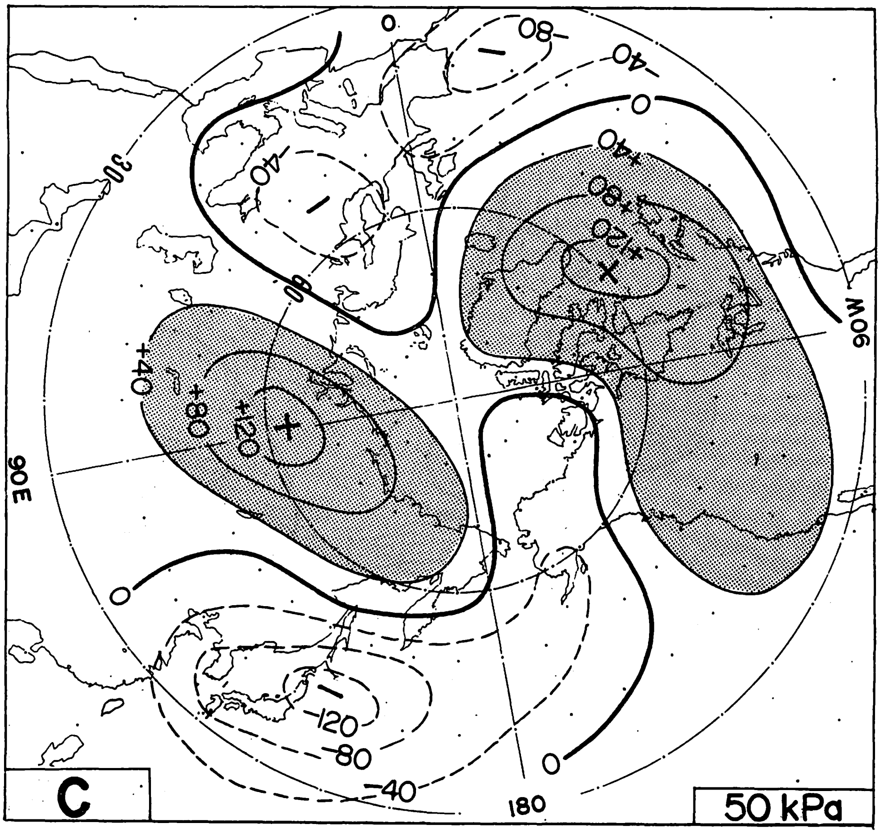


Fig. 11c.

Also, in Japan some practical techniques of one-month forecasts have been explored, using the synoptic features of stratospheric circulations. For example, the date of onset of the Baiu (see Section 3.5, end of) is found to be closely related to the date of the first occurence of easterly winds in the stratosphere over Marcus Island (25°17′N, 153°58′E); it is found statistically that the Baiu sets in over West Japan about one month after the stratospheric westerlies over Marcus Island switches to an easterly flow in May. This relation suggests that the beginning of the Baiu in Japan has a lag relation with the northward shifting of the easterly jet stream in the subtropical stratosphere.

5.2.5. *Dynamical Method*

Fundamental research in the dynamics of the general circulation during the past years indicates the applicability of purely hydrodynamical and thermodynamical methods to the long-range forecasting problem. The methods are basically designed to answer the question as to how solar energy is ultimately utilized and how the atmosphere responds in order to transfer heat most efficiently. The answer may require more exact knowledge of such elusive physical processes as release of latent heat, momentum and water-vapor changes, internal turbulent exchanges, radiation transfers and, in fact, the entire gamut of meteorological processes.

Attempts have been made to provide useful long-range forecasts by a combination of hydrodynamical and empirical methods. E. Blinova has made a study of experimental forecasts of winds and temperatures over large areas for periods of 40 to 70 days (Blinova and Kibel, 1957). The wind forecasts were prepared by applying a linearized barotropic model to each of the principal harmonics of the true 50 kPa height field. The temperature near the ground was extrapolated using a modified thermodynamic equation. In recent years, Adem (1962) attempted to formulate a numerical prediction model for periods of a month or a season. The basic equations used are those of conservation of thermal energy at the surface of the Earth and in the mid-troposphere. The model predicts the anomalies of temperature at the underlying surface and in the mid-troposphere.

However, the dynamical methods mentioned above have, so far, met with little success in long-range forecasting practice and, at present, an accepted dynamical method of long-range forecasting cannot be said to exist.

5.2.6. *Other Methods*

Persistence tendency. The persistence of monthly anomalies of circulation and weather has been recognized. The persistence tendency varies during the season, and the verification percentage of forecasts in some season can be considerably higher than the percentage obtained by chance. In general, adjacent months have some degree of persistence, with summer having a higher persistence than winter in both upper air pattern and temperature, but lower persistence in precipitation.

Singularities. The relative frequency of meteorological events counted for a long climatological period varies, day by day. For example, the grosswetterlage has different frequencies throughout the year. The most frequent types are called *singularities*. A characteristic example is the severe typhoon landfall in Japan, late in September.

Contingency tables. The whole possible range of the predictand is divided into a few broad classes, with the predictors also classified, and the frequency of occurrence of each predictand class contingent on the prior occurrence of each possible combination of predictor classes is found.

Pure climatological probabilities. The forecaster has available for reference a handbook in which numerous climatological statistics are displayed.

Forecaster's judgement, based on experience. This is also quite important under the present status of long-range forecasting techniques.

5.3. ONE-MONTH FORECASTING PROCEDURES

The final aim of the one-month forecasts is to prepare a mean 50 kPa prognostic chart from which temperature and precipitation can be estimated by using methods described earlier. In order to arrive at a prediction of the 50 kPa pattern for a month ahead, numerous tools which have their bases in synoptic, statistics, and large-scale physics are employed. The practical methods for preparing prognostic charts employed by Japan Meteorological Agency (JMA) are as follows:

(1) Significant periodicities are derived from the current 5-day 50 kPa height data at each grid point around Japan, using harmonic analysis, and their amplitudes are estimated. The significant waves at each grid point are extrapolated into the future, and from this the 5-day mean 50 kPa prognostic charts with anomaly patterns are constructed for a month ahead.

(2) A monthly mean 50 kPa prognostic chart is prepared, using regression equations derived from 50 kPa data for past years over the Northern Hemisphere. The equations for each grid point around Japan are based on local month-to-month or season-to-month autocorrelations with significant coefficients.

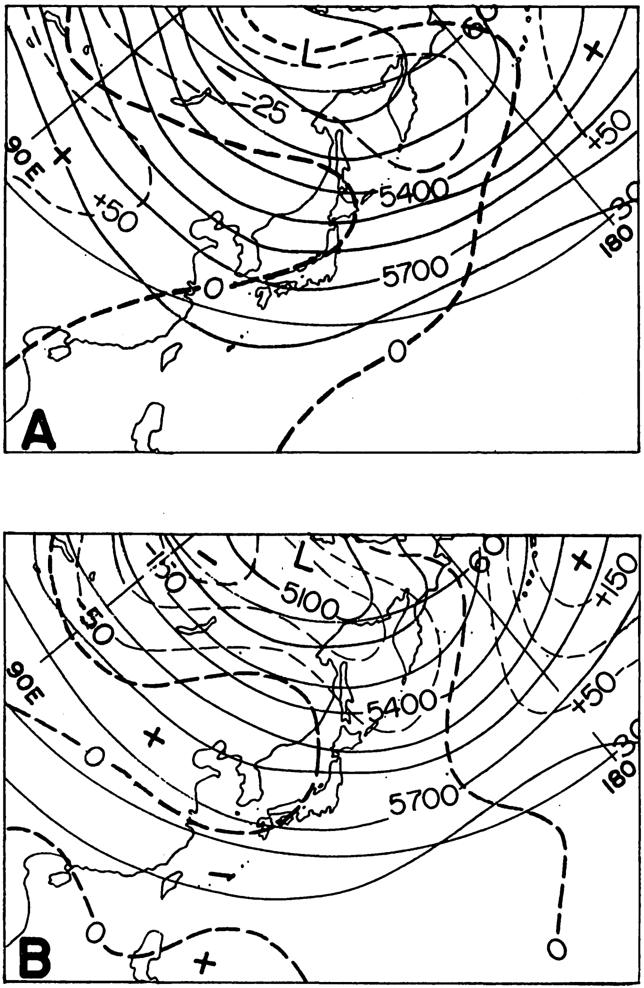


Fig. 12. Prognostic and actual charts of the 5-day mean 50 kPa height (solid line) and its anomaly (broken line) during 2 to 6 November 1966 (in gpm). (a) By harmonic analysis and (b) actual situation. (After Wada, 1969.)

(3) A tracing method of positive or negative anomalies on the 5-day mean 50 kPa charts is applicable to the construction of prognostic charts for a month ahead.

(4) The selected months analogous to the current 50 kPa height pattern also give information for constructing prognostic charts.

In general, it is not easy to construct a one-month prognostic chart because the method seems to reduce in the end to that of a subjective judgement by the forecaster, based on his experience supplemented by a number of different methods. Especially, the current sets of daily or 5-day mean 50 kPa charts and those of the daily 3 kPa charts over the Northern Hemisphere present much valuable information for one-month forecasting. Forecasters pay attention to the following points:

(1) The behavior of the polar and polar night (in winter season) vortices over the Northern Hemisphere. Toward which of the Hemispheres (Eastern or Western) is the vortex displaced?

(2) The process of the zonal index in the troposphere over the Northern Hemisphere and the Far East region. What kind of index pattern can be expected in the future?

(3) The situation of blocking over the Northern Hemisphere. Are there any signs of onset of a blocking situation?

(4) The development or decay of the Pacific and Tibetan highs.

(5) A possibility of typhoon genesis.

The above information is highly useful in constructing a mean prognostic chart. An example of a prognostic chart is shown in Figure 12, with an actual 50 kPa chart.

The final forecast is usually drafted after a lengthy technical meeting has been held amongst a number of workers. The information obtained from many methods is reviewed, and general agreement is reached on the conclusions which can be justified by the evidence. The final stages include the drafting of the forecast and its routine for printing and dispatch. The forecasts in Table III are issued by the JMA. An example of a 1-month forecast is given in Annex 1.

TABLE III

Forecasts issued at forecast centers in Japan

	Type of forecast	When issued	Period of validity
Nationwide, issued at Tokyo	1-mo.	10th and beginning of each month	1 mo.
Regional, issued at each center	1-mo.	End of each month	1 mo.
Nationwide, and *Regional*	3-mo.	20th of each month	3 mo.
	Warm season (summer)	Beginning of March	6 mo.
	Cold season (winter)	Mid-Oct.	6 mo.

6. Seasonal Weather Forecasting

For longer ranges – for example, 3-month or seasonal – the use of kinematic techniques has not been successful because of the importance of seasonal change. Therefore, the use of other techniques, particularly statistical ones, become more desirable for 3-month and seasonal weather forecasting. However, atmospheric circulation seems to behave coherently over a long time period, and this then is a proper target for seasonal weather forecasting.

Recently, it has become clear that there are many characteristic features in the seasonal changes of general circulation over the Northern Hemisphere, and that they give some clues for the seasonal weather forecasting techniques from a synoptic viewpoint. In this section practical techniques of seasonal weather forecasting are described, giving examples used in Japan.

6.1. BASIC APPROACHES

6.1.1. *Climatic Change in Recent Years*

A survey of the regional climatic change, which of course is closely related to the hemispherical or global climatic change, is of vital importance for seasonal weather forecasting. In general, the climatic fluctuations show appreciable horizontal differences, which indicate the dominant rôle of a redistribution of temperature, precipitation, and atmospheric pressure. Such changes are generally affected by certain aspects of the hemispherical circulation pattern.

World-wide changes of climate are associated with variations in the general vigor of the global atmospheric circulation. For example, from about 1890 to 1940 the general but irregular trend was toward intensification of the global atmospheric circulation: northward displacement of the polar fronts in both the atmosphere and ocean, northward displacement of ice boundaries in the arctic, weaker development of anticyclones over the continents, and more northward cyclone paths. Conversely, recent decades have exhibited opposite trends: weakening planetary circulation, southward shifts of ice boundaries and cyclone paths, sharp cooling, and different rainfall patterns over continents.

Hemispherical or global averages of surface temperature have been available only since about 1870. Mean annual temperatures for various latitude bands are shown in Figure 13. The figure reveals a slow rise of temperatures up to about 1940 and then an apparently more rapid drop. It is stressed that since 1964 a marked cooling has been going on in the higher latitudes, and that in winter a remarkable decrease in the monthly mean temperature of about 3 °C was observed between the decades 1951/60 and 1961/70 in the polar region, with its center at the Barents Sea.

Under these circumstances the horizontal distributions of seasonal mean temperature in summer in Japan have shown a marked trend in recent years, with hot summers in western Japan and cool ones in northern Japan. Furthermore, such a change of summer temperatures in North Japan is explained by its relation to the variation of the

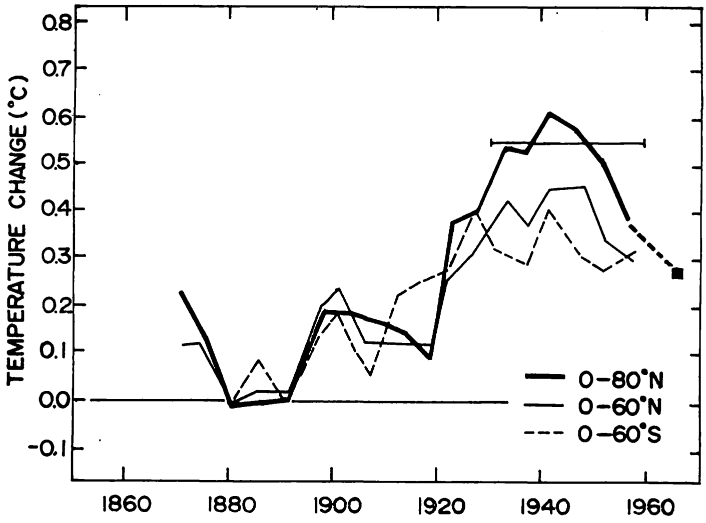


Fig. 13. Mean annual temperatures for various latitude bands, 1870 to 1966. The horizontal bar shows the mean value of temperatures in the 0° to 80° N band for 1931 to 1960. (After Mitchell (1961) and Pütz (1971).)

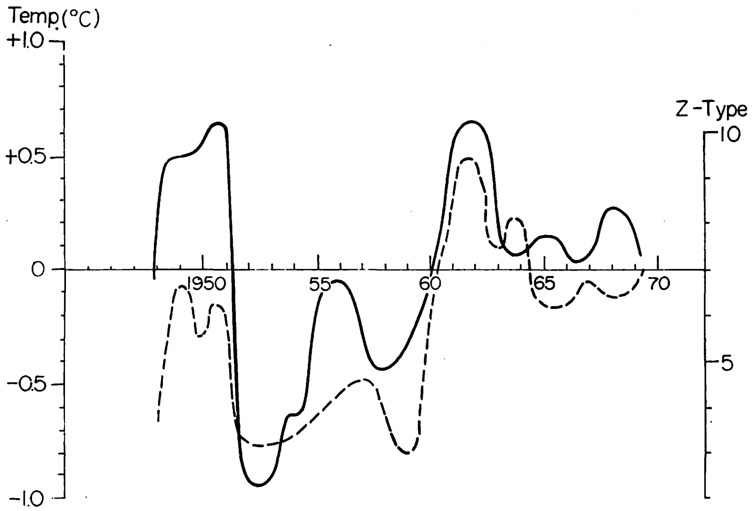


Fig. 14. Temperature anomaly in North Japan (solid line) and frequency of zonal type patterns over the Eastern Hemisphere (broken line) for summer (3-yr running mean). (After Wada and Kitahara, 1971.)

zonal index over the Eastern Hemisphere, as shown in Figure 14. The relationship is that a high index pattern in the Eastern Hemisphere brings a hot summer to North Japan while a low index pattern brings a cool summer, because the frequency of the meridional type pattern is the reverse to that of the zonal one.

It is emphasized that there are some systematic features in climatic changes which should be explained from a synoptic viewpoint, and that it is very important for seasonal weather forecasting to grasp the features in recent climatic changes. Anomaly sequence graphs for monthly mean temperatures and total precipitation at representative stations in a country should be available for seasonal weather forecasting.

6.1.2. *Solar Activity and Climate*

If irregular solar activity exerts a decisive influence on large-scale changes of general circulation it is important for seasonal weather forecasters to be aware of this possibility and of the effects to be expected. Usually, sunspot counts (e.g., Wolf number) remain as the common indicator of solar activity because of the long history of observation since 1610. The number of sunspots varies, with a mean period of about 11 yr. The sunspot cycle, as is well known, disturbs the upper atmosphere, including the ionosphere, during periods of high solar activity.

It is evident that sunspot cycles are far too large in scale to apply directly to seasonal forecasting. On the other hand, it is known that the grosswetterlage varies greatly within the same phase of the double or single sunspot cycle. Thus, the selection of an analogy period for seasonal weather forecasting should be based not only on the sequence of the Northern Hemisphere general circulation anomaly patterns, but also on the seasonal sequence of sunspot activity, for such sequences vary greatly at the same phase of the double sunspot cycle.

In Japan, the relation between the solar activity index deduced from long records of sunspot numbers and the characteristics of the general circulation was studied statistically. It was demonstrated that cool summers in North Japan are apt to occur within a few years of the year with the minimum sunspot number, and that abnormally cool summers persist within a few years of the year with the minimum number immediately following the year with the extreme maximum number. Especially, it should be kept in mind that the world-wide abnormal weather in winter in 1963–64 occurred within the minimum period of the sunspot number immediately following the highest ever observed solar activity in 1957.

If solar activity is indeed a controlling factor of the general circulation, then it will be necessary to determine the specific nature of the pertinent emissions involved and to establish reliably the physical linkage between solar emission and the ultimate reaction of the general tropospheric circulation.

6.1.3. *Sea Temperature and Climate*

Sea surface temperatures in the open ocean areas are important in connection with both the generation and suppression of storm systems, and otherwise affect the general circulation. In general, it is recognized that if sea temperatures are much warmer than normal, cyclones will develop very rapidly into intense storms. Low temperatures in the same area will, conversely, result in weak lows or, in special cases, anticyclone development.

It is presumable that anomalies in the heat received by the atmosphere from the oceans may be of major importance in the production of anomalies in the general circulation, and that an anomaly of the general circulation results in climatic change.

On the other hand, because of the large heat capacity of water, sea temperatures change slowly and anomalies tend to persist; they thus have some predictive value in the seasonal weather forecasting. However, at present, there are many difficulties for the application of air-sea interaction to seasonal forecasting. The difficulties stem from the fact that the feedback mechanism between them has not been made sufficiently clear to be applicable to seasonal forecasting.

Besides sea temperatures, studies should be made of the time-lag mechanism between ocean currents, ice distribution, snow condition, and atmospheric circulation. For example, the extent of the arctic ice may be important; a larger than usual cold source region is likely to have an effect on wind flow and temperature distribution in middle latitudes through the behavior of the polar vortex. Furthermore, in winter, anomalies in the depth of snow cover on land must similarly be taken into account.

6.2. SUMMER WEATHER FORECASTING

6.2.1. *Seasonal Change of the General Circulation and Summer Weather in Japan*

The weather in summer season in Japan is greatly affected by the behavior of the polar vortex and the subtropical high over the Northern Hemisphere. The subtropical high over the Northern Hemisphere is generally composed of 6 cells in summer, each of which has a peculiar feature in its vertical structure. For example, a cell called the *Tibetan high* which is most noticeable in summer in the upper troposphere, is composed of warm air throughout the troposphere. On the other hand, one called the *Pacific high* is distinctly noticeable in the lower troposphere as a cold air mass. The behaviors of the Tibetan high and the Pacific high are closely related to the dates of onset and end of the Baiu rainy season in Japan.

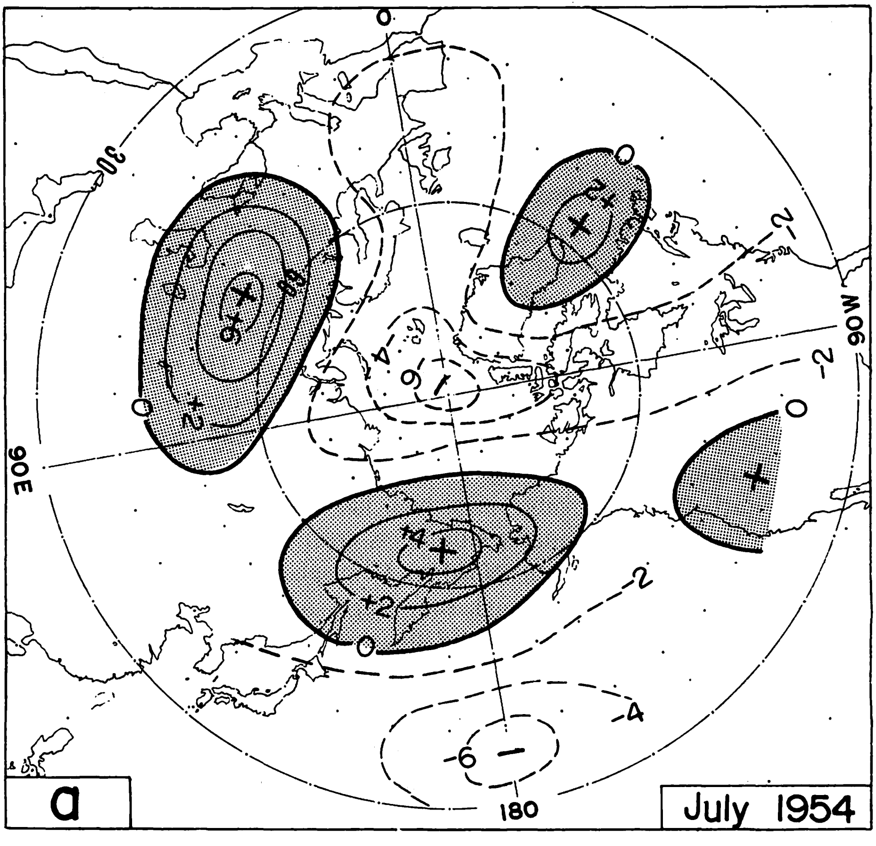
On the other hand, it is very important for summer weather forecasting to know, with a conception of dynamic climatology, the seasonal change of the general circulation over the Northern Hemisphere from winter to summer. The mean circulation in the troposphere in winter is characterized, as mentioned earlier, by the westerly flow around two polar vortices over eastern Canadian Arctic and eastern Siberia. The circulation in summer is such that the polar vortex weakens with the center located around the North Pole. The subtropical high has 6 centers along 30° N latitude, through which the weather in middle latitudes is greatly affected.

The change of circulation over the Northern Hemisphere from winter to summer on the normal mean charts goes through four stages of height increase of constant pressure surfaces in the troposphere as follows. (1) The winter circulation of the 3-wave type breaks down, coincidently with shallowing of the polar vortex (Jan.–Mar.). (2) A blocking high forms in Europe through which meridional heat exchange becomes active (Apr.–May). (3) A blocking system forms over the Okhotsk Sea, with which meridional heat exchange occurs in the eastern coast of the Asia Continent, resulting in a rainy season in Japan (June–July). (4) The intensity of the subtropical high reaches its maximum, while that of the westerly flow reaches its minimum (July–Aug).

The Tibetan Plateau forms a heat source during spring, becoming intense by summer, and together with a cold source over the Okhotsk Sea plays an important role in the circulation over the Far East. Furthermore, the seasonal variation from winter to summer of the circulation in the troposphere has a close connection with that in the stratosphere. In particular, the process in which the collapse of the polar night vortex generally occurs during March to April, and the one in which the transformation of stratospheric winter circulation pattern to spring pattern takes place, are deeply related to the tropospheric circulation features of the coming summer season.

6.2.2. *Cool Summer in North Japan*

As summer weather is a very important factor for the rice harvest in North Japan, long-range forecast studies for summer weather have been made since the early 1900's. The temperature during a cool summer in North Japan generally has a close connection with the geographical features there and also with the tropospheric circulation situation around Japan. From this, the characteristics of weather conditions for cool



Figs. 15a–c. Monthly mean surface pressure anomaly (0.1 kPa) with typical cool summer in North Japan for July 1954 (a), 1931 (b), and 1957 (c). (After Wada, 1969.)

summers in North Japan were analyzed synoptically in relation to the circulation pattern at the surface and 50 kPa levels over the Eastern Hemisphere. It was found that the circulation pattern for cool summers is divided into two types: one under a marked low index pattern with an *M*-type circulation (1st class), and the other under a high index pattern with *Z*-type circulation (2nd class). Especially, the 1st class type brings an unusually cool summer to North Japan, accompanying a marked blocking situation over the Nothern Hemisphere.

Of unusual weather occurring throughout the world in recent years, the summer of 1954 is given as an example. During this summer, Great Britain and Central Europe experienced cold and stormy weather, and floods were reported from Iran, East Pakistan, and Eastern India. North Japan also was dominated by abnormal coolness and persistent rain for nearly two months, and in China hundreds of kilometers of the Yangtze Valley were flooded, while the central part of the United States was plagued by hot weather and drought.

Analogous examples of unusual weather were observed during the summers of 1931 and 1957, bringing cool summers to North Japan. The distributions of pressure

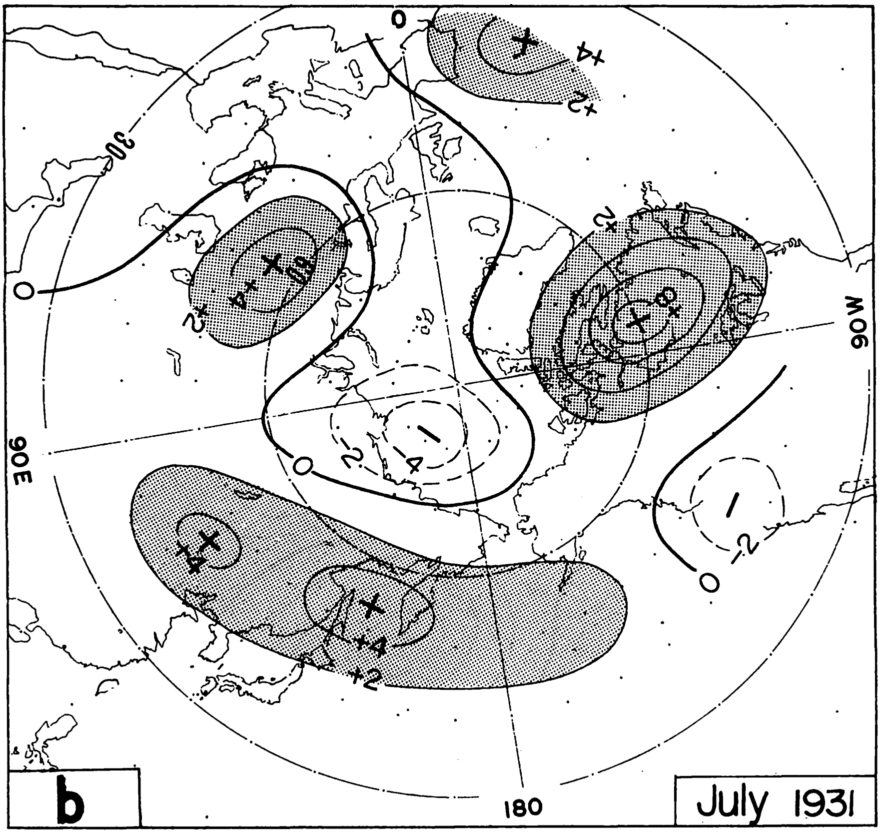


Fig. 15b.

anomaly during these summers, seen in Figure 15, are extremely analogous to one another, showing a so-called 3-wave pattern with positive anomalies in Baffin Land, Kamchatka, and the western part of Asia. Thus, it is clear that the abnormal summer weather took place on a world-wide scale during these years, and it should be understood that an abnormally cool summer of 1st class type in North Japan occurred as a link in the general circulation of the atmosphere over the Northern Hemisphere.

Figure 16 shows a lag correlation field between monthly mean temperatures at Sapporo, in North Japan, for July and a 50 kPa height for May. In spite of a two-month lag, it is found from the figure that if low pressure persists over the Okhotsk Sea in May then the temperature at Sapporo in July will be very low because of a high positive correlation around the Okhotsk Sea. The relation is explained synoptically by the behavior of the polar vortex in the troposphere; the displacement of the polar vortex toward the Okhotsk Sea in May is a symptom for a cool summer in North Japan.

As mentioned earlier, North Japan suffered from abnormally cool weather in 1954. During this year, world-wide blocking occurred from March to May as is seen in

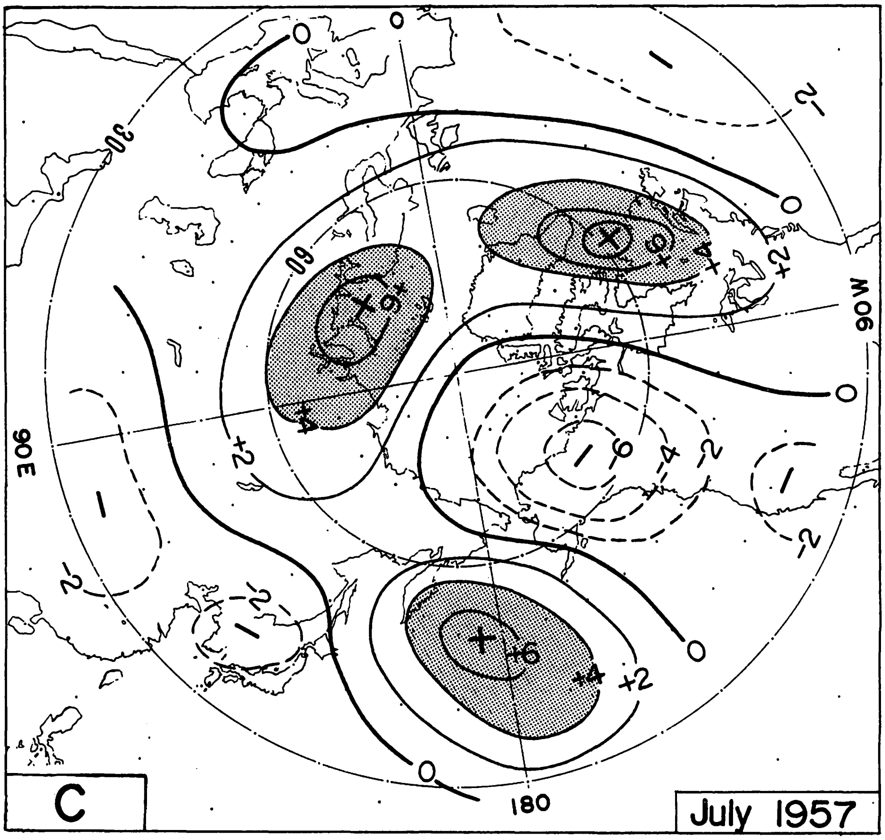


Fig. 15c.

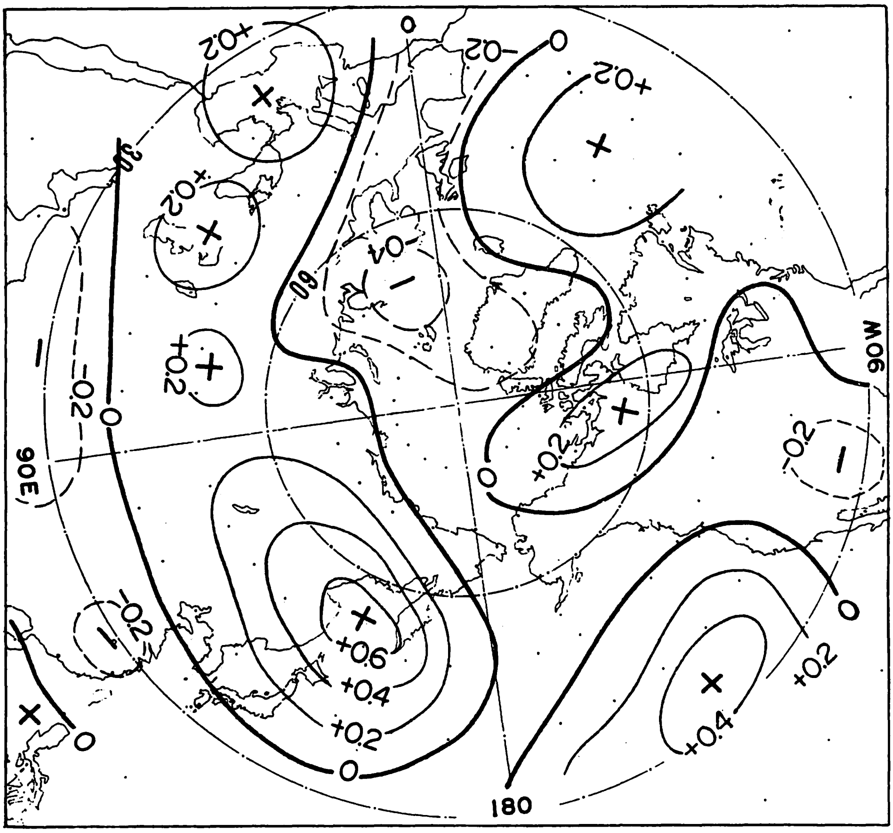


Fig. 16. Lag correlation field between monthly mean temperature at Sapporo (43°03′ N, 141°20′ E) for July and 50 kPa height for May (1946–1965). (After Wada, 1969.)

Figure 17, which shows the origin of a large-scale blocking pattern on the northern part of the Pacific Ocean, leading to a markedly cold outbreak to Siberia in April and pushing the polar vortex to the Okhotsk Sea in May. It is an important fact for forecasts of cool summer in North Japan that such an extensive cold air mass (represented by a remarkable negative anomaly), pooled over the arctic region during wintertime, gradually invades the mid-latitudes after about three months in spring.

It is also found that there is some relation between the time of final sudden warming in the stratosphere and the summer weather in North Japan. The final sudden warming generally occurs during early spring, but the time varies quite a bit from year to year. For example, in 1955 (hot summer in North Japan) it appeared in early January but in 1954 occurred in mid-March. It may be said statistically that a cool summer in North Japan occurs when the final warming is late compared to other years. If this relation holds in the future it may be a very useful symptom for summer weather forecasting in North Japan.

In addition to the synoptic methods described so far, many statistical long-range forecasting techniques are put to practical use for summer weather forecasting in

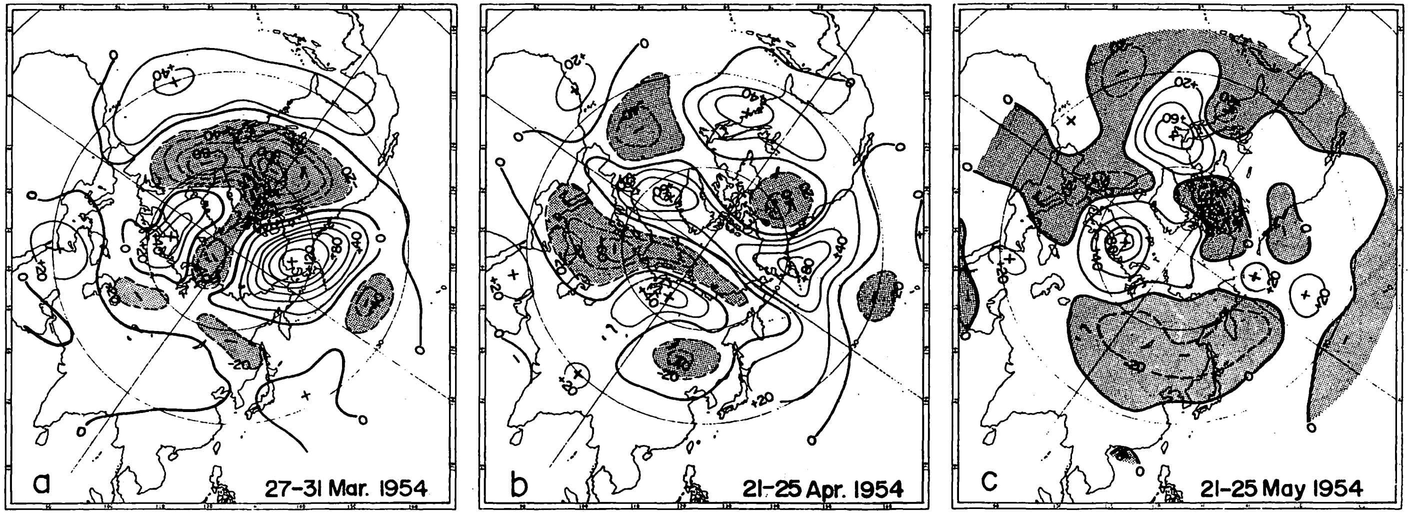


Fig. 17. Series of selected Northern Hemisphere, 5-day mean, 50 kPa height anomaly charts from March to May 1954 (in gpm). (After Wada, 1969.) (a) A large-scale blocking occurred over the Northern Hemisphere, so that an extensive blocking high (positive anomalies) was formed over Alaska. (b) The blocking high over Alaska extended towards the north Pole, pushing the cold air mass (negative anomalies) into middle latitudes. (c) The cold air mass, located in the higher latitudes in March, gradually invaded the middle latitudes, and a main part occupied the eastern part of Siberia at the end of May.

Japan, taking into consideration the trend of climatic changes and also the trend of solar activity in recent years.

Typhoons are one of the most terrible calamities which strike Japan. On the other hand, Japan suffers from a drought when no typhoons are observed. Therefore, it is a matter of great concern for summer weather forecasting to know beforehand whether typhoons will approach Japan or not. In recent years, new techniques have been developed on the basis of the general circulation. Of course, it is very difficult to make a long-range forecast for typhoon occurrences. However, it is quite interesting to note that the annual frequency of typhoon genesis is closely related to the frequency of the zonal type pattern (*Z*-type) in summer in the Eastern Hemisphere, as shown in Figure 18; more typhoons are generated with high index pattern than with the low index pattern. This relation gives some light upon future studies of long-range typhoon forecasting from the synoptic viewpoint.

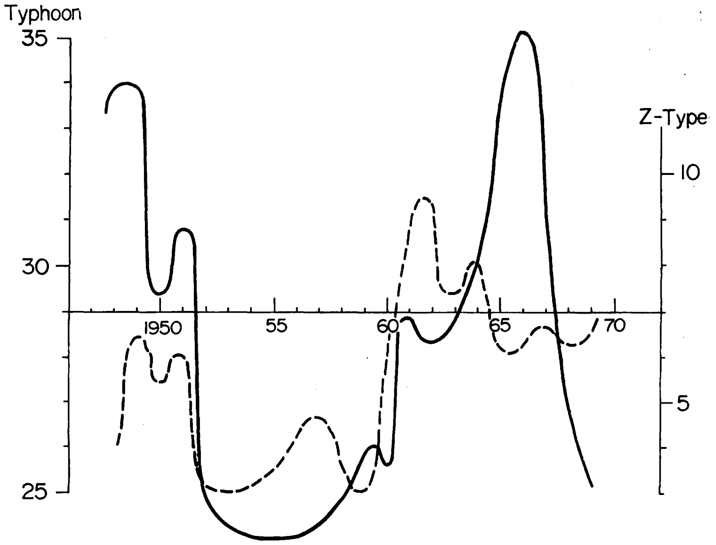


Fig. 18. Annual number of typhoons (solid line) and frequency of zonal type patterns in the Eastern Hemisphere (broken line) for summer (3-yr running mean). (After Wada and Kitahara, 1971.)

An example of a summer weather forecast is given in Annex 2.

6.3. WINTER WEATHER FORECASTING

An important requirement imposed on winter weather forecasts in Japan is to predict whether the coming winter will be very cold or not, because an abnormal cold winter, which usually brings heavy snowfall to Japan, greatly affects human welfare and transportation networks. Winter weather in Japan is decisively affected by the behavior of the polar vortex in the troposphere and the polar night vortex and Aleutian high in the stratosphere (Wada, 1968, 1970).

In general, a warm winter in Japan is associated with a high index circulation pattern, which is characterized by a strong but shrunken polar vortex centered over the Taimyr Peninsula. The existence of the vortex results in a cold outbreak into Central Asia and the Near East. In this case, wave number one of the harmonics of the upper westerly waves is often predominant both in the troposphere and the stratosphere. On the other hand, a cold winter is associated with a low index circulation pattern of a weak but expansive polar vortex. In this case, wave number two or three of the harmonics of the upper westerly wave is predominant. The stratospheric Aleutian high shifts to the west from its normal position, and the ridges at the 50 kPa level develop over Kamchatka and the Bering Sea. As an example, a composite 50 kPa anomaly map for a cold winter in Japan is illustrated in Figure 19, which shows a remarkable low index pattern over the Northern Hemisphere with an extensive cold pool around Japan.

In general, a seasonal process of circulation pattern in winter does not always take place smoothly, but changes rhythmically with the accumulation and dissipation of a cold air mass over the Northern Hemisphere. For the purpose of predicting winter

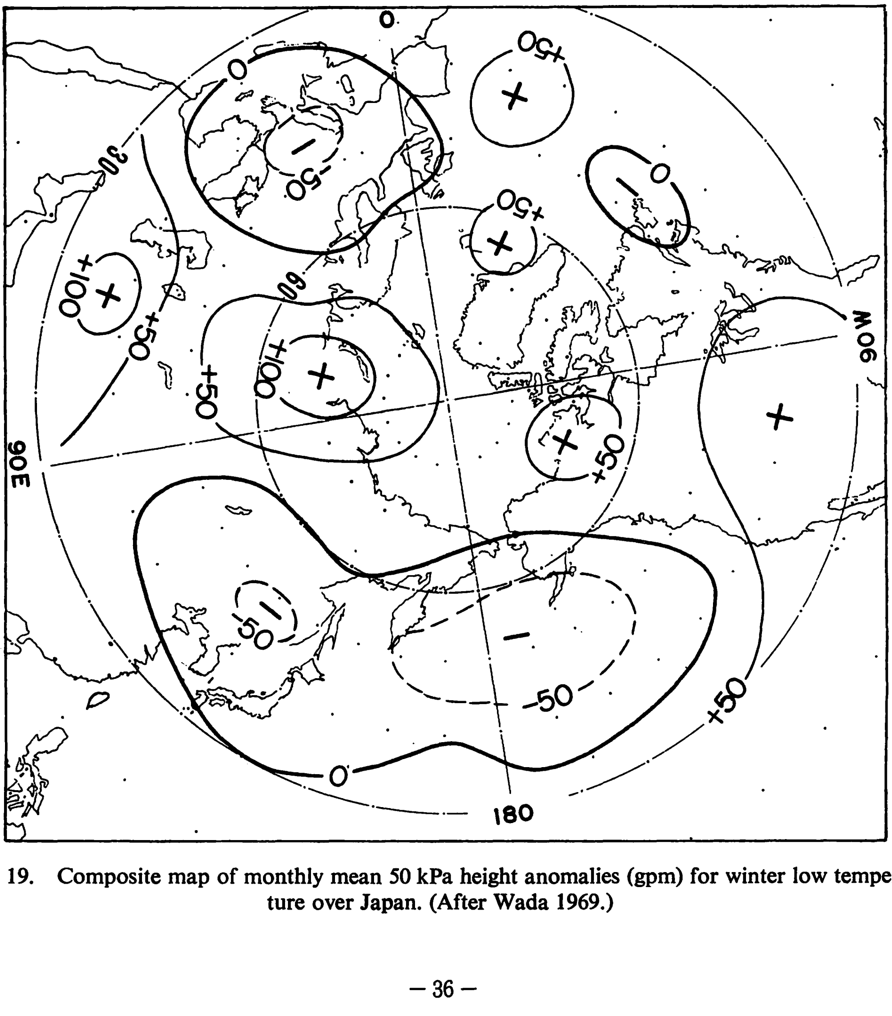


Fig. 19. Composite map of monthly mean 50 kPa height anomalies (gpm) for winter low temperature over Japan. (After Wada 1969.)

temperatures it is necessary to pursue the seasonal change of the circulation pattern from summer to winter. An approach to grasping a precursory tendency for a cold winter in Japan is summarized as follows:

(1) Composite maps of the seasonal mean height anomaly of 50 kPa for the summer and autumn preceding a cold winter in Japan are constructed. The result shows for a cold winter that a reversal of height anomaly sign take place over Europe, Central Asia, the Far East, and Alaska in each season. In addition, some maps are constructed with trajectories of significant lag correlation points between the 50 kPa height for preceding months and winter temperature in Japan, which also proves a reversal process from summer to autumn. As an example, Figure 20 shows lag correlation

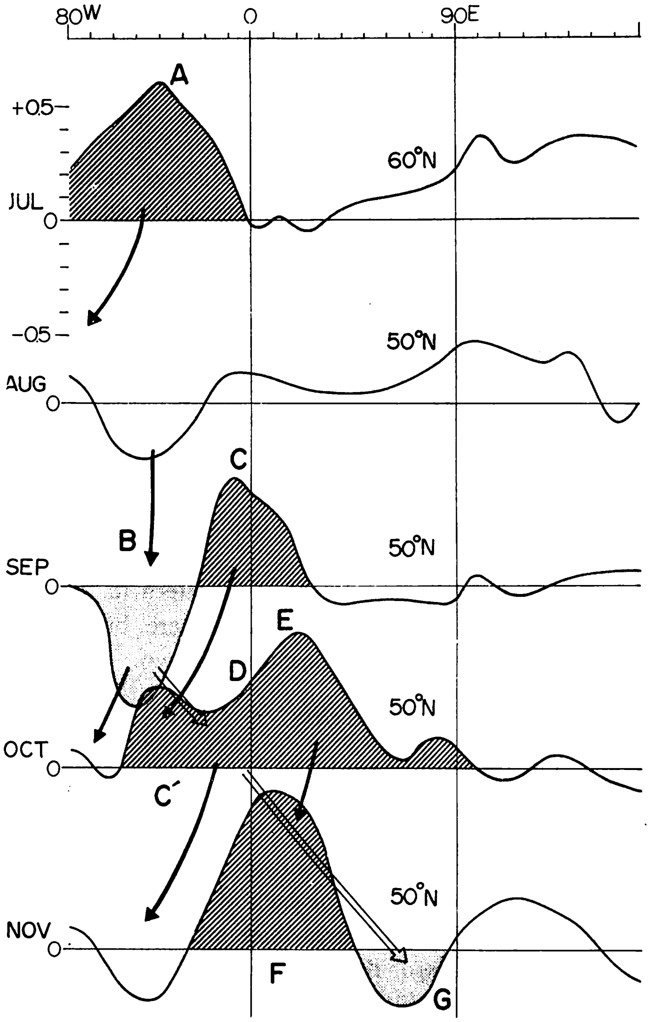


Fig. 20. Lag-correlation profiles along 50° N (60° N for July) between 50 kPa height and the mean temperature at Tokyo for winter. (After Wada, 1969.)

profiles along 50° N (60° N for July) between the 50 kPa height and the mean temperature at Tokyo for winter. From this figure it is seen that a significant positive correlation area is located at about 40° W in July, but changes to negative in September. Thus, a significant positive correlation area grows over Europe in November, which results in a negative one over Central Asia. These significant correlation areas can be traced with a synoptic meaning in relating to the cold winter in Japan. Thus, it may be possible to predict a winter temperature tendency by taking these correlations into consideration.

(2) From the trace of migrations of the polar vortex on the monthly mean 50 kPa map it is found that the polar vortex changes its position considerably from September to October, and its displacement toward the Far East can be a clue to a coming cold winter in Japan.

(3) An early formation of the polar night vortex in the stratosphere, with its displacement to the Far East in autumn, is an indicator of a forthcoming cold winter in Japan.

These are some of the practical methods, from the synoptic viewpoint, used for winter weather forecasting in Japan, along with statistical methods.

The circulation of January 1963 was quite abnormal, world wide, as stated earlier. Especially near the Japan Sea, an unprecedented heavy snowfall took place during the last 10 days of January. On the other hand, it is well known that during this winter a dramatic, explosive, stratospheric warming occurred in the beginning of January, with a large-scale blocking in the troposphere, and that the amplitude of wave number 2 grew remarkable only in the stratosphere at the end of December 1962, about one month previous to the heavy snowfall. Furthermore, during this January, the Aleutian high in the stratosphere shifted considerably westward, with a marked elongation of the polar night vortex. This suggests that the prediction of the behavior of the stratospheric circulation is very important from a synoptic viewpoint for the development of winter weather forecasting.

It is emphasized that, in general, a large-scale pattern in the troposphere has a close relation with the change of that in the stratosphere, bringing about abnormal weather over the world which persists for a month or two.

6.4. VERIFICATION OF LONG-RANGE FORECASTS

In general, it is difficult to rate the skill of long-range forecasts adequately or fairly with single numbers. In Japan, as stated earlier, the expected monthly mean temperature or total precipitation is given as one of 5 categories. The degree of forecast accuracy is given by the contingency table shown in Table IV.

The one-month forecasts are verified for each of three areas in Japan: Northern, Eastern, and Western Japan. For each area there are 5 verifying stations. From the results for each area an average for the entire nation was calculated for three years from January 1964 to December 1966. The number of forecasts totaled 72, since the forecasts are issued twice a month. The mean number of forecasts in the various categories of success for three years is shown in Table V. It may be said that the A and

TABLE IV

Verification of forecasts

Forecast / Actual	Much below	Below	Average	Above	Much above
Much below	A	B	D	E	E
Below	B	A	B	D	D
Average	C	B	A	B	C
Above	D	D	B	A	B
Much above	E	E	D	B	A

TABLE V

Mean number of verification result in the various categories for one-month forecast (1964–1966).

	Temperature	Precipitation
A (No serious error)	2	2
B (Good agreement)	6	5
C (Moderate agreement)	3	3
D (Little agreement)	0	2
E (No real resemblance)	1	0

B forecasts are forecasts which are better than pure chance. For this table, the percentages for temperature and precipitation become 66 and 58, respectively.

Verifications of seasonal weather forecasts are also made, but the method is complicated compared with that of the one-month forecast. Only the result of the verification of seasonal forecasts for summers and winters is shown in Table VI, in terms of

TABLE VI

Verification of seasonal weather forecast

	Year	Category
Summer weather forecast	1963	B
	1964	B
	1965	B
	1966	C
Winter weather forecast	1963/1964	D
	1964/1965	B
	1965/1966	B
	1966/1967	B

the 5 categories. This table shows poor results for the winter of 1963–1964, when Japan had an unusually warm winter.

7. Summary

Because of the availability of extensive data and high speed computing methods, long-range forecasting techniques have recently been developed much further than ever before. Especially, the relationship between long-term weather anomalies, which is an important target of long-range forecasts, and the features of circulation patterns over the hemisphere has been clarified from the synoptic viewpoints, so that long-range forecasting techniques have been greatly improved in the field of synoptic methods. However, the improvements are far from perfect at present.

What kind of research is needed to make further improvements in long-range forecasting?

It is evident that any reasonably satisfactory long-range forecasting technique will have to make allowance for the changing pattern of the behavior of the general circulation. From the theoretical viewpoint, to do this it is necessary to formulate a complete, fluid dynamics problem and use the laws of conservation of momentum, mass, and thermal energy. However, the solution of the complete problem is very complex and there exists at present no satisfactory general theory, although extensive studies are being carried out on the theory of the general circulation. It is necessary in the search for the cause of long-term weather anomalies that one should include and examine such factors external to the atmosphere as sea surface temperature, snow and ice cover, soil moisture, and possibly solar variations.

In any case, it is obvious that a better understanding of the internal mechanics of the general circulation is a first requirement for more effective long-range forecasting.

Fortunately, a long maintained observational programme to monitor atmospheric and meteorological parameters is being organized by the World Weather Watch (WWW), in which artificial Earth satellites provide a powerful new means of global observation. Also, a vast research effort, GARP (Global Atmospheric Research Program), has been mounted as a companion of WWW. Thus, it is expected in the near future that the accumulated global data by WWW will contribute to the further study of long-range forecasting through a better understanding of the internal mechanics of the general circulation.

It is stressed that the author has not tried to depict a rosy picture of long-range weather forecasting, but has made an effort to describe its factual status, and to point out that the improvement of long-range weather forecasting is one of the most important tasks of contemporary meteorology.

Acknowledgement

This article was partly supported by a Grant in Aid for Natural Disaster Research from the Japanese Ministry of Education.

Annex 1. Example of 1-Month Forecast

1-Month Forecast

August 10, 1972

Issued by Forecast Division,
Japan Meteorological Agency

GENERAL OUTLOOK

It is anticipated that the Pacific High will shift somewhat to the north and develop. Temperatures can be expected to be high, with many sultry days. However, over North Japan there may be unstable weather from the last 10-day period due to frontal effects, and temperatures may drop temporarily. Further, two to three approaching or landfall tropical storms (or typhoons) may be expected.

(1) *Weather*

Second 1/3 of August: The Pacific High will develop, and hot clear days over the entire nation are expected to continue. A tropical storm may approach close to or come onshore.

Last 1/3 of August: There is a possibility of frontal activities over North Japan and the Japan Sea coastal region, resulting in heavy rain due to the appearance of a cold high to the north. There is also a possibility of a tropical storm coming close to or tracking onshore, and, in general, bringing unstable weather over the entire nation. The area from the Kanto Region westward can expect many hot and sultry days.

First 1/3 of September: West Japan will be under the influence of the Pacific High and continue to be hot. However, with a high to the north of Japan, making frontal and low passages readily over North Japan, the areas from the Kanto Region northward can expect to see changeable weather.

(2) *Temperature and Precipitation Outlook*

Period / Parameter	2nd 1/3 Aug.	Last 1/3 Aug.	1st 1/3 Sept.
Temperature	Somewhat higher than normal.	North Japan – normal to somewhat lower. Other areas – normal to somewhat higher.	North Japan – normal to somewhat lower. East Japan – somewhat higher.
Precipitation Amount	West Japan – normal Other areas – somewhat less than.	Japan Sea coastal areas – normal to somewhat more than. Other areas – normal.	North Japan – normal. Other areas – normal to somewhat less than.

Annex 2. Example of Seasonal Forecast

Seasonal Forecast for Warm Period

March 10, 1972

Issued by Forecast Division,
Japan Meteorological Agency

It is expected that large variations in weather will be seen again this year during the warm period (April–September).

There will be many warm and clear days during April and May. However, a low temperature period may come about temporarily, bringing a possibility of late frost over the inland areas.

The onset of the Baiu over West Japan may come somewhat earlier than usual, and over other areas, normal to somewhat later. The Baiu front is expected to be active, bringing much cold and unfavorable weather. Precipitation will be normal to somewhat greater than normal. Heavy rain will be apt to occur during the latter half of the Baiu period. Ending of the Baiu will be normal to somewhat later than normal. Weather during the summer season will be quite variable, but on the average, high temperatures will be the same as for an average year. Over North Japan there will be times when very low temperature periods may occur.

The onset of autumn weather in September may come earlier than normal.

There will be approximately 30 tropical storm developments (28 for a normal year) and of these it is anticipated that 4 to 5 will affect Japan.

Note: The variation of weather this year is very large, due to the high intensity of the Arctic cold air and the subtropical high. This trend will continue further for some time, and as for weather and for temperatures, there may be extremes. For instance, there are concerns for high temperatures during late spring, late frost over North Japan, bad weather and heavy rain during the Baiu period, summer typhoons, low temperatures over North Japan in summer, and the early onset of low temperatures in autumn. Please consult the monthly issues of the 3- and 1- month forecast bulletins.

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LONG-RANGE WEATHER FORECASTING を掲載するにあたって

昭和48年3月のある日，アメリカのフロリダ州にあるNova 大学のMarkowitzという人から便りがあった。内容はアメリカのNamiasからの推薦で，Markowitzが編集長をしているGeophysical Surveysという雑誌に，「長期予報」という題名で書いて欲しいとのことであった。当時の私は，名古屋に転勤が決まっており，何となく忙しい日々であったが，日本における長期予報を，世界に紹介する良い機会と考え，一大決心をもって引き受けることにした。

この雑誌は，第一号が発刊したばかりで，その中に東大地震研究所の力武教授が「日本における地震予知」について展望を発表しておられた。また，力武教授は，この雑誌の編集委員をしていたので，いろいろお伺いして，名古屋へ着任すると共に，早速準備を始めた。

実はこれより以前気象庁在任中に，外国から研修生が来ると，長期予報について講義する機会が多かった。その際に，英文のテキストの必要性を痛切に感じていたので，コツコツと英文の長期予報をまとめていた。その内容は，私の「長期予報新講」に，その後の新しい研究を追加したものの概要であり，別に目新しいものではなかった。このような基盤があったので，掲載雑誌のいろいろな條件に合うように書き直して，原稿を送付したのが，1年後の昭和49年の3月であった。

しかし，つたない英文の悲しさで，編集長から数々の指摘があり，書き直しや訂正を行ない，秋になってようやく英文としてまとまった。この時の編集長からの手紙に“多大の労力で，ようやく貴殿の原稿の修正が完了した”と書いてあった。ところが，これですぐ印刷というわけでなかった。技術的な面についてのreviewのため，編集委員のSmagorinskyが担当したが，実際には，同氏が長期予報のことは分らないというので，Princeton 大学の都田博士が検討し，実に親切な多くの意見を寄せてこられた。またNamias からも，貴重な忠告を頂いた。

以上のような経過で，多くの方々の援助で，満2年で日の目を見たのがこの論文である。内容そのものよりも，日本の長期予報が，世界的にも高く評価されていることを理解して頂き，さらに，このつたない英文が，将来長期予報に関する論文を書く際に，読者にとって少しでもご参考になれば幸いである。

昭和50年7月

和　田　英　夫

長期予報ルーチン作業の内容について

— グロースペッター編集部 —

§ 1　はしがき

気象庁における長期予報業務のうち，各月の予報発表前の会報の様子については，さきに本誌第5巻第3号に掲載されている。今回は，ルーチン作業に取り入れられ，予報根拠としてFaxでも放送されている各方法の技術的内容について紹介することにした。

これは，長期予報課杉本予報官が課内職員を対象になされた研修を基にして当編集部が整理し，各担当者に実例の提供や加筆訂正をしていただき，さらにそれぞれの方法を開発された方々に目を通してもらったものである。

そのほか，長期予報課内の多くの方からアドバイスをうけ，また原稿整理をしていただいた。これらの皆さんに厚くお礼を申しあげる。

なお，一部は，前掲の和田氏のLONG-RANGE WEATHER FORECASTING の内容と重複している部分もあるが，この点ご了承いただきたい。

§ 2　用いられている資料や検討項目の概説

現在使用できる資料は，第1～3表に示すとおりである。南半球の資料はまだ利用段階にないので省略する。

第1表の基礎資料を基にして，第2表の物理量が求められ，また波数解析が行なわれている。

第1表　基　礎　資　料

	（北半球）	
高層	500，300，100mb　Zと△Z 1000～500，500～100mb　Hと△H	半旬，月，3か月
地上	地上Pと△P	月
	（アジア地域）	
	地上Pと△P	半旬
	△T	半旬，月
	（日本）	
	気温，降水量，日照率およびその偏差（比）	半旬，月
	最深積雪	月（11月～4月について）
	（南・北両半球）	
気候値	地上気圧，気温および偏差 降水量，降水日数，降水階級	月

注）　Z：高度，H：層厚，P：気圧，△：平年との差

第２表　物理量

A_Z, A_E, K_Z, K_E	日，半旬，月
$C(A_Z, A_E)$, $C(A_E, K_E)$, $C(K_E, K_Z)$, $C(A_Z, K_Z)$	
500mbと1000mbのU'^2, $U'V'$, $H'U'$, V'^2, $H'V'$	
$U'\omega'$, $H'\omega'$, $V'\omega'$, H'^2	
波数解析（n＝1〜10の振幅と位相）	半旬
超長波合成図（n＝1〜3）	
長波合成図（n＝4〜7）	

注）　C：各種エネルギーの変換量，それぞれの記号は，慣用のもの

第３表　その他の資料と補助図

日々の500mb，100mbのZ
日々の500mb空間平均偏差図
日々の50mb，30mb ZとT（ベルリン天気図）
北半球と極東域の半旬平均Zonal index偏差
北日本，東日本，西日本，沖縄の半旬平均気温偏差
70〜80°N帯の月平均500mb高度Profile
極東域の半旬平均20〜40°NのZonal index偏差
北半球の象限別の月平均Zonal index偏差
大陸（30〜120°E），太平洋（130°E〜140°W）の半旬平均Zonal index偏差
0〜80°E，90〜170°E，0〜170°Eの半旬平均Zonal wind
北半球緯度平均空気量の南北変動図（半旬平均）
500mb高度前月差，$\langle V'^2 \rangle$イソプレット
その他

波数解析は球面調和関数を用いて解析しているものと，緯度圏に沿って500mb高度を調和分析したものとがある。前者は東西・南北両方向の波数の組み合わせになっており，南半球と北半球では，赤道をはさんで対称的な高度分布をするように仮定している。

これらの物理量や第３表に示した資料・補助図のほかに，各自が持っている資料も活用されている。

予報会報で説明検討される方法の詳細については§４以下で述べるが，まず概念をつかむために作業の荒筋について説明しよう。

ア．場の推移のは握

各面の天気図を用いて，現在の場を立体的に解析し，大気大循環の立場からどのようなベースにあるかをは握し，将来のパターンのイメージを描く。

イ．Zonal indexの変動

この量はKzの変動や環流型と関連をもつ。全球，極東域，大陸，太平洋の各領域について解析している。

ウ．動力学的な解析

短期予報ではイサロバールをしばしば利用するが，長期予報では50°Nの500mb高度について前の5日平均と現在の5日平均の差をとり，これを毎日について計算している。季節変化や定常振動を消去し，ゆっくりと移動する波動だけをとらえているわけである。ここでみているイサロバールは，5日平均したうず度の時間変化に相当している。

エ．予想図の作成

旬平均については調和解析に基づくもの，和差法，リズム法と異なった3つの方法で作成している。Faxで放送しているものはこのうちで予想のイメージに最もよく合っているプログノである。月平均については，調和解析，リズム法，相関シノップ法に基づいて作成している。

オ．種々の要素についての周期補外

周期法は長期予報の主要な方法である。ルーチンに行なっているものは，東西指数偏差，特定格子点の500mb高度偏差，緯度平均の層厚偏差と気圧偏差などについての周期補外である。これらのほかに極東の北氷洋域（70～80°N）の500mb高度偏差があるが，これは極方面の寒気の動向をみるためのものである。

カ．類似を用いる方法

よい類似を選びだすことは将来の予測を行なううえで非常に大切である。符号一致率による類似天気図の抽出，高相関類似法による気温・降水量の予想，半旬平均500mbの類似天気図の抽出などがある。

以上のようにいろいろな方法が用いられているが，これらはいずれも現象の一断面をみているだけで，それぞれの予想結果が矛盾するような場合にはさらに検討し直して，予想期間の大循環の変化のイメージを確立する必要がある。

§3　時間平均天気図について

本論に入る前に，長期予報で用いられる半旬平均とか月平均といった天気図の意味について考えてみよう。

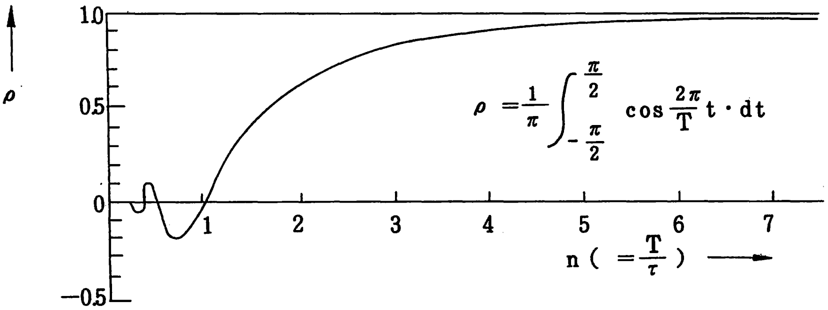
かって，Baurは，はん天候は5日ぐらいのリズムで変化することが多いので，長期予報では少なくとも旬平均ぐらいの天気図が適当であるとし，またMultanofskyは，高気圧の動向には5～10日のリズム（自然期間）があるので，5日平均天気図は総観的な面からの背景をもっていると主張している。これらの平均天気図は大循環の特性を理解する目的で作られることはたしかである。しかし，物理的な意味については，短周期の波を消しているものである，といった程度で，明確に

説明されているわけではない。

5日平均天気図では，超長波は残っているとみられるが，じょう乱の移動速度をかりに10度/日とした長波を考えると，波数が7ぐらいより大きい波は大部分消去されている。これについては，研修のあとでも種々討議されたが，スッキリと結論をだすまでには至らなかった。

L. F. 会員の皆さんからのご意見をお待ちしている。

討議中に，次のような考え方もだされた。すなわち，ある期間について平均を行なうと，どのような周期の波の振幅が，どの程度減衰させられるかを考えてみる。第1図がこの関係を示したもので，ρは周期Tの振動を期間τについて平均したときの最大振幅の減衰率を表わしている。



第1図　周期Tの振動をτ期間平均したときの
nとρの関係

これによると，周期Tが平均期間τの約1.6倍以下の振動では，最大振幅は半分以下に減衰するかまたは消えてしまい，位相が逆（ρが負）になることもある。私達が扱う振動は，短周期のものほど振幅が小さいから，$T \approx \tau$以下の振動は，より周期の長い振動に較べると，この図で見るよりもずっと減衰したように見えるであろう〔図の意味は，たとえば，5日平均図（$\tau = 5$）の場合は，周期Tが5日の振動は（$n = 1$で，$\rho = 0$だから）完全に消去され，Tが8日（$n = 1.6$）以下の振動では最大振幅が半分以下しか表現されていない，ということである〕。

なお，Faxで毎日送画されている空間平均関係の天気図では，波長が約3,000Km以下のものはほとんど消去されていることが示されている（「週間予報資料(2)」，気象庁予報部，昭和47年3月)。

§4　予想天気図の作成

1.　和差法

旬平均500mb高度偏差を△Hとし，

$$L_n = \frac{\triangle H_{n+1} + \triangle H_n}{2}$$

$$S_n = \frac{\triangle H_{n+1} - \triangle H_n}{2}$$

とおく。

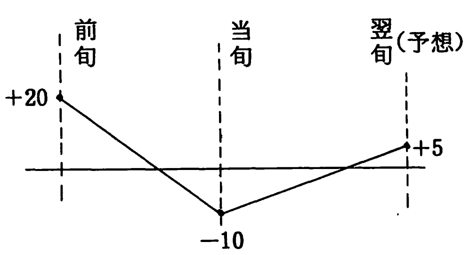
ここで，$\triangle H_{n+1}$：1半旬後，△H：その旬を表わす。L_n，S_n の予想ができれば，それらを加えて $\triangle H_{n+1}$ の予想が可能となる。

$$\triangle H = A\cos \omega n t,\ \omega n = \frac{2\pi}{Tn}$$

とおくと，和は△Hを積分した $\frac{TnA}{2\pi}\sin\lambda$ となり，長周期の振幅が大きくなり，短周期の振幅は小さくなる。

一方，差は△Hを徴分した $\frac{2\pi}{Tn}\sin\ \omega nT$ となり，この方は短周期の振幅が大きく，長周期の振幅は減少する。 微

この和と差の系列を天気図上の各格子点（アジア25地点）について計算するわけだが，和の変化はゆるやかなので，これには補外法が適用される。差の系列には反転の法則を用い，実際には次の例のようにしている。



すなわち，ある地点について前旬の値が＋２０，当旬の値が－１０のときは

$20+(-10)=10 \quad 10\div 2=5$

$-10+5=-5$　この符号を変えて

＋５が翌旬の予想値となる。

最後に和，差両系列の予想値を加え合わせて予想値となる。２旬後，３旬後，４旬後についても同じ方法をとる。

2. リズム法

また，和，差の系列を求め，差の系列については調和解析を行ない，卓越波２つを採用する。そして，予想値と予想開始期の値のレベルを合わせるために，卓越周期の３倍の期間だけ前にもどって，改めて調和解析を行ない，振幅と位相差を計算し，将来を補外する。

次に和の系列に関しては，各格子点について，

$$x(t)=a_0+a_1x_1(t-1)+a_2x_2(t-2)+a_3x_3(t-3)$$
$$x(2t)=b_0+b_1x_1(t-2)+b_2x_2(t-3)+b_3x_3(t-4)$$
$$x(3t)=c_0+c_1x_1(t-3)+c_2x_2(t-4)+c_3x_3(t-5)$$
$$x(4t)=d_0+d_1x_1(t-4)+d_2x_2(t-5)+d_3x_3(t-6)$$

なる傾向方程式の係数 a_i，b_i，c_i，d_i を行列式を用いて決めて補外する。

最後に和，差両系列の予想値を加えて予想値とする。

3. 調和解析による方法

(1) １か月予報のための旬平均プログノの作成

月２回，４旬先までの極東域25格子点についての予想を行なっている。卓越周期を決めるための

資料としては最近の66半旬を用い，統計的にみて卓越しやすい4, 5, 7, 9, 14, 19, 29各半旬周期の中から有意な（σの0.41倍以上の振幅をもつもの）周期を選び，それを用いて補外する。

大気の周期現象は一般に非定常時系列であるから，過去の資料から求めた振幅や位相角と共に変化すると考えられる。そこで採用周期について，cos項（$A\cos n\lambda$），sin項（$B\sin n\lambda$）の振幅の時系列を用いて振幅を時間に関してテーラー展開（例，$A(t)=Z_0+\frac{\triangle Z}{1!}+\frac{(\triangle Z)^2}{2!}$）して補外し，卓越周期の振幅と位相を求め，それを合成して予想する。

(2)　7か月予報のための月平均プログノの作成

最近29か月の資料を用い，1, 4, 7, 10月の3か月ごとに年4回，この方法で予想図の作成を行なっている。

採用周期とそれに使用する分析期間は次のとおり。

採用周期	分析期間
$22/3$ = 7.33月	22か月
$17/6$ = 2.83 〃	17 〃
$15/4$ = 3.75 〃	15 〃
$7/4$ = 1.75 〃	7 〃

ベースとしては，持続性（8か月以上の長周期を含む）の考えを用い，回帰係数を用いて決定した次の係数を過去の値に乗じている。

長周期変化を推定する係数

実況 予想	当月	1か月前	2	3	4	5	6	7	8	9
1か月後	0.25	0.04	0.06	0.01	0.06	0.00	0.03	-0.03	0.05	0.03
2	0.11	0.08	0.02	0.07	0.01	0.03	-0.02	0.05	0.05	-0.01
3	0.11	0.03	0.06	0.02	0.04	-0.03	0.05	0.05	0.00	-0.02
4	0.06	0.08	0.03	0.03	-0.02	0.05	0.05	0.00	-0.01	0.03
5	0.09	0.03	0.04	-0.01	0.05	0.05	0.00	-0.02	0.01	0.07
6	0.07	0.04	0.00	0.06	0.05	0.01	-0.01	0.02	0.10	-0.05
7	0.04	0.00	0.06	0.05	0.01	-0.01	0.02	0.10	-0.05	0.07

周期の有意でないもの（振幅が標準偏差の0.49倍より小さいもの）は棄却され，すべての周期が有意でない場合は，補外値はベースのみとしている。

(3)　任意の項数の調和解析によるプログノの作成

年系列で予想する場合，例えばある格子点について1月だけの時系列の値を使って，周期分析する方法で現在では1946年以降の資料が使える。予報地点は極東の25地点で，この方法によるプログノは暖・寒期予報を行なうときに作っている。

候

§ 5　相関シノプティックスによる気温・降水量およびプログノの予想

1. 気温・降水量の予想

△Tまたは△Rとの北半球197地点の△Z_{500}との lag 相関係数を用いて高相関を示すKey Point をさがす。たとえば，降水量の予報については，iというKey Pointの△Zと，予報対象地域の降水量との相関係数をr_i，500mb高度(Z)と月降水量の立方根($\sqrt[3]{R}$)の標準偏差をそれぞれσ_{Zi}，σ_Rとし，独立なN個のKey Point につき予想値の算術平均値

$$F = \frac{1}{N}\sum_{i=1}^{n}\frac{r_i}{\sigma_{Zi}}(Z_i - \overline{Z_i})\times\sigma_R$$

が29年の資料ならば，29個求められる。これら29個のFと実際の降水量の立方根との相関係数$r_{F\cdot R}$を用いて次の式によって降水量を推定している。

$$\sqrt[3]{R} = \frac{1}{N}\sum_{\substack{i=1\\ j\ ?}}^{29}\frac{r_{F\cdot R}}{\sigma_F}(F_j - \overline{F})\times\sigma_R + \overline{R}$$

月平均 北半球500mb高度偏差と
月降水量との相関係数表
1963、11月. 気象協会刊　p.6 参照
降水量の長期予報(第2報)
昭37、11月、気象庁予報部　p.11参照

2. 各月についての予想図の作成

予報対象月の極東域25地点の500mb 高度偏差について，各地点に北半球197地点の△Z_{500}との lag 相関係数を計算し，比較的高相関を示すKey Pointを探す。 たとえば暖候期（4～9月）の各月のプログノを求めるためには，10～12月の月平均500mb高度偏差を用い， 1.と同じ方法で各格子点における△Z_{500}を算出することができる。

このほかでは，第2次暖候期予報用として6～9月の各月のプログノを3月と4月の実況を用いて，また寒候期予報用として12月～3月の各月のプログノを6～8月の実況を用いて作成している。

§ 6　周期補外による旬単位の予報

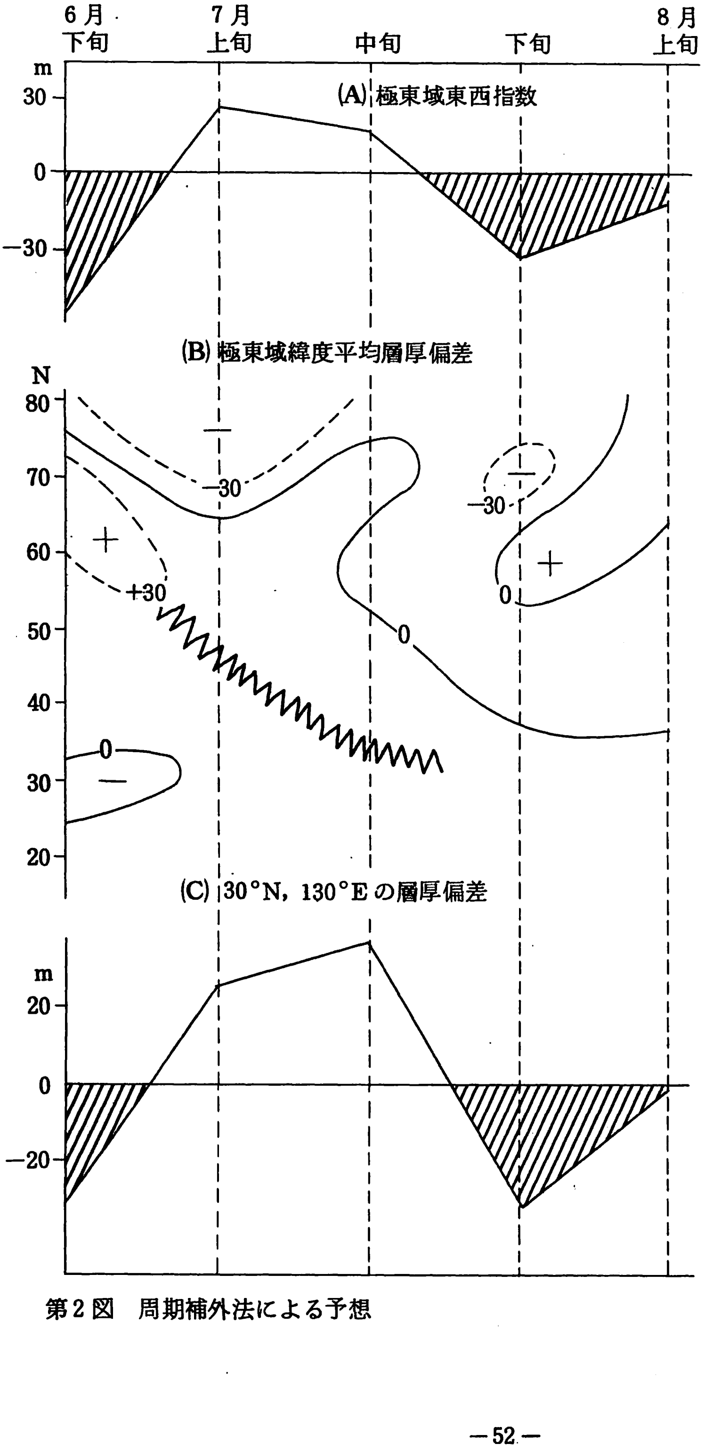
二

1か月，3か月予報の場合に行なっているものであるが，会報時までの36旬（72半旬を2半旬ずつ平均）の資料を使い，36項調和解析して卓越周期を2つだけ取りだし，各々の波を補外し，それを合成して旬単位の予想を行なっている。要素としては，北半球・極東域・大陸（30～120°E）・太平洋（130°E～140°W）の東西指数偏差，北半球・極東域の緯度平均層厚偏差（△H），日本付近における6格子点の△H，大陸(80～130°E)，太平洋(130°E～180)の緯度平均気圧偏差(△P)，極東域の北氷洋域(70～80°N平均）の△Z_{500}などである。補外する場合に，最近の変動を重視すると共に，計算した予想値が現況と大きくずれることを防ぐため，卓越周期の3倍の期間をとって，もう一度，振幅と位相角を計算し直して予想値を決めるようにしている。この場合，周期の3倍分だけの資料がとれない場合は2倍の期間をとって振幅と位相角を計算する。

大気が周期的な動きをしているときは，この方法はかなり有効な手段となるが，何らかの原因（

調節すること

大規模なブロッキングパターンの出現など）で，周期がくずれだすと，次に安定するまでに相当の時間がかかるので，予想資料としては使いにくく，これまでの経過と現況を絶えず監視していることが必要である。第2図は，ことしの6月第4半旬までの資料を使って予想した実際の予報例の一部である。（A）の極東域の東西指数偏差は，波数9〔36旬／9～4旬（40日）周期〕と波数11〔36旬／11～3.3旬（33日）周期〕が卓越しており，6月下旬の低指数が7月上～中旬には高指数となり，下旬から8月上旬にかけて再び低指数に変わる。（B）の極東域の緯度平均△Hは，高緯度では2～3旬周期だが，ブロッキングに伴う暖域は6月下旬に最も強く，中緯度では7月上～中旬に暖気におおわれやすくなっている。（C）の30°N, 130°E地点の△Hは，波数11と9が卓越していて，東西指数と同様な変化を示している。これらを総合すると，6月下旬に梅雨型パターンが活発だが，7月上旬後半から中旬にかけては，夏型の天候となり，西日本の梅雨明けは，やや早まりそう。下旬には北方から寒気が南下し，不安定な天候が予



第2図　周期補外法による予想

想される。

§ 7　類似法

1. 北半球・極東域の500mb 高度偏差の符号一致率による類似年の抽出

これは，一般によく知られている方法であるし，それに本誌P18以下に和田氏が詳細に述べられているので，それに譲ることにして，ここでは，この場合の一致率の検定についてだけ説明しよう。　た

計算は北半球197地点，極東域54地点について行なっているので，一致率はそれぞれ57％，65％以上の場合が有意となる。このことは，次のように考えるとよい。すなわち，北半球全域（197地点）の場合についてみると，サンプルn個のうち，符号の一致するものをX，一致する割合をPとするとXは2項確率分布に従い，X/n の母平均はP，母分散はPq/n，（ここで $q = 1 - P$），となる。nが大きいときは

$$Z = \frac{X - nq}{\sqrt{npq}} = \frac{\frac{x}{n} - p}{\sqrt{\frac{pq}{n}}}$$

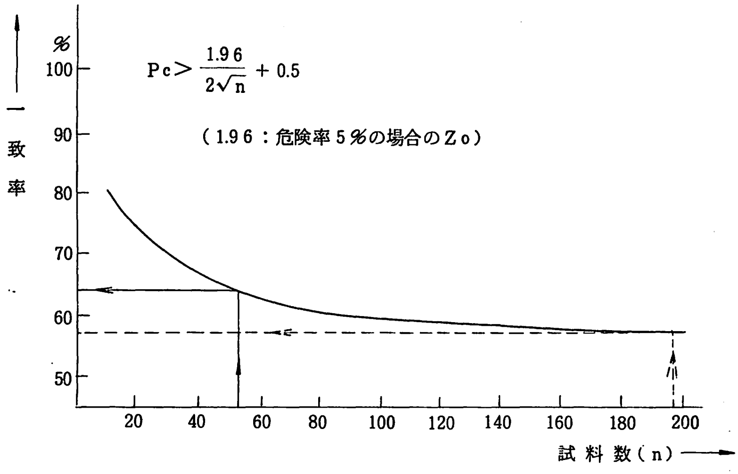
| |

は標準正規分布N（0, 1）に従う。正規分布表より危険率5％では $|Z| > Z_0 = 1.96$（両側で5％危険率の境界）のとき有意となる。この場合は，$n = 197$ なので $P = 0.5$ とおくと，X/n の下限を求めることができる。X/n が得られたとき，$P = 0.5$ と有意な差があるかというかの検定は

どうか？

$$\frac{X}{n} = p_c \quad \text{とおくと} \qquad P_c \geqq \frac{Z_0}{2\sqrt{n}} + 0.5$$

のとき Z_0 の水準に対して有意となる。$n = 197$，5％危険率では $P_c > 57$ となり，57％以上が有意というわけである。この場合の試料数と一致率との関係を図示すると第3図のようになる。



第3図　試料数と有意（$\alpha = 5$ ％）な一致率の関係

なお，符号一致率が統計的有意であっても，物理的な意味で一致しているかどうかについては何も言っていない点に注意すべきだろう。

2. 高相関類似法

現在，この方法で月単位の気温偏差と降水量（%）の予想をしているが，計算方法は共に同一プログラムを使用しているので，気温を例にとってのべてみる。

予想する地域はテクニカルノートNo.5（季第545号の2）に基づき5地域（北海道，東日本，日本海，西日本，沖縄）。

データは月平均北半球500mb高度偏差△Z_{500}と各地域の月平均気温偏差を用いる。

計算であるが，まず過去の北半球197地点（緯経度10度ごとの格子点）の△Z_{500}と△Tとのlag相関を求め，そのうちの相関係数のよい（r≧0.3）地点をひろい出す。つぎに最新の月平均（1か月予報のときは20日平均）の北半球△Z_{500}と同じ月の過去（1946〜74年，毎年1年ずつふえる）の北半球△Z_{500}との符号の一致率を高相関（r≧0.3）の地点についてのみ算出して類似年をみつける。

第4表は'75年5月の20日平均より6月の北海道の△T類似年を予想した結果である。順にみてみると相関図符号51%とあるのは第4図と第5図の197地点についての符号の一致率である。次には，

第4表　高相関類似年5月（20日平均）より6月の△T予想

```
1975 NEN 5GATU          6GATU HOT
SOKAN ZU FUGO 51. PERCENT
 SOKAN KEISU. GT. 0.30     52. PERCENT KOSU 44

              ANALOGY BY CORRELATION     1975NEN 5GATU--6GATU
                             R. GT. 0.30        44

           1971 1970 1973 1966 1946 1952 1968 1950 1949 1955 1964 1969 1948 1965 1967
           M234 S 24 S 34 S 14 Z124  Z   Z124 Z124 S 34 Z123 Z124 Z124 S 24  Z   M123
PERCENT     70.  64.  60.  58.  57.  57.  57.  56.  53.  53.  52.  52.  51.  51.  51.
MEAN SQ    41.0 48.4 40.9 67.3 53.0 50.5 73.4 36.4 43.1 52.0 92.7 43.6 54.8 52.1 97.2
  HOT      -0.3  0.9  0.8 -0.6  2.8  1.2  1.2  1.1 -0.4  0.7  0.0  0.2  0.6  0.7  4.7

           1960 1957 1958 1972 1956 1959 1954 1962 1953 1961 1974 1947 1963 1951
            Z   M234 M134  Z   S 34 M123  M   Z124 M123 Z124 S 13 M124 Z123 M134
PERCENT     50.  49.  49.  49.  48.  47.  45.  44.  43.  43.  43.  42.  41.  40.
MEAN SQ    37.1 44.8 49.7 39.5 51.1 38.4 60.1 63.5 58.8 49.7 43.7 45.0 55.7 46.8
  HOT      -0.3 -1.6  0.7  1.0 -0.2  0.0 -1.7  0.9 -0.2  2.2  0.3 -1.3  0.4  0.8
```

その内で r≧0.3の地点数が44個，それにかぎっての符号の一致率が52％であるということである（この両方のパーセントが高いと正相関となって気温の高い類似が多いことになるが，この場合は50％程度であるので何とも言えない）。

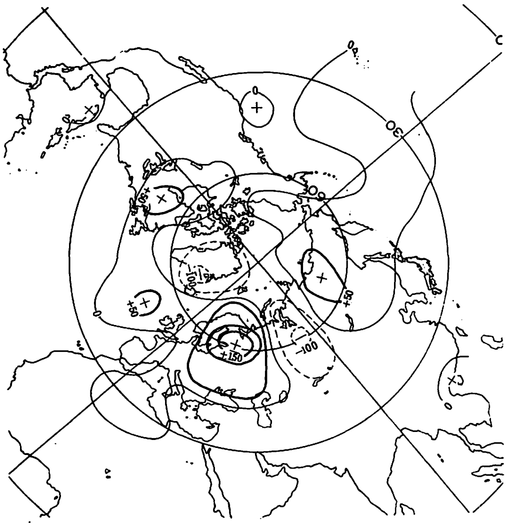
次に類似率のよい順に類似年，その年の環流型，r≧0.3以上の44地点についての類似年と MEAN SQUARE（％が同じ値なら，これが小さい方が信頼度大），その年の予想月の実況の気温偏差（HOTは北海道の気温という意味）が印刷されている。ここで類似年として'71，'70，'73，'66年などがあがってきている。

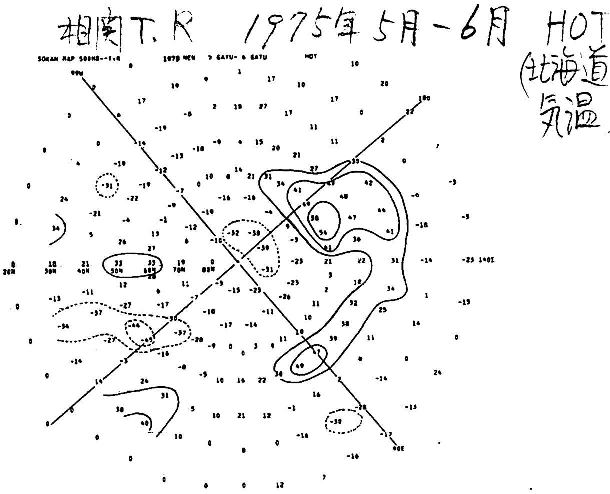
符号一致率の検定をすると，前記のように危険率5％では個数44個の内29個以上（66％）が有意となるわけで，'71年だけが有意ということになる。次に第4図と第5図について，目視で正相関域，負相関域の対応をみるわけである。この場合はアリューシャンから太平洋にかけての正相関域が目につく。

その他，類似年にあがった年と第4図との目視による対応（'70，'66年がアリューシャン～太平洋域での対応がよい），環流型，類似の持続性，符号一致率による類似（20日平均$\triangle Z_{500}$では'71，'48，'55，'73，'50年など。環流型はM_{124}）などを総合して予想をだすが，この例の場合は，北海道6月の気温予想は総合して並～やや高めとなった（この結果は実況と比べると良好だった）。

問題点としては，月が変わると類似にあがってくる年が違ってくることがあり，この点は500mb高度の前月差，3か月平均$\triangle Z_{500}$などを考慮して検討していくべきだろう。

この階級区分はナシ





第4図　1975年5月・
20日平均500mb高度偏差

第5図　1946～'74年 $\triangle Z_{500}$と
北海道$\triangle T$（'46－'74）の相関図

対象月は？

降水量についても，各地域毎の平年比（％）を用いて，同様な方法で予想を行なっている。

3. 半旬５００mb類似

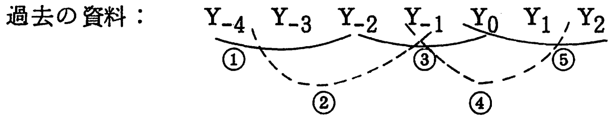
１か月予報のために，半旬500mb 天気図の類似を抽出する類似法がある。これには，(A)機械的に電算機で抽出する段階と，(B)選び出された類似年の中から目視によってさらに類似度の高いもの
二
を選び出す段階の2つがある。

まず，(A)について説明しよう。

予報時の過去３半旬の資料を，次表のようにX_{-2}，X_{-1}，X_0，1946～74年の29年間の毎年について，予報時をはさむ７半旬の資料をY_{-4}，Y_{-3}，Y_{-2}，Y_{-1}，Y_0，Y_1，Y_2とする。

X_{-1}

今年の資料：　X_{-2}，X_{-3}，X_0



今年の資料X_{-2}，X_{-1}，X_0に対し，過去29年間の前後７半旬を取り上げ，上表の①～⑤の対応する組み合わせを考える。

５グループ×29年，つまり 145個の組み合わせができる。

つまりX_0 なる半旬に対しては，前後２半旬ずらして，29年全部について，あとで述べる要素について類似度を調べるわけである。

もし，今年のX_{-2}，X_{-1}，X_0に対して，過去のある年のY_{-2}，Y_{-1}，Y_0すなわち③が類似として取り上げられるとすると同位相，Y_0，Y_1，Y_2すなわち⑤が取り上げられるとすると，今年が２半旬遅れということになる。

類似をみるために次の各要素が取り上げられる。

Ⅰ　過去３半旬の北半球の経過
Ⅱ　過去３半旬の極東域の経過 ─┐
Ⅲ　過去10日平均の北半球のパターン ─┘ Ⅵ
Ⅳ　東半球（0°～180°～160°W）領域の半旬差 ─┐
Ⅴ　過去15日平均図の北半球のパターン ─┘ Ⅶ

例えば，Ⅰの過去３半旬の北半球の経過としては，145個の組み合わせについて符号一致率を計算し，その中から一致率の良いものを順番に13個，逆に一致率の悪いものを13個抽出する。Ⅱ～Ⅴについても行なう（ただし，Ⅲ～Ⅴについては一致率の良いもの，悪いものそれぞれ９個ずつ）。

さらに，Ⅵについては，Ⅲの一致率の良いものをベースとして，しかもⅡの良いものを抽出し，Ⅶについては，Ⅳの一致率の良いものをベースとして，なおかつⅤの良いものを抽出する。

結局，この７要素について一致率の良い例と，逆に悪い例を過去の資料から月に３回，電算機を用いて探し出すわけである。

どのような方法で類似度を表現するかという問題があるが，経験的には，単純な符号一致率でも一致率の良いものは視察による実感とかなり合っている。計算方法でも，どのような要素を取り扱かったらよいか，北半球全体がよいか，極東域がよいか，平均期間をどう扱~~か~~ったらよいか，作用中心をどのような形で組み入れるか，などが大切のようである。

現在は，北半球的な要素（例えば15日平均図）をベースとして，それに極東の天候を特徴づけるパターンを重要視している。

以上のようにして，類似年が数年選ばれる。しかし，このようにして抽出された類似天気図は必ずしもパターンの良い類似を示すとは限らない。そのため(B)の段階として，抽出年の状況を必ず今年のものと対比し，不適当なものはWeightを落としている。

この場合は，パターンの対応だけでなく，東西指数の経過，地上パターン，地上気象要素の変化などについても対応を調べ，現在が何年の何半旬に対応しているかを決める。このようにして，最終的には二~~2~~つないし三~~3~~つの例が残される。

以下に，1975年６月10日発表の１か月予報の際に行なった，この方法について例示する。

○1975年６月上旬の会報

○資料：５月下旬までの資料

○状況：５月月末の500mb 天気図では，第６図に示すように極東では沿海州のブロッキング高気圧の影響で偏西風は分流し，30°N付近にSub．Jet があり，前線活動が活発となり南九州で梅雨入りとなった。

○計算結果：７要素について一致率の良いもの（数値で示してある）と逆に悪い例（×印で示してある）を1946～74年の各年について示したのが第５表である。

これによると，1953年，′54年，′55年，′57年，′60年 が選ばれたが，検討の結果では，10日平均図や15日平均図の良い′53年，′54年 を選出し，さらに目視の結果（第6, 7図参照）′53年を重視した。

○毎日の気圧系の検討からは′53年とほぼ，同日付で良く，梅雨前線の活動を重視した。

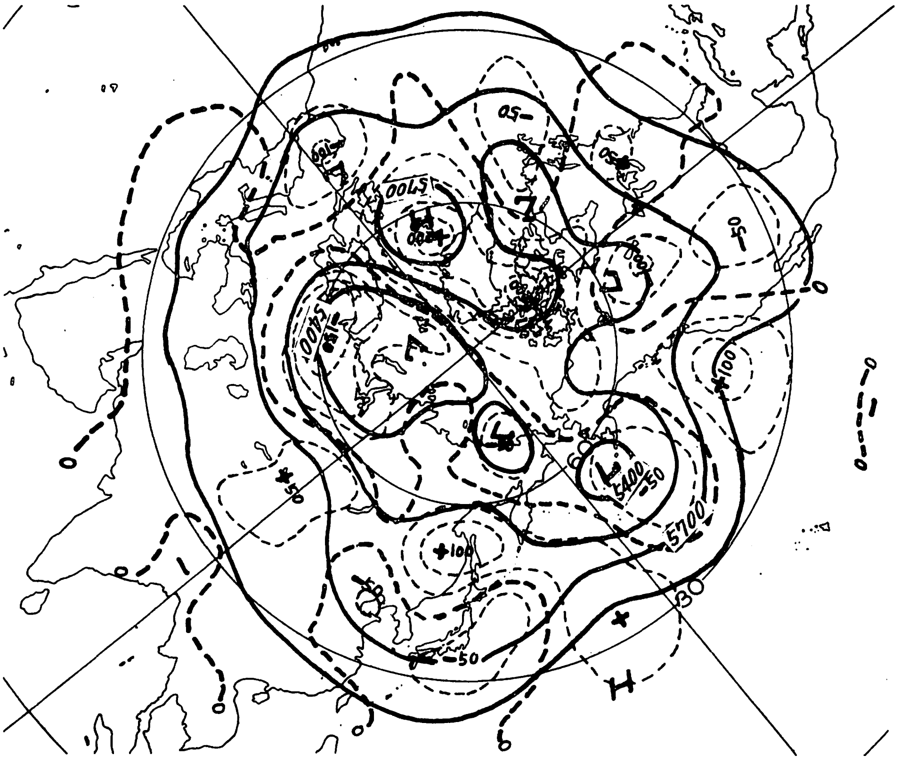
○５月および６月の天候経過の′53年と′75年の対応は第８図に示してあるが，かなりよい対応をしている。

第5表　500mb半旬類似

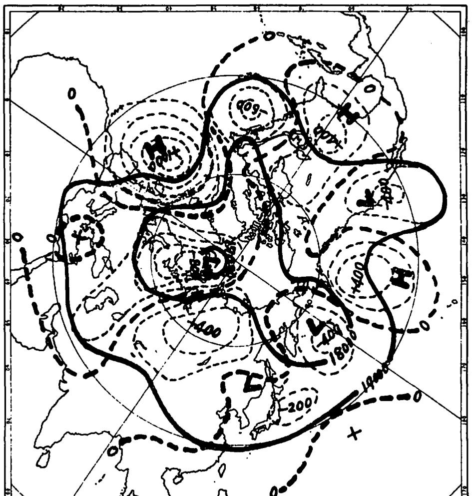
5月の第6半旬　30半旬　1975

	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74
I	28					32	30	30	31	30	×	29		28		×	31	×	×				28		×	32	×		
										31	×							×							×		×		
										28	×							×											
II			28			28		29	31	30	×	32		31	31	×	32	×	×		×		×	30	×				
			32					30								×	×	×											
								31								×		×											
																		×											
III					30	32			32	29	×	29			29	×	31	×	×				31						
											×						32	×	×										
																		×											
IV					28		31			31	×	31			32	×		×					29						
					30					29						×		×											
										30						×		×											
																×		×											
V	×	×	×	31					29	28		30	×		28			32	31					32	×		30	×	
				×						×									×										
II・III		28				28		30	32	30	×				32	×		×	×						×		×		
								29	31									×											
								31										×											
																		×											
IV・V	×			31						28	×	30	×		28			32	×					32	×		30	30	×
				×											32			×									×		

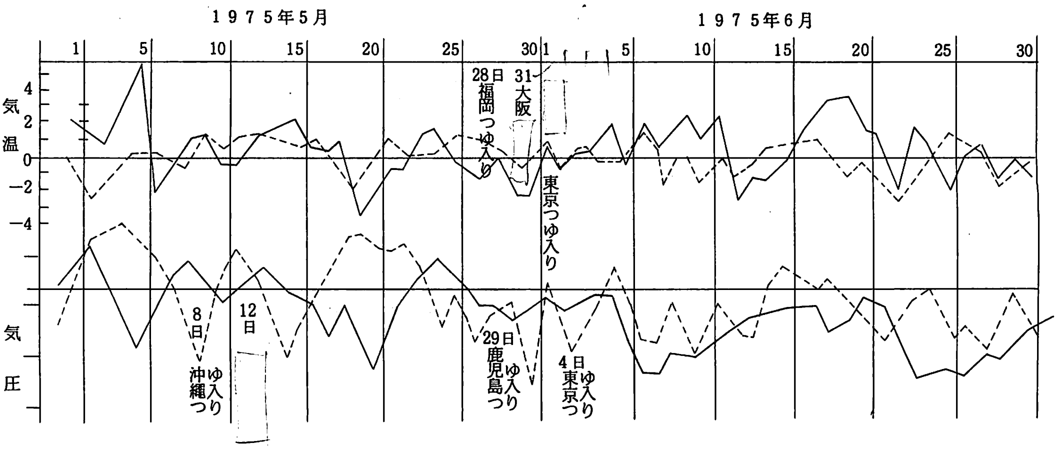
（例）　1953年の欄の最上段の数値30は1975年の28～30半旬と1953年の28～30半旬の一致率が良いことを意味する。×印は一致率の悪いことを意味する。



第６図　北半球500mb高度および偏差（m）
1975年5月26～30日



第７図　北半球500mb高度および偏差（ft）
1953年5月26～30日



第８図　東京の気温，気圧変化（１９５３年と１９７５年の対応）

——— １９７５年

----- １９５３年

§８　あとがき

以上のほか，会報では第２表に示した各種エネルギーおよびそれらの変換量，顕熱および運動量の輸送などの特徴と，その面からみた類似年が示され，また波数解析，合成図の特徴なども示される。さらに第３表に掲載した資料や補助図に基づいた予想結果が報告される。

案

当番予報官は大循環の動きに主眼をおいてこれらの結果を総合し，その年のくせなどを加味して予報文をまとめる。さらに，以上の予想資料の中から，おもなものを選び出して，予想根拠を作成している。

今後の長期予報業務は，多層のしかも南半球まで含んだ天気図類，各種物理量などが整備されてくるので，方法的にも質的にも，これまでとはかなり変わってくるものと思われる。

1975年度L.F.グループ総会の報告

1. 日　　時　　5月20日　15～17時

2. 場　　所　　気象庁長期予報課作業室

3. 出席者数　　約45名

4. 総会概要

(1) 講演

内田英治“ヨーロッパを視察して”

宜

栗原宣夫“最近のアメリカにおける気象の研究について”

(2) 1974年度事業報告

ア. グロースベッター（第13巻）の刊行

1・2合併号（1974年12月刊）の印刷費は，これまでのものに比べて2倍以上となり，会費の値上げが余儀なくされた。3号（1975年4月刊）については印刷所を秀研社に改め，オフセット印刷とした。

イ. 新入会員募集の成果

L．F．グループの活動状況をチラシなどで全国的に周知し，積極的に加入を働~~ら~~きかけた結果，新たに82名の方が加入された。会員総数は総会当日現在541名。

ウ. グロースベッター在庫品の処理

第12巻までの在庫品395部を販売した。

(3) 1974年度会計報告

1975年5月20日現在

収入		支出	
前年度繰越金	69,468円	昭49年度総会補助として	1,900円
会費	320,900	グロースベッター印刷費	286,000
（昭48年度分……… 22,800円 昭49 〃 ……… 293,300 昭50 〃 ……… 4,800）		（第13巻1～2合併号（タイプ）… 220,000 第13巻3号（オフセット）…… 66,000）	
グロースベッター残部売上	40,700	通信費	1,415
雑収入	2,800	次年度繰越金	145,102
利息	549	（グロースベッター第14巻1号印刷費に充当予定）	
計	434,417		434,417

以上の通り相違ありません。　　（会計担当　池田誠也）

1974年度L．F．グループ役員　片山　昭，朝倉　正，池田誠也

(4) 1975年度役員

荒井　康(気研)，関根勇八・舘英男（以上長期予報課），
会計担当………平沼洋司（長期予報課）

以上

連絡事項

1. 今年度の会費について

昨年度はたくさんの方に新入会いただきありがとうございました。

つきましては50年度の会費をなるべく早く官署ごとにまとめてご送金いただければ幸いに思います。

＜送金方法＞

(1) 郵便振替を利用する場合

加入番号：L．F．グループ
口座番号：東京 165913

(2) 銀行普通預金口座を利用する場合

富士銀行本店営業所（千代田区大手町１丁目）〒100

店番号	口座番号	名称	代表者
110	203156	L．F．グループ	平沼洋司

2. 会員の移動について

本年度もかなりの会員の方が移動されました。大方の移動は連絡を受けておりますが，各官署別に名簿を送付しますので転動などされた方がございましたら，お手数ですが，各官署別にご連絡ください。