A METHOD OF SELECTING ANALOGOUS SYNOPTIC SITUATIONS, AND THE USE OF PAST SYNOPTIC SITUATIONS IN FORECASTING FOR EAST-NORWAY

BY

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INTRODUCTION.

Archives of well analysed weather maps have been collected in Norway at the three weather centrals "Meteorologisk Institutt" Oslo, "Vervarslinga på Vestlandet" Bergen, and "Vervarslinga for Nord-Norge" Tromsø. Since 1920 the analyses of the weather maps have been founded upon the same theoretical principles, namely the front and air mass theory of the Norwegian meteorological school. Comparatively long series of weather maps with modern analyses are consequently in our possession. The archives in Oslo, which provide the material for this investigation, contain about 50,000 weather maps with front-analyses.

In the daily weather forecasting, it would be a great advantage if this extensive material could be utilized as much as possible. Questions often come up which could be best answered if an analogous weather map from the archives were easily found. Anyone, however, who has tried to find a weather map of a specified type knows how long a time it takes to seek it out and how difficult it is to decide whether or not the map found represents the best analogy.

The aim of this investigation has been to provide a method of selecting analogous synoptic situations. In addition, I have tried to meet another desire, brought to my notice by Dr. *Gjessing*, namely that of having a means to compare such meteorological events as front-passages and shift of air masses with curves indicating certain medical or biological events. A third aim has been to provide a means for a rapid survey of the past weather conditions in Oslo, which will be of especial benefit when answering questions by the public.

I am much indepted to *W. Hårvig* for his assistance in the drawing of the diagrams, and to *A. Nygaard* for his assistance in reproducing the diagrams.

1. THE PROBLEMS.

Weather maps contain a very large number of individual meteorological observations (e.g. pressure, tendency, temperature, wind, hydrometeors, etc.). The air mass characteristics, the fronts, the isobars and other isolines contained in any chosen chart, give to a certain degree a synthesis of these individual observations, but when dealing with the succession of weather situations over a long range of time, the need for a synthesis of a higher order arises. The problems in this connection may be formulated as follows: (*a*) to find a form of synthesis giving the best aid to a rapid identification of any analogy to the actual synoptic situation, with special stress laid on movements of air masses and fronts, (*b*) to give such a synthesis a form which permits an easy comparison with time-curves of other phenomena depending upon the weather; and (*c*) to develop methods for applying past synoptic situations in the forecasting, and to assess the usefulness of such methods.

One may propose to solve the first of these problems by classifying the weather maps according to pressure systems, positions of air masses and fronts, upper air winds, etc. Each map might be given a classification card, and an analogous synoptic situation might be found mechanically by means of the classification system.

The idea of some kind of systematic classification is an old one. *Teisserenc de Bort*, *Abercromby*, *Köppen* and *v. Bebber*, *Gold*, *Ekholm* and others have tried to classify according to pressure distributions.

According to *Chromov*[1], the results derived from the application of such methods are disappointing. I have therefore had my doubt as to taking up the question again, but I have done so due to a feeling that the methods hitherto employed have been too static.

A successful classification must, I think, take into account the movement of the systems, the fronts and air masses. If this were done, the classification might be very useful, although the work involved in the provision of such a classification system might be found to be impracticable owing to the great variability and complexity of the atmospherical movements.

To solve the problems mentioned above, I have therefore tried a new way, namely a procedure of constructing diagrams which show the movements of fronts, air masses and pressure systems with reference to *one point* on the map, the point chosen being Oslo.

2. THE CLUE DIAGRAMS.

The diagrams consist of 36 plates of which reproductions are printed at the end of this paper. The size of the original plates is 1 m × 0.6 m. Some details have dropped out in the shrinking process of reproduction, but the chief features stand. (For the following, see the enclosed reproductions of the diagrams.)

Each plate contains 7 diagrams over the same month for 7 years, the name of the month being placed at the top of the plate, and the year to the left in the beginning of the rectangles where the diagrams are drawn.

In the diagrams time is abscissa with a linear scale, straight vertical lines represent each 24 hour period. The dates are placed between these lines above each diagram.

[1] S. P. Chromov: Einfuhrung in die synoptische Wetteranalyse. Wien 1942, page 446.

The ordinate is horizontal distance from Oslo. The origin, Oslo itself, is drawn as a thick, straight horizontal line, *the time axis*. The thinner straight horizontal lines each represent (on the reproduction) distance increments of 400 km.

3. CONSTRUCTION OF THE CLUE DIAGRAMS.

Within an area with a radius of 1,200 km around Oslo the distances are measured to *the nearest point* on all fronts which are assumed to influence the air masses over Oslo. Generally the distances are measured from Oslo in a direction normal to the fronts.

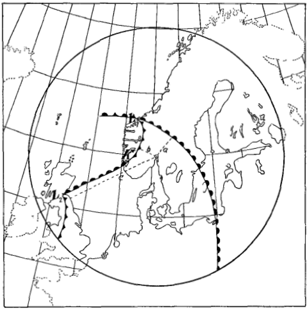


Fig. 1. Measured area and samples of frontal distances.

Fig. 1 gives the area encircled and samples of frontal distances indicated by dotted lines *a*, *b* and *c*. The boundary between two air masses is to be considered as *one* front even though it may be partly a warm front and partly a cold front (compare L_2K and KL_1 on fig. 1); but if the front line by wave formation produces a cusp, where the tangent to the front line becomes indeterminate, (e.g. L_2), a new front is considered to begin at this point.

Each measured distance is plotted as a point on the clue diagrams. Through these points lines are drawn, which below are introduced as the *distance lines* for each front. The distance on the cold side of a front is plotted as positive, on the warm side as negative. Thus the distance lines of a warm front go from the top down to the right of the diagram (fig. 2 and 3, the lines marked with the letter **W**). The distance lines of a cold front go from the bottom upwards to the right (fig. 2 and 3, lines marked **K**).

The occlusions are initially always indicated by distance lines downwards to the right, similar to the warm fronts; afterward continuity is decisive for the direction, avoiding, if possible, breaks in the lines.

The distance lines for occlusions are drawn as broken lines, whereas for warm and cold fronts they are drawn as full lines.

Dotted lines also appear on the clue diagrams. They represent fronts whose existence is particularly uncertain.

Frontogenesis and frontolysis are indicated by circular symbols. If a distance line starts with this symbol, then we have frontogenesis. If, on the other hand, a distance line ends with the same symbol, then we have frontolysis (see fig. 4).

The air mass analysis is, on the weather maps in our archives, partly indicated by colours. Tropical air is indicated by an even red tint. Arctic air is a blue colour. The continental polar air in winter also has a blue colour on these maps when it is very cold and, on the whole, has the same properties as the arctic air. The remaining air masses are not coloured, and only rarely indicated by letters.

On the original plates of the clue diagrams tropical air and arctic air, as well as continental polar air, are similarly indicated by colours. Tropical air is drawn as a red coloured band at a distance above the time axis corresponding to the horizontal distance to the nearest point in the tropical air mass. Arctic air is indicated only if it has reached Oslo, and then by a blue coloured band, resting on the time axis.

One can very easily identify the tropical and arctic air bands also on the reproduction in this paper, where the air mass bands are not coloured but hatched, because the tropical air comes in with a warm front and disappears with a cold front. The hatched band of the arctic air, on the other hand, always rests on the time axis, and generally begins with a cold front passage and ends with a warm front passage.

The breadth of the band corresponds to the genuineness of the air mass. By letting the band narrow and end in a point, indicates that the air mass is losing its specific tropical or arctic properties and has changed to ordinary polar air over Oslo. The band representing tropical air generally follows the front until the occlusion process reaches the point of the front which is nearest to Oslo. From this moment the front is represented as an occlusion, and the tropical air band goes away from the distance line. (See fig. 3.)

The source region of the tropical air approaches in summer the measured area. Then it may occur that the tropical air comes within the area without being delimited from the adjacent air masses by a distinct front line, as the zone of transition is broad and vague. The tropical air band then comes in on the clue diagrams without following any front. It also occurs at times in summer during high pressure situations that parts of the measured area may act as a source region for tropical air. During the transformation to tropical air, the hatched band for the tropical air begins at a point on the clue diagrams and increases in breadth as the tropical air properties develop. (See fig. 2.)

The measured area may in winter act as a source region for cold continental air with properties similar to those of the arctic air. This air may then flow over Oslo without any distinct front line before it. In this case the hatched arctic band starts on the time axis with no frontal passage before it, and broadens gradually. This occurs sometimes during high pressure situations.

No distinctions between continental and maritime air masses are to be found on the clue diagrams, but the character of the air masses may be seen indirectly from the small charts which are placed beneath the diagrams, and which below are introduced as the *path-charts* (paths for the cyclones and anticyclones). The path-charts indicate the successive pressure situations. Anticyclones are denoted by ***H***. If the high pressure is displaced during the space of time indicated in brackets above the chart (e.g. fig. 4, where the bracketed time is from 8^h 25^{th} April to 19^h 30^{th} April 1927), an arrow from ***H*** indicates the course of the displacement.

The courses of the cyclones are indicated by arrows. If the cyclone centre has not passed out of the area of the path-chart during the time indicated by the brackets above, the arrow for the cyclone in question will be transferred to the following path-chart, where it begins at the same point as where the arrow on the preceding chart ended. By means of arrows, the path of the cyclone may be traced from one path-chart to another.

Cyclogenesis and cyclolysis are indicated by circular symbols similar to those used for the distance lines of the fronts. See for instance fig. 6, where cyclolysis occurred over the Norwegian Sea and over the Gulf of Bothnia, while cyclogenesis occurred over Skager Rack.

Just below the time axis numbers and symbols are plotted indicating the weather in Oslo. Uppermost is the precipitation measured at 8^h and 19^h, in the middle is the minimum temperature for the night and the maximum temperature for the day marked down at 8^h and 19^h, respectively. Below is " past weather " put down at 8^h, 14^h and 19^h. These data are introduced on the clue diagrams chiefly in consideration of telephonic inquiries about Oslo weather.

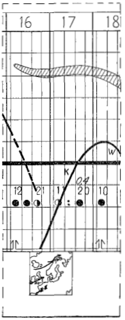
4. DETAILS OF THE CLUE DIAGRAMS.

The clue diagrams are principally meant to be used in the scale in which they are drawn on the original plates. A number of details have become indistinct owing to the great diminution by the reproduction. To make the construction of the original diagrams more clear, and to facilitate the reading of the data, I have allowed some of the details to be printed only slightly diminished.

As on the original plates, the synoptic hours are indicated on fig. 2–6 by thin vertical lines. The number of horizontal lines are twice as many as on the reproduction, and the distance between each represents 200 km. Examples of what may be deduced from these details follow:—

Fig. 2.

From the 16^{th} to the 18^{th} of August 1920: From the path-chart the following deduction may be made: Anticyclonic wedge over France moves slowly towards Spain. Cyclone near Lofoten (Northern Norway) moves landwards to Finnmark, where it dies away. This cyclone precedes another cyclone, which in the course of the 48 hours indicated by the brackets above, has travelled from Iceland across the Norwegian Sea into the Arctic Sea north of Murmansk. The path is about 3,000 km and the average velocity is accordingly 60 km per hour. Still another cyclone develops and traverses England to the North Sea. The air transport over Europe north of the anticyclone is mainly from west towards east.

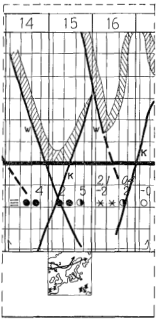


$^{16}/_8$—$^{18}/_8$ 1920.

Fig. 2.
Detail of clue diagrams.

From the diagram one may deduce that the air in Oslo is of a polar type, as no hatched band appears on the time-axis. According to the main air transport, the polar air must be of a maritime type. At a distance of about 800 km from Oslo, in the high pressure field, tropical air gradually develops, though without any front having come into existence.

A warm front from the west came towards Oslo during the night of the 16^{th} of August. It occluded and passed Oslo shortly after 8^h, without releasing precipitation, continued with the same velocity, and could be followed 250 km past Oslo. The distance line shows a velocity of about 45 km per hour towards Oslo. A cold front approached Oslo on the night of the 17^{th}, the displacement being 500 km in 13 hours. With some experience one can almost with certainty read out of the diagram that the cold front was connected with cyclone number 2, and assume that the latest developed cyclone, number 3, near Eire, was due to wave formation on the cold front, which retarded after the passage and returned as a warm front towards Oslo again on the 18^{th}. The cold front passage caused a precipitation of 0.4 mm in Oslo.



$^{14}/_{12}$—$^{17}/_{12}$ 1923.

Fig. 3.
Detail of clue diagrams.

Fig. 3.

The 14th to the 17th of December 1923: High pressure over the Bay of Biscay and over Ukraine. Cyclone near Iceland went across the Norwegian Sea and northern Scandinavia. Cyclone number 2, came in over northern Iceland, went towards Trondheim and turned northwards along the coast. A new cyclone developed simultaneously over the middle part of Sweden and went towards south-east. Afterwards a cyclone came from west near southern Iceland. The cyclone paths and the locality of the high pressure indicate that the air transport must be predominantly westerly over northern Europe, and that the air masses over Norway must accordingly be maritime.

A tropical air sector from the west moved towards Oslo in the course of the 14th. The velocity of the warm front towards Oslo was 50 km per hour, and it passed about 22^{h}. From now maritime tropical air prevailed over Oslo till the cold front swept it away at 10^{h} on the 15th. No precipitation was observed in Oslo; the wind must have been just westerly enough for the mountains to destroy the precipitation area. It was cloudy in the tropical air sector, and the temperature was above zero in Oslo even at night. The tropical air band narrows, after the passage, towards the cold front, which indicates a comparatively rapid transformation to polar air.

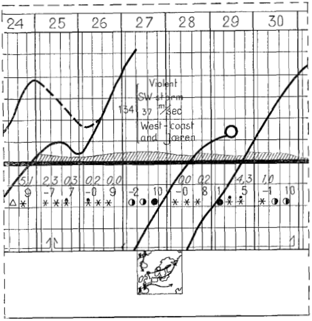
Cyclone number 2 brought a second current of maritime tropical air with the velocity 60 km per hour, towards Oslo.

The tropical air sector occluded before reaching Oslo, and the occlusion passed on the 16th about 11^{h}. The occlusion caused snow the whole forenoon. The occlusion point was speedily displaced southwards along the warm front. This is shown on the diagram by means of the tropical air band, which goes (without any front) abruptly upwards and out of the diagram. There is reason to assume that the new cyclone over Sweden was developed in connection with the occlusion process. A cold front followed, and it passed during the night of the 17th.

Fig. 4.

The 25th to the 30th of April 1927. An anticyclone over the Bay of Biscay went at first in NE, later in E direction towards southern Russia. Another went simultaneously from Greenland across the North Atlantic towards Eire. A cyclone over the North Sea moved eastward, turned NE over the Baltic countries and NNE towards the Barents Sea. Low pressure centre number 2 developed near the Faroe Islands, made a loop over southern Norway, and continued towards NE over the Bay of Bothnia. The northward movement of the cyclones suggests an influence of a high pressure system over East Russia.

A comparison between the path-chart and the rest of the diagram for the period makes it quite evident that a flow of arctic air has passed southwards over the Norwegian Sea. On its

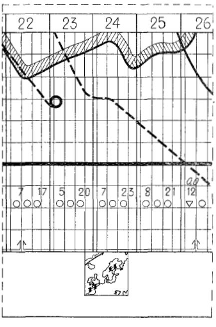


$^{25}/_{4}$—$^{30}/_{4}$ 1927.

Fig. 4. Detail of clue diagrams.

way the air has accumulated a considerable amount of moisture. The air current curved over Norway mainly in E and NE direction, and some precipitation was released over Oslo for each cold front. The cold front, which advanced on the 27th, was connected with the cyclogenesis near the Faroe Islands. As the newly-developed cyclone reached Western Norway on the night of the 28th, a storm occurred. Information about this is to be found on the clue diagrams as a little note above the time axis. Such notes are taken from press clippings, which are catalogued in our library. The number 134 before the note in question, is the number in the catalogue. One can easily find the clippings by means of this number, if one wishes more accurate details about the reaction of the public concerning the weather, as far as it may be gathered from the newspaper reports. The notes contain the clue to the chief contents of the newspaper reports—the localities, phenomena and effects.

The cold front retarded after the passage in the middle of the day on the 28th, and died away at a distance of about 200 km from Oslo. The arctic air must originally have been very cold, as it caused snow and sleet in Oslo at this time of the year, although it came in from SW and W. However, its vertical depth must have been inconsiderable, as the temperature increased rather speedily (cp. maximum temperature 10° C April 27th and 30th).



22/5—26/5 1939.

Fig. 5. Detail of clue diagrams.

Fig. 5.

From 22nd to 26th of May 1939. Oslo lies in an extended ridge of high pressure with two centres, one over the Bay of Bothnia, and one over the Bay of Biscay. It is clear weather and the temperature amplitudes are very large, even as much as 16° C. The cyclone paths near Greenland and in the south-eastern parts of Europe seem to be controlled by the high pressure ridge, which may be assumed to have a stationary character. The notes "Weather past" show no cloud formation, despite the strong heating of the atmosphere during the day. This suggests that the air mass over Oslo must be stable.

To a certain extent, especially if one has some experience in reading the clue diagrams, one can find the direction from Oslo to the fronts by studying the diagrams. Example fig. 5 is one of the more difficult ones.

The hatched band above the time axis shows that there is genuine tropical air at a distance between 800 and 1,100 km from Oslo. A front is observed in front of it. This indicates that the air has moved away from its source region. The tropical air remained, largely speaking, at the same distance, without occluding or losing its genuineness. It is therefore logical to assume that it has not moved very far from its source region. The path-chart indicates possibilities for the flow of the tropical air, either from SE over Ukraine and Poland, depending on the cyclone movements there, or it may have come from W, caused by the cyclone movements NW of Iceland. The latter possibility may be eliminated, as the tropical air then must have travelled far from its source region. The tropical air must accordingly be situated SE of Oslo.

It is probable, with a pressure system such as the one the path-chart exhibits, that an eventual tropical air flow over the Atlantic from west, would have occluded before it reached Oslo. The two occlusions which are found above the time axis, were, as might be expected, of that kind, and were situated west of Oslo. The first dissipated 500 km from Oslo, and the second passed on the night between 25th and 26th of May, and released slight precipitation over Oslo. The high pressure over Scandinavia then moved eastwards.

One can, in a similar manner, by surveying the clue diagrams, generally form a well supported opinion about the movements of the air masses in question, their source region and life history. A rather detailed classification would have been necessary to give a more perfect shading.

5. COMPARISON TO ISOPLETH-DIAGRAMS.

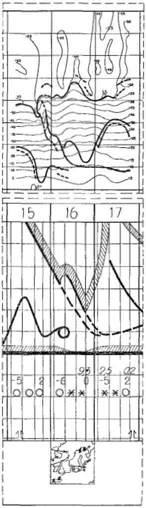
Isoplethdiagrams of the movements of the frontal surfaces at a height above a certain region are frequently used in meteorological literature. The clue diagrams have many points of resemblance to such isoplethdiagrams. If the change in structure of a system is slow and its velocity of propagation known, the time section can be interpreted as a space section, that is "succession replaces vicinity" (nacheinander gleich nebeneinander), a principle familiar through its usage by Bergeron, J. Bjerknes, Palmén, and others.

Fig. 6 presents a rather complicated isoplethdiagram, and at the bottom is a fragment of the clue diagrams. The time axes are orientated in accordance with one another. This isoplethdiagram has earlier been dealt with by J. Bjerknes and E. Palmén.[1] The clue diagrams fragment is prepared from measurings on synoptic weather maps in accordance with current methods, without using sounding balloon ascents.

The scale along the time axis is the same on both diagrams. The ordinate scale on the clue diagrams fragment is 1/100 of that on the isoplethdiagram.

Comparing the two diagrams, it is evident that the frontal surfaces on the isoplethdiagram appear with their characteristic features on the distance lines of the clue diagram. The flow of tropical air is found on both diagrams. The path-chart indicates that the tropical air comes from west and is maritime. It is seen how the Tropopause is lifted upwards as the tropical air comes in. The temperature of the stratosphere fell from —50°C Febr. 15th to —60° C Febr. 16th, as the tropical air advanced towards Oslo.

The diagrams reveal the same phenomenon, and they harmonize with each other, apart from the fact that the tropical air disappears from the clue diagrams fragment during the night of Febr. 17th, while on the isoplethdiagram it appears again along the warm front, which advances in the course of Febr. 17th. The air in the rear of this warm front was not supposed to be warm enough at the bottom to be termed tropical air on our weather map in question, but sounding balloon ascents showed that the air mass in the upper Troposphere on the whole had the properties of the tropical air. The harmony is, moreover, so good that the reader, by comparing the two diagrams, may find the significance of the various symbols on the clue diagrams, the isoplethdiagram being a well-known mode of presentation.



15/2—17/2 1935.

Fig. 6. Isoplethdiagram and clue diagrams.

6. THE DISTANCE LINES AND THE INCLINATION OF FRONTAL SURFACES.

The construction of the isoplethdiagram is based on vertical studies of the air over a region. As previously mentioned, the clue diagrams are constructed in a similar manner, but are based

[1] Printed on a somewhat different scale in: "Investigations of selected European cyclones by means of serial ascents", case 4: February 15th–17th, Geofysiske Publikasjoner Vol. 12 Number 2, page 31. The drawing of the isoplethdiagram is based on 27 sounding balloon ascents from Ås (situated 27 km south of Oslo).

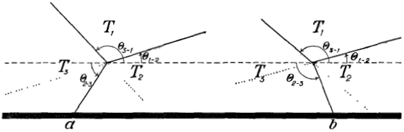


Fig. 7. Occlusions of *a*) warm, *b*) cold front type.

on horizontal measurements of the air masses. The same phenomena are thus seen in two different aspects.

If the inclination angle of the frontal surface is known, it is possible to read the vertical structure of the air over Oslo directly from the clue diagrams. If, for instance, the inclination angle is 1/100, the thin lines above the time axis represent 2, 4, 6, ... (and so on) km height over Oslo.

The clue diagrams cannot give any exact information about the vertical structure of the air over Oslo. But the distance lines are drawn in such a way that a right impression is obtained, qualitatively speaking. A distance line for a warm front drawn above the time axis at the moment in question indicates a warm front over Oslo. The same may be said regarding the distance lines for the cold front. If the displacement occurs without acceleration or deformation, the distance lines above the time axis may even be interpreted as a vertical cross section along the direction of the movement, similar to the isopleth-diagram.

As will be shown below, it is somewhat more difficult, where the occlusions are concerned, to get a correct idea of the air mass structure over Oslo from the clue diagrams.

The inclination angle Θ of a front may be computed from the equation:

$$\tan \Theta_{1\text{-}2} = \frac{T_1 i_2 - T_2 i_1}{T_1 - T_2} = i_2 + \frac{T_2}{T_1 - T_2}(i_2 - i_1) \quad [1]$$

where i_1, i_2 refer to the slopes of the isobaric surfaces, T is the temperature, and the subscripts $_1$ and $_2$ indicate the two air masses, which are in contact with each other along the front.

The three air masses which are contigous at the occlusion point are denoted by the subscripts $_1$, $_2$, and $_3$, as indicated on fig. 7, where a is an occlusion of the warm front type, and b of a cold front type. By introducing the proper indices from fig. 7 in equation 1, and by subtracting, we find:

$$\tan \Theta_{3\text{-}2} - \tan \Theta_{1\text{-}2} = T_2 \left(\frac{i_2 - i_3}{T_3 - T_2} - \frac{i_2 - i_1}{T_1 - T_2} \right) \quad [2]$$

For static reasons we always have $i_2 > i_1 > i_3$ (corresponding to the kink of the isobar at the fronts). We obtain:

$$(i_2 - i_3) > (i_2 - i_1) > 0 \quad [3]$$

T_1 is always the highest of the three temperatures round the occlusion point. From this follows:

$$(T_3 - T_2) < (T_1 - T_2) \quad [4]$$

$(T_3 - T_2)$ must be positive if the occlusion is of the warm front type (fig. 7 a). From equations 2, 3, and 4 we obtain:

$$\tan \Theta_{3\text{-}2} > \tan \Theta_{1\text{-}2} > 0 \quad [5]$$

The occlusion must accordingly have a larger inclination to the horizontal than the warm front surface above.

If the occlusion is of the cold front type (fig. 7 b), it may be found in a similar manner that the occlusion surface is more steeply inclined to the horizontal than the cold front surface above the occlusion centre.

The occlusion front must, in all cases, be drawn with a kink downwards in respect to the frontal surface above. This kink must be found in any cross section which intersects the occlusion line, also in the horizontal cross section. The angle which the occlusion surface makes downwards in respect of the frontal surface above, may be computed from equation 2. *Werenskiold*[1] has found an elegant form, which may be used with a sufficient degree of approximation, provided that the temperatures do not differ very much. By introducing the expressions from fig. 7, it may be written:

$$\tan \Theta_{2\text{-}3}(T_3 - T_2) + \tan \Theta_{3\text{-}1}(T_1 - T_3) + \tan \Theta_{1\text{-}2}(T_2 - T_1) = 0 \quad [6]$$

If for instance the difference in temperature between the two cold air masses equals the difference between the warm air and the warmest

[1] W Werenskiold: Trykkgradientens brytning i en grenseflate. Fra Fysikkens Verden. Oslo. 1941, page 129.

of the two cold air masses, then the inclination of the occlusion surface to the horizontal is equal to the sum total of the inclination of the cold front and twice the inclination of the warm front. Similar cases occur frequently in winter.

If the difference between the temperature of the two cold air masses is small compared to the difference between the temperature of the warm air and the warmest of the two cold air masses, then the occlusion surface is very steep. This occurs mostly in summer, especially when the warm air is continental, and the two cold air masses are maritime. One may in such cases consider the occlusion surface as practically vertical. The occlusion surface is mostly so steep that the projection of the occlusion line cannot be discerned from the ground front of the occlusion.

The distance lines for the occlusion (the broken ones), which give the horizontal distance to the surface front, can, owing to the great variability concerning the slope and height of the occlusion surface, not be utilised as a measure for the vertical distance to the frontal surface. Further, when the occlusion changes character from warm front type to cold front type or conversely, it is not convenient to distinguish between the two types of occlusion in the same way as between the warm front and the cold front, i.e. by means of the direction of the distance lines. All occlusions are drawn in the same way (see page 7). If the occlusion, for instance, has passed Oslo, but then turns and passes anew, the distance line for the first passage intersects the time axis downward to the right; the distance line for the second passage goes upward to the right independent of the type of occlusion.

As far as warm and cold fronts are concerned, it is only the part of the distance line which extends above the time axis that indicates the vertical structure of the air over Oslo. In respect to occlusions this is not the case. Above as well as below the time axis, a dashed distance line may indicate a front surface over Oslo.

7. THE APPLICATION OF THE CLUE DIAGRAMS.

It is self-evident that the simplification of many ten thousands of weather maps to the 36 plates of the clue diagrams is not possible without sacrificing something. The clue diagrams should therefore be considered as an extract of the weather map analyses seen from Oslo, and can neither give so comprehensive information as the weather maps nor replace them.

The application must, therefore, to a certain extent, be based upon the fact that the clue diagrams are not to be used isolated, but as a supplement to the weather map archives, acting as a clue which enables one to find what is needed from the archives.

The course of procedure may be indicated as follows: Given a fixed or presumed movement of pressure systems, air masses and fronts, one wishes to know what weather situations of the same kind from the chart archives can tell about such a movement. One then reads through the clue diagrams as indicated in the examples in section 4, until the most promising situations are found. The weather maps in the archives concerning these situations are easily produced and can be studied.

Thus the clue diagram is a tool, facilitating works of various kinds in meteorology. The following ways of application may be emphasized. 1) In the daily weather service the forecaster prepares prognostic maps of pressure systems, fronts and air masses. Having done this he has in his forecast to draw the conclusions from the atmospheric movements he thus has fixed. This may often be difficult concerning the localities of, for instance, precipitation, temperature, winds, etc. Older situations found from the archives by means of the clue diagrams may give him very good support, frequently a better help than statistical researches, for the latter intermingles many situations with only poor connection with the given situation, while the clue diagrams search out the best analogy for the purpose. Also in preparing his prognostic maps, the forecaster may use the clue diagrams as a tool seeking out older weather series that may be of any support to him. This will be discussed in the next section. 2) If an urgent report about a weather situation is needed, where the details are of no great importance, the desired survey may be read directly from the clue diagrams. Even though it is easy to find one's way through the chart archives when the point of time is given, the information there is often not survey-able enough, and the turning over of maps takes more time. If the researches concern a longer space of time, simplification is necessary in order to obtain an adequate mode of representation, the number of weather maps being too large.

This is especially the case when another complex of occurences is going to be compared to the meteorological one in order to ascertain interdependence. If it concerns for instance a medical report about the condition of a patient during months or perhaps years, one cannot avail oneself of piles of weather maps in order to compare with curves concerning blood pressure, pulse, etc.

Recent meteoro-biological researches made by such scientists as *B. de Rudder*, *William F. Pettersen*, *Bernhard Düll* and others, have indicated that the change of different air masses, that is frontal passages, exert an influence on the organism. The way the clue diagrams represent the changes of air masses renders a comparison with medical scientific curves fairly easy, and it is to be hoped that it will prove itself applicable in meteoro-biological researches, and also for other investigations concerned with matters influenced by the atmospheric processes. 3) A series of statistical computations may be made with comparative facility with the clue diagrams as a basis, such as average annual, seasonal and monthly frequency of front passages; average frontal velocity towards Oslo; average annual condition of different air masses over Oslo, for instance: temperature in tropical air or arctic air; distribution frequency and average duration of certain types of weather; etc.

I hope that I will have an opportunity later to en'arge upon this subject. In this investigation I have limited the discussion to concern the use of the clue diagrams as an auxiliary aid to prognosis.

8. THE PROBLEM OF PROGNOSIS.

In order to obtain a reliable prognosis the main point is to determine the most important features of the next day's, or, contingently, the following day's, weather charts.

The latest weather chart, which furnishes the chief basis for the prognostication, is denoted by F_o, and t_o represents the synoptic hour for this weather chart. Let F represent a weather map at the time t within the space of time which the prognosis comprises. The question is how to express F by aid of F_o and the preceding weather maps. The problem would be solved exactly, if F could be expressed by F_o by aid of the hydrodynamic equation system. But general, exact solutions of the hydrodynamic equation system, are not known as yet. The forms used in the prognostication are either kinematic forms, or they give only approximations, because the simplifications necessitated in order to find these forms, do not conform with what is observed in nature.

The equation system, however, is defined, and exact solutions must exist. It must therefore be possible to write such a solution in the form:

$$F = F\,[F_o, (t—t_o), A_o, B_o \dots A_t, B_t \dots] \quad [1]$$

where A_o, $B_o \dots$, A_t, $B_t \dots$ denote a number of parameters, which enter into the solution owing to the boundary surfaces and other influences upon the atmosphere from without.

The assumption is justified that an infinite number of such parameters exists, corresponding to an infinite number of outward influences. Some parameters exert an influence on the development of weather over large regions, others are merely local.

The parameters may be divided into two categories, according to their variability:

a) Parameters entering in the solution in the same manner independent of season (A_o, B_o ...). By way of estimate I should suggest that the most important are the following: distribution of land and sea; the main ocean currents; the relief of the country; and the structure of the country, e.g., woodland, barren extents, tracts of sandy soil, open fields, etc.

b) Parameters entering into the solution as implicit functions of time (A_t, B_t . . .). The most important must be: the altitude of the sun; the surface temperature of earth and sea; and the extent of snow-covered ground, the structure of snow surface, the altitude of the subsoil water and aqueousnes of the earth's surface, etc. All these parameters vary with season, the diurnal rhythm and the preceding weather situations.

It must be borne in mind that the chart area comprises only a restricted region of the earth's surface. One must therefore take into account an influence from the adjacent atmosphere, and this influence varies with time. For all forecasting methods this influence is an unknown and quite variable quantity. It may be plausible to assume that the influence decreases as the map area increases.

It may also be worth while to mention the variability of the friction with the earth's surface due to the seasonal change of the vegetation. The friction is much greater in summer, caused by the foliage, than in winter, when trees are naked and the snow covers and smooths cavities and inequalities of the ground.

Because no exact solution to the problem of prognosis is found, one must, to a considerable extent, rest satisfied with a prognostication based on assumptions. The prognosticator must in his estimate give consideration to the parameters, which he generally does, using his experience.

The influence exerted by the parameters A_o, B_o . . . is easily taken into account, because they enter the solution in the same manner all the year round. It is difficult, on the other hand, to gather experience about the influence of the parameters which vary with time. An ability to remember the development of the weather which occurred a year or several years before, without intermingling it with experiences from other seasons, is here presupposed.

9. ANALOGY PROGNOSES.

Although we do not know general, exact solutions of the hydrodynamic equation system as applied to the atmosphere, we still have a great number of solutions evidenced in the successive synoptic weather maps in the chart archives. One may for any time within the time interval which the weather chart archives comprise, write:

$$F' = F' [F'_o, (t'-t'_o), A'_o, B'_o \ldots A'_t, B'_t \ldots] \quad [1]$$

where the primed letters indicate a solution of the prognosis problem with respect to the time t'_o. The following weather charts give the solutions $F'_t, F'_{t+6}, \ldots$.

It should be natural to utilize previous solutions as a pattern for the actual, current problem of prognosis. As already stated, this is done when the prognosticator makes use of his experience. This personal experience is of great value, but it is desirable to eliminate everything subjective insofar as possible, and, above all, to establish a method which does not require the empirical studies of years before it may be utilized.

A prognosis modelled on solutions of previous weather maps is called an *analogy prognosis*. The idea of prognosis of this kind is old, and the attempts to systematize weather charts mentioned on page 6 are mainly made with such prognosis in view.

The best synthesis of all observations plotted on the weather map, that is the best and most complete expression for F_o, is, according to modern conception, the spatial distribution of the air masses and the fronts at time t_o. In attempting analogy prognosis, the greatest stress must be laid upon the conformity regarding movements of the fronts and the air masses.

One must, moreover, bear in mind the significance of the parameters, varying with time, A_t, B_t, . . ., which even though the conformity with F_o may be good, may have a modifying influence on the solution F, especially if the seasons do not correspond.

The following working plan for the clue diagrams as an auxiliary aid for prognostication is based on these considerations.

i) By aid of the clue diagrams, weather maps are selected from the archives, maps which harmonize with the current one, especially in respect of the distribution and movement of air masses and fronts.

ii) The selection is limited to charts from the same season, or, more precisely, from the same month and the months immediately preceding and following the current situation.

iii) One prefers analogies with the same diurnal rhythm, that is, the analogy chart which furnishes the basis for the prognosis ought to be from approximately the same hour as the present weather map.

iiii) One also prefers analogies where historical sequences regarding precipitation, etc., over the area are as alike as possible.

Using the symbolical terms introduced in this and the preceding section, we may according to i) put $F_o \simeq F'_o$ with the approximation which the current material in the chart archives permits. If selection is made according to ii), iii), and iiii), the chances are at their greatest for the time varying parameters to be approximately equal: $A_t \cong A'_t$, $B_t \cong B'_t$ ....

One assumes that, according to their nature, $A_o = A'_o$, $B_o = B'_o$ ....

F and F' being solutions of the same hydrodynamic equation system, it is logical to assume that in approximately the same degree as one succeeds in finding good analogies, the solution which is sought should also approximately equal its analogy.

After a number of experiments with analogy prognoses, to which I will return later, I have found it expedient to introduce a couple of new definitions.

A. *Tangency:*

A meteorological tangency is an analogy which remains sufficiently alike at least for 48 hours, to admit a detailed prognosis over the entire prognosis area for the forecasting institution concerned.

The restriction of the analogy to concern the prognosis area only, e.g. an area with a diameter of say about 600 km, has proved itself eligible according to the tests which are made. If the tangency should involve the whole chart field, the harmony would seldom be sufficiently good to admit a detailed description of the development of the weather. A kind of nodal point seems to shape itself on the weather map where the difference between the two analogous series of charts is negligible, and the further one recedes from this nodal point, the less detailed is the analogy. One studies therefore the weather map primarily with a view to the prognosis area, secondly, as a whole. The choice of analogy is, therefore, to a certain degree, modified by the area for which the prognosis is going to be made. In reality then F is a function of such a kind that the main stress is laid upon the salient features of the fronts and air masses which already have invaded, or which may be expected to invade, the prognosis area. A similar point of view has always asserted itself consciously or subconsciously during the analysis of the charts. This is evident from the different bulletins, where the analysis is more detailed when the prognosis area is concerned, but becomes more gross and inaccurate the further one recedes from this region.

It is important to note that the similarity between the two series of weather maps during a tangency is of sufficient duration for one to be able to detect the analogy even before the point of time when the maximum of analogy is reached. One may therefore generally have

$$|F - F'| < |F_o - F'_o|$$

where F_o denotes the weather map when the analogy was detected and F denotes the weather map 24 hours later.

B. *Intersection:*

A meteorological intersection is an analogy which lasts less than 48 hours. In such cases one cannot expect to discover the analogy till shortly before maximum of similarity is reached, because the duration is too short in comparison with the time interval between the weather maps. One must, therefore, generally consider $|F - F'| > |F_o - F'_o|$, at least in prognoses for time intervals of 24 hours or more. The harmony between the series of maps decreases the following day, and one must endeavour to find a new and more suitable analogy for the next prognosis.

It may be assumed that $|F - F'|$ may grow so large that the analogy is not serviceable as a model for the prognosis, and may at times be delusive. Decisive in this connection is:

1) How large is the deviation $|F - F'|$ compared to the deviation between F and the extrapolated weather chart according to current forecasting methods, which do not utilize analogy. If the extrapolated weather chart in question is denoted by F_e, then a better result would be obtained by using the analogy in all cases where $|F - F'| < |F - F_e|$, even though the agreement the following day is not good enough to furnish the basis for a new analogy.

2) To what degree, with the comparison between F_o and F'_o as a basis, can one compute or estimate the differences which may arise, without slavishly operating with F' (see section 13), but with a series of charts, which by physical and kinematical discussions are corrected to a better correspondence with F?

All kinds of transition between meteorological tangency and intersection exists as a matter of course.

10. TESTS.

During the last four years I have obtained some experience in the use of analogies found by aid of the clue diagrams. As indicated above, they have not been used slavishly but in combination with other methods as a basis for the prognostication. A sufficiently good analogy was not always to be found, but the analogies have very often helped to a better understanding of the processes going on in the atmosphere.

It may be of some interest to know to what degree of success the analogies lead when slavishly operating with this method alone. During the war I made four tests with the aid of material from the archives, viz.. one month from spring, summer, autumn and winter, respectively. *J. Eriksen* and *N. J. Schumacher*, who then were students of meteorology, helped me and arranged everything as if for actual forecasting. The area for the prognosis was south-eastern Norway, i e. Östlandet, Telemark, Sórlandet and the mountain districts Jotunheimen and Dovrefjell. The aim of the test was to ascertain the value of the analogies found by aid of the clue diagrams, especially compared to the prognostication issued and put down in the forecasting records of the Institute at the point of time concerned. The analogy forecasts had to be put down in common text to facilitate the comparison with the forecasting records, and they were often very detailed, because the analogy charts had to be followed precisely. The rules i) to iiii) in the programme outlined on page 15 were followed as closely as possible. The procedure was as follows:

1) A small sector of the clue diagrams from the last 72–96 hours up to the time for the preparing of the forecast, was at first copied on transparent paper.

2) This cut (sector) was compared to other cuts of the clue diagrams by moving it along the diagrams. It mostly paid first to compare the path-charts and then to study the front lines and air masses. The dates for eventual analogies were noted as the work proceeded. The amount of such dates was generally about 5.

3) The weather maps for the noted dates were found in the archives and compared. In most cases only a couple of the noted situations had to be studied more minutely. The rest proved to be useless, even with a preliminary survey of the charts.

It was impossible at times to find analogies which were serviceable. Analogy forecasts were, however, prepared also in these cases for the sake of comparison. The main stress was then laid upon the influence of the orography, e.g., when the current weather situations had say a cold front passage from W, the greatest similarity among all situations with cold fronts from W was used as analogy. It was then often impossible to apply rule iii) in the outlined programme on page 15. One often had to choose a point of departure which harmonized with the position and the velocity of the front, independent of the diurnal rhythm.

It happened at times, when the analogy was poor, that two or three series of charts were alike, but in such a manner that the situation for which they were going to furnish the basis, was lying between them. The forecast was in such cases based on the mean value of the analogies.

11. THE PERCENTAGE OF SUCCESS IN THE FORECASTS.

I had hoped by aid of the tests to obtain a quantitative comparison with current forecasting methods. To achieve this in some degree, the percentage of success in the analogy forecasts and in the forecasts covering the same period and recorded at the Meteorological Institute in Oslo had to be computed. To obtain as exact comparison as possible, the rules which have been current for the Meteorological Institute in Oslo since June 1st 1926, have been applied. These rules are, because of their comparatively long usage, well established, and have influenced the recorded forecasts. These rules have not previously been printed, but have been placed on the analyst's desk. As they are important for the estimation of the success, and also for other reasons may be of interest, outlines of them are printed here.

Control of wind forecasts:

1) Certain stations as representative as possible are selected for which control is going to be

carried into effect. One is chosen for each forecasting district.

2) The success is to be computed separately for wind force and wind direction.

3) The wind force is to be estimated according to the values of actually observed maximum wind force within limits as in the following table:

The forecast	*Value of maximum wind force*
Calm, light air, light breeze or gentle breeze	4 or less
Breeze	3–5
Fresh breeze	4–6
Strong breeze	5–7
Moderate gale	6–8
Fresh gale	7–9
Strong gale	8–10
Whole gale	9–11
Storm	10–12
Hurricane	11–12

The forecast is considered correct (mark 1) if the maximum wind force occurs within the stated interval. The wind during the night and the wind during the day is estimated separately. The mean value for the whole forecasting period is marked 1 if the forecast succeeded both day and night, 1/2 if it succeeded only by day or only by night and 0 if no success was achieved.

4) Estimation of the wind direction is based on ordinary observations the following day (additional observations are also taken into account). The forecast is considered correct when the deviations do not exceed $\pm$ 45 degrees from the stated direction. If two limits are indicated with the term " to," then the wind has to keep within these boundaries $\pm$ 45 degrees, and has to vary at least a corresponding angle. If the wind forces do not exceed 5 Beaufort, one of the observations may give a wrong direction without the direction being considered erroneous, provided all other observations during the period are correct. If a variable breeze is forecast, the observations must show a variation of direction amounting at least to 90 degrees. Direction is, as a rule, not forecast for light wind or gentle breeze. If the velocity is in error, then the direction is considered in error as well. If the wind force is in error only during the day or during the night, then the direction forecast is halv correct.

Controll of precipitation forecasts:

The following classification of the forecasting terms is to be used:—

1) *Fine weather, fair weather, no precipitation:* No precipitation or at least not more than traces of precipitation must fall at any telegraphing station in the district.

2) *Slight rain (snow), drizzle, traces of rain (snow), flakes of snow, slight showers (rain or snow):* From 0.0 mm–0.4 mm precipitation must fall at least at one of the stations in the district, and no station must have more than 0.4 mm. The forecast is half correct if the precipitation exceeds 0.4 mm.

3) *Rainy weather, some rain (snow), showers (rain, snow), some precipitation, and all terms indicating heavy types of precipitation:* At least 0.4 mm precipitation must fall at least at one station in the district. If there has been some precipitation, but not as much as 0.4 mm at any station, the forecast is half correct.

4) *Clearing weather:* Transition from overcast, contingently with precipitation, to fair or fine weather, amounts of clouds 0–6 tenths. If a predicted clearing occurs too early, so that 6 tenths or more of the sky is void of low clouds in the evening of the same day over all stations in the district, then a forecast of clearing weather for the coming night and day is erroneous. No precipitation must occur at any station during the afternoon of the following day.

5) *Increasing cloudiness, followed by precipitation:* Transition from fine or fair weather (amount of low clouds 0–6 tenths) to cloudy or overcast (amount of clouds 7–10 tenths): No precipitation must occur at any station prior to the midday observations the following day. Precipitation must fall at least at one station in the afternoon or night.

6) *Improving weather, improvement:* A precipitation forecast must be issued in this connection, and the forecast is considered correct if the precipitation of the night conforms with the forecast, and if this precipitation exceeds the precipitation of the following day.

7) *Increasing cloudiness:* This term is estimated as no precipitation is predicted.

The terms "clearing" and "increasing cloudiness followed by precipitation" (4–5) cover 24 hours, if nothing else is explicitely stated. Otherwise the forecasts are estimated individually for the night (19–08) and the following day (08–19). The same procedure is used when the amount of precipitation is being checked. The final result is expressed in one number (0, $^1/_4$, $^1/_2$, $^3/_4$, 1). No measurable amount of precipitation must fall either in the day or in the night if a predicted ,, no precipitation " is to be considered correct (mark 1). If, for instance, the forecast is slight precipitation and the precipitation at night is 0.6 mm and in the day 0.2 mm, the mark for the night forecast is ½ and for the day forecast 1, the resulting mark is $^3/_4$.

12. COMPARISON.

The comparison from chart to chart conveyed an impression of the adequate accuracy of the analogy forecasts (F in proportion to F'). Even with such a comparatively long series of charts as from 1920–40 the analogies proved themselves deficient, and it was rather a disapointment to turn over the charts and see that no better harmony was obtained.

A comparison chart for chart is, however, a rigid critique, because all deviations then become too conspicuous. Everyone who, applying the current forecasting methods, has tried to draw a prognosis chart (F_e) 24 hours ahead, and so compared it with the coming weather chart (F), will know how great are the discrepancies that may be found, even in cases where the written formula of the prediction has been successful.

To get a reliable basis for the comparison, therefore, the analogy forecasts had to be written down in the same manner as the forecasts in the records. According to the rules for the computation, the dictation (choice of words) is to some degree decisive for the success attained. Computed successes for analogy forecasts exhibit, therefore, a dispersion to both sides in proportion to a direct comparison, dependent upon a more or less happy choice of words. This fact is of little consequence for the mean values of a longer series of forecasts, even though it is difficult to avoid personal estimate exerting its influence upon the written formula.

The analogy forecasts for the first test from $^{10}/_3$ 1938 to the end of the month, were prepared for the coming night and the following day. They were compared to the evening forecasts in the forecasting records for the same space of time. The following table shows the result: A indicates the success for the analogy forecasts, P for the forecasts in the records. The success for wind are means for the coastal stations Ferder, Jomfruland, Grimstad and Oksöy. The success for precipitation is the averages for the four coastal stations and nine inland stations (see page 20):

Point of time		Percentage of success			
for the forecast t_o	for the analogy t_o'	for wind		for precipitation	
		A	P	A	P
1938 $^{10}/_3$ 19h	$^{13}/_3$ 1926 19h	100	88	98	84 5
,, $^{11}/_3$,,	$^9/_3$ 1929 11h	75	100	75	77
,, $^{12}/_3$,,	$^{14}/_3$ 1923 19h	100	100	100	100
,, $^{13}/_3$,,	$^{18}/_3$ 1929 19h	100	100	100	84.5
,, $^{14}/_3$,,	$^{20}/_3$ 1929 05h	25	88	89	15
,, $^{15}/_3$,,	$^{19}/_3$ 1927 14h	100	75	31	23
,, $^{16}/_3$,,	$^{21}/_3$ 1929 19h $^8/_3$ 1926 23h $^3/_3$ 1926 15h	100	75	48	40
,, $^{17}/_3$,,	$^{21}/_3$ 1921 19h	88	38	81	62
,, $^{18}/_3$,,	$^{23}/_3$ 1921 14h	100	38	86.5	84.5
,, $^{19}/_3$,,	$^2/_3$ 1926 19h	75	50	75	44
,, $^{20}/_3$,,	$^8/_3$ 1930 14h $^{31}/_3$ 1925 02h $^3/_3$ 1926 19h	75	69	42	31
,, $^{21}/_3$,,	$^1/_4$ 1925 08h	100	100	79	86.5
,, $^{22}/_3$,,	$^{20}/_4$ 1925 08h	75	100	69	96
,, $^{23}/_3$,,	$^{22}/_3$ 1938 19h	100	94	84.5	96
,, $^{24}/_3$,,	$^{29}/_3$ 1933 19h	38	31	81	17
,, $^{25}/_3$,,	$^3/_3$ 1926 14h $^4/_3$ 1926 14h $^9/_3$ 1926 19h	63	100	79	86.5
,, $^{26}/_3$,,	$^5/_3$ 1926 11h $^{10}/_3$ 1926 14h	44	50	83	17
,, $^{27}/_3$,,	$^6/_3$ 1926 19h	100	75	100	84.5
,, $^{28}/_3$,,	$^7/_3$ 1926 19h	88	88	54	67
,, $^{29}/_3$,,	$^8/_3$ 1926 19h	38	69	62	90
,, $^{30}/_3$,,	$^{10}/_3$ 1926 19h	31	63	42	36.5
Means		77	76	74	63

The second test $^8/_7$–$^{30}/_7$ 1939 covers the forecast at 19h for the night and the following day. The result of the comparison is seen in the following table:—

Point of time		Percentage of success			
for the forecast t_0	for the analogy t'_0	for wind		for precipitation	
		A	P	A	P
1939 $^{8}/_{7}$ 19h	$^{6}/_{6}$ 1929 19h				
	$^{30}/_{7}$ 1931 19h	94	94	95	64
	$^{28}/_{7}$ 1927 19h				
,, $^{9}/_{7}$,,	$^{6}/_{7}$ 1928 19h	75	38	58	69
,, $^{10}/_{7}$,,	$^{7}/_{7}$ 1928 02h	81	56	77	58
,, $^{11}/_{7}$,,	$^{7}/_{7}$ 1928 19h	88	38	77	77
,, $^{12}/_{7}$,,	$^{27}/_{7}$ 1928 02h	94	63	46	46
,, $^{13}/_{7}$,,	$^{28}/_{7}$ 1928 05h	63	50	65	62
,, $^{14}/_{7}$,,	$^{13}/_{3}$ 1939 19h	50	75	48	41
,, $^{15}/_{7}$,,	$^{3}/_{7}$ 1929 19h				
	$^{14}/_{7}$ 1931 19h	81	63	46	77
	$^{7}/_{7}$ 1938 19h				
,, $^{16}/_{7}$,,	$^{8}/_{7}$ 1938 19h	88	75	82	71
,, $^{17}/_{7}$,,	$^{19}/_{7}$ 1924 19h	38	44	82	75
,, $^{18}/_{7}$,,	$^{17}/_{7}$ 1936 19h	75	63	58	73
,, $^{19}/_{7}$,,	$^{15}/_{7}$ 1939 19h	100	100	92	75
,, $^{20}/_{7}$,,	$^{2}/_{7}$ 1936 19h	94	63	71	60
,, $^{21}/_{7}$,,	$^{22}/_{7}$ 1938 19h	100	50	52	39
,, $^{22}/_{7}$,,	$^{22}/_{7}$ 1924 19h	100	88	95	80
,, $^{23}/_{7}$,,	$^{23}/_{7}$ 1924 14h	69	44	75	39
,, $^{24}/_{7}$,,	$^{18}/_{7}$ 1938 19h	75	81	39	85
	$^{9}/_{7}$ 1936 08h				
,, $^{25}/_{7}$,,	$^{1}/_{8}$ 1928 19h	100	88	85	92
,, $^{26}/_{7}$,,	$^{1}/_{8}$ 1928 19h	100	100	75	85
,, $^{27}/_{7}$,,	$^{6}/_{8}$ 1928 19h	88	88	89	69
,, $^{28}/_{7}$,,	$^{7}/_{8}$ 1928 14h	100	50	85	10
,, $^{29}/_{7}$,,	$^{30}/_{7}$ 1938 19h	100	100	69	50
,, $^{30}/_{7}$,,	$^{26}/_{7}$ 1938 19h	94	94	45	41
Means		85	70	70	62

The third test $^{7}/_{10}$–$^{30}/_{10}$ 1938 comprises, as to the previous ones, forecasts prepared with the evening chart at 19h for the night and the following day. Furthermore forecasts based on the morning chart at 8h were prepared covering the period from the coming night until the afternoon of the next day. The comparison between the maps (F and F') conveys mainly the same impression as the test for the spring month. I am, therefore, stating only the mean success without recording the dates of the analogies.

	Wind		Precipitation	
	A	P	A	P
Forecast on the morning chart	85	76	77	74
Forecast on the evening chart	86	87	79	79

Mean percentage of success for each station separately, is as follows:—

Name of station	March 1938				July 1939				October 1938				The three tests			
	Wind		Precip.		Wind		Precip.		Wind		Precip.		Wind		Precip.	
	A	P	A	P	A	P	A	P	A	P	A	P	A	P	A	P
Ferder	73	68	82	71	70	60	75	64	84	88	79	86	76	72	79	74
Oslo			88	68			76	63			86	75			83	69
Lillehammer			74	64			71	64			81	83			75	70
Flisa			71	58			60	52			87	74			73	61
Røros			51	45			58	53			56	72			55	57
Dombås			64	54			68	60			63	74			65	63
Nesbyen			77	73			65	52			70	82			71	69
Dalen			75	69			75	64			95	83			82	72
Gvarv			79	75			75	60			82	73			79	69
Jomfruland	83	81	85	67	96	72	72	67	86	79	87	80	88	77	81	71
Grimstad	85	77	67	61	96	80	74	74	87	87	84	85	89	81	75	73
Oksøy	67	75	74	69	79	66	71	68	86	92	79	79	77	78	75	72
Byglandsfjord			77	61			73	64			80	83			77	69
Means	77	75	74	64	85	70	70	62	86	87	79	79	83	77	75	68

The analogy forecasts show a poorer success in respect to wind on Oksöy and in respect to precipitation in Röros. For all other stations the analogy forecasts proved to be the best. The analogy forecasts gave on average values which were 6 % better for the wind forecasts and 7 % better for the precipitation forecasts.

This comparison is, however, hardly representative. The number of forecasts used as a basis for the comparison is too small. The tests give only an idea of the analogies found by the clue diagrams compared with the actual forecasts at a time when the clue diagrams were not at hand. I have, therefore, given the dates for both, so as to enable the reader to compare them himself. The result of the test may be said to be encouraging. It is to be hoped that a more elaborate statistical investigation will be possible when the method has been tested enough in actual form.

Noteworthy is the poor success of the forecasts for Röros, according to both methods. It may perhaps be the labile conditions over the watershed-line between north and south, which make all methods insecure, or it may be due to the rules used for the computation of the percentage of success.

The correlation coefficient between the success for analogy forecast on one hand, and the forecast in the forecasting records on the other, was computed for 69 pairs of precipitation forecasts to $r = 0.46$. This is a strikingly low correlation. Even though the materials for the tests have not been large enough to secure reliable conclusions, it might seem logical to assume that the two methods to some extent are independent of each other. Supposing this to be the case, there would then, by a simultaneous use of both methods, exist possibilities for evaluating the accuracy of the forecast, even at the time of the issuing of it.

13. APPROXIMATION.

The sustaining idea of the Norwegian meteorological school is that the forecast is to be based upon physical, logical thought, and not on formal reflections. This is also going to be the basic idea of the clue diagram method. The selection of analogies must be based on a physical estimate of the charts.

The analogy forecasts recorded previously were slavishly worked out according to the analogy, in order to obtain as highly objective a comparison as possible between the analogy and the current forecasting methods. Common practice does not necessitate this constraint, and the clue diagrams method is not to be encumbered by it.

The analogy has, however, a momenteous significance for the method in that it furnishes the basis for a more extensive application of physical logic. The problem is, with the known analogy as a basis, to find the differences or deviations from the analogy, instead of, as is the case with the current methods, to concern oneself directly with the total displacements and the total changes in the air masses.

Generally it is not difficult to decide qualitatively in which direction the deviations from the analogy will tend. E.g.: A warm air current comes from SW. Observations from the ground and upper air show that the humidity of the warm air is greater now than on the analogy being used. The precipitation on the present map is also more abundant in the district where the warm front has passed than it was on the analogous map. It is legitimate on the basis of these data to draw the conclusion that the warm front, when it reaches the district, will cause more precipitation than was observed on the subsequent charts in the analogy series, provided that the conditions are otherwise unchanged.

The deviations may also be found quantitatively almost to the same extent as quantitative computation is possible according to common methods.

14. PRACTICAL ADAPTIBILITY.

Of vital importance to the practical adaptability of the clue diagrams method are the following questions:—

A. Is the method speedy enough to get the forecast ready within a reasonable space of time?

B. How long a time will it take to learn the method in order to apply it in a justifiable manner?

According to my experience the selection of analogies on the clue diagrams seems to take place rather quickly. Less than a quarter of an hour is, in most cases, sufficient time to single out the five or six situations which are adequate as analogies. The next step is the most time-wasting, viz., to find the maps in the archives and to examine the selected situations in order to find the most suitable analogies among them. The time needed varied considerably during the tests. Only a few minutes sufficed if a good analogy was found. On the other hand, when it was difficult to find an adaptable analogy at all, a critical examination and comparison with the actual chart had to be effected, before any choise could be made. This often required much time.

It happened once or twice during each of the test periods that tangency occurred, which reduced the work as long as the tangency lasted. It was not necessary to look for new analogies, because the maps were analogous chart for chart.

During the test in October 1938 forecasts were prepared twice a day, at 08^h and 19^h. During 23 days analogy was changed from 08^h till 19^h only 9 times, whereas 14 times it was unnecessary to seek a new analogy at night.

It must, however, be borne in mind that the amount of work with the clue diagrams method is considerably larger than with the current forecasting methods. The analyst must be minutely conversant with the actual chart; he must, moreover, study one or perhaps several series of analogy charts with meticulous care. The physical-logical brain work itself is more complicated, as the forecast is based upon two or more series of maps, instead of on the actual series only.

Let us turn to question B. It might be supposed that the clue diagrams method, being more complex, would create greater difficulties for novices than the current methods.

The first step, the selecting of the analogy, presupposes a considerable amount of skilled knowledge of map analysis and of the symbols of the clue diagrams.

Map analysis is the basis of any forecasting method. It is a well known fact that a long time is needed to acquire this ability.

The perspicuity of the clue diagrams is so apparent that its symbolism is easily learned. The two students who were assisting me in the tests, had as early as after a month's work reached so far that I could test their ability to work entirely dependent on themselves. With the clue diagrams method as an auxiliary aid, they prepared forecasts twice a day (morning and evening charts) for the coming 24 hours from $^6/_{12}$ to $^{31}/_{12}$ 1937. It was interesting to watch their work and to discover the errors caused by lack of training. Obviously erroneous selections of charts occurred, though infrequently. This occurred mostly when no good analogy was to be found among the charts in the archives. An increasing number of errors occurred in the next step of the approximation, viz., in the estimate of the deviations from the analogy. Such an error may in many cases be of considerable consequence for the forecast, but mostly it is not decisive. The choise of analogy and the estimate of the deviations are related terms of first and second order in a convergent progression. If the term og first order is correct, one is not entirely in error, even though the form of second order is erroneous.

As a preliminary estimate of the practical adaptability of the clue diagrams method, I may mention that the method seems applicable in all cases, where an eligible analogy is available. The work then proceeds satisfactorily.

The eligibility of an analogy is to be tested by the following questions:—

1) Is the pressure system and the wind distribution fairly alike?
2) Do the air mass distributions harmonize?
3) Is the diurnal rhythm the same?
4) Has the life history (movements) of the air masses been fairly alike?
5) Does the isallobaric distribution harmonize?

One will in practice see how important it is to have these criteria verified. For the tests, about one third of the analogies was characterised as good; of the remaining two thirds, one was considered as medium and the last as poor. The poor analogies gave a low percentage of success, and a long time was required for the preparing of the forecast. In such cases the clue diagrams method should not be applied.

If an eligible analogy exists, the clue diagrams method will render very detailed forecasts possible. The analogy situations afford facilities for a meticulous examination of the weather situation. Material from non-telegraphing stations and precipitation stations may also be taken into consideration, and the net of stations, upon which the forecast is based, will accordingly be multiplied.

It may be possible to utilize a good analogy for forecasts of the quantitative kind. With the test in October 1938 quantitative forecasts were, by way of experiment, prepared at 19^h every day for the coming 24 hours according to the following scale:—

Precipitation	Change in temperature
1) 0 to 0.0 mm	fall greater than —13 degrees
2) 0.0 ,, 0.4 ,,	between —13 and — 7 ,,
3) 0.4 ,, 5 ,,	,, — 7 ,, — 3 ,,
4) 5 ,, 10 ,,	,, — 3 ,, — 1 ,,
5) 10 ,, 15 ,,	,, — 1 ,, 1 ,,
6) 15 ,, 25 ,,	,, 1 ,, 3 ,,
7) 25 ,, 45 ,,	,, 3 ,, 7 ,,
8) 45 ,, 75 ,,	,, 7 ,, 13 ,,
9) above 75 ,,	rise more than 13 ,,

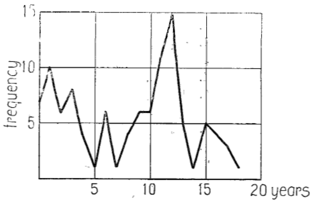
The change in temperature was forecast for the maximum temperature of the day and the minimum temperature of the night compared to the previous one. Success within the forecasting interval got the mark 100, in the adjacent interval 50, and outside 0 (erroneous forecast). The result was:—

Station	Precipitation	Max. temp.	Min. temp.
Lillehammer	72 %	72 %	70 %
Oslo	80 %	78 %	68 %
Byglandsfjord ...	64 %	72 %	66 %

The percentage lies approximately on the same level as for the qualitative percentage succes of the current forecast.

15. TIME DISTRIBUTION OF THE ANALOGIES.

If any periodicity exists in the weather situations, it ought to evince itself in the distribution of the analogies. It may be expected that



Difference in time between the actual chart and the analogy.

the analogy preferably appears in those time intervals where the phase in the periodicity is comparatively the same. On fig. 8 the abscissa is the difference in time between the actual chart and the analogy, and the ordinate is the frequency of the analogy. All analogies chosen for the tests are included.

The maximum frequency of analogies seems to occur at 11–12 years difference in time. If this accords in a sufficient number of cases, it may to a certain extent facilitate the selection of analogies. It may then yield a good result to pay special attention to weather maps issued 10–11–12 years previously, and to the weather charts for the same year as the actual chart or the preceding year, when approximately the same phase of the sunspot period occurs.

16. EXTENDED PROGNOSIS BY AID OF CLUE DIAGRAMS.

Presupposing that meteorological tangency is detected so early that a sufficiently long time of tangency period remains, it ought to be possible to utilize the clue diagrams method in prognosis extended to more than the common 24–36 hours. To get a basis for the verification of this question, the following 100 tangencies were found by aid of the clue diagrams:

	Weather situation					Weather situation					Perm
1.	$^{9}/_{1}$	till	$^{10}/_{1}$	1935	is tangent to	$^{7}/_{1}$	till	$^{8}/_{1}$	1922	2	24^{h}]
2.	$^{18}/_{1}$	,,	$^{20}/_{1}$	1932	,,	$^{16}/_{1}$	,,	$^{18}/_{1}$	1925	3	
3.	$^{29}/_{1}$	,,	$^{3}/_{2}$	1937	,,	$^{29}/_{1}$	,,	$^{3}/_{2}$	1926	6	
4.	$^{6}/_{2}$	,,	$^{10}/_{2}$	1939	,,	$^{6}/_{2}$	,,	$^{10}/_{2}$	1928	5	
5.	$^{6}/_{2}$	,,	$^{8}/_{2}$	1938	,,	$^{5}/_{2}$	,,	$^{7}/_{2}$	1927	3	
6.	$^{20}/_{2}$	,,	$^{22}/_{2}$	1937	,,	$^{18}/_{2}$	,,	$^{20}/_{2}$	1926	3	
7.	$^{24}/_{2}$	,,	$^{26}/_{2}$	1938	,,	$^{13}/_{2}$	,,	$^{15}/_{2}$	1927	3	
8.	$^{18}/_{2}$	,,	$^{20}/_{2}$	1934	,,	$^{9}/_{2}$	,,	$^{11}/_{2}$	1934	3	
9.	$^{5}/_{2}$	,,	$^{7}/_{2}$	1922	,,	$^{4}/_{2}$	,,	$^{6}/_{2}$	1921	3	
10.	$^{5}/_{3}$	,,	$^{16}/_{3}$	1935	,,	$^{12}/_{3}$	,,	$^{23}/_{3}$	1923	12	
11.	$^{12}/_{3}$	,,	$^{15}/_{3}$	1935	,,	$^{11}/_{3}$	,,	$^{14}/_{3}$	1924	4	
12.	$^{11}/_{3}$	,,	$^{14}/_{3}$	1924	,,	$^{18}/_{3}$	,,	$^{21}/_{3}$	1923	4	
13.	$^{12}/_{3}$	,,	$^{14}/_{3}$	1927	,,	$^{18}/_{3}$	,,	$^{20}/_{3}$	1923	3	
14.	$^{27}/_{3}$	,,	$^{29}/_{3}$	1938	,,	$^{6}/_{3}$	,,	$^{8}/_{3}$	1926	3	
15.	$^{14}/_{3}$	,,	$^{15}/_{3}$	1929	,,	$^{11}/_{3}$	,,	$^{12}/_{3}$	1928	2	
16.	$^{17}/_{3}$	,,	$^{19}/_{3}$	1929	,,	$^{14}/_{3}$	,,	$^{16}/_{3}$	1928	3	
17.	$^{10}/_{4}$	,,	$^{16}/_{4}$	1932	,,	$^{15}/_{4}$	,,	$^{21}/_{4}$	1922	7	
18.	$^{19}/_{4}$	,,	$^{21}/_{4}$	1933	,,	$^{15}/_{4}$	,,	$^{17}/_{4}$	1932	3	
19.	$^{12}/_{4}$	,,	$^{18}/_{4}$	1932	,,	$^{5}/_{4}$	,,	$^{11}/_{4}$	1921	7	
20.	$^{20}/_{4}$	,,	$^{22}/_{4}$	1933	,,	$^{9}/_{4}$	,,	$^{11}/_{4}$	1921	3	
21.	$^{16}/_{4}$	,,	$^{21}/_{4}$	1922	,,	$^{4}/_{4}$	,,	$^{9}/_{4}$	1921	6	
22.	$^{7}/_{4}$	,,	$^{10}/_{4}$	1935	,,	$^{12}/_{4}$	,,	$^{15}/_{4}$	1924	4	
23.	$^{19}/_{5}$	,,	$^{22}/_{5}$	1923	,,	$^{3}/_{5}$	,,	$^{6}/_{5}$	1922	4	
24.	$^{26}/_{5}$	,,	$^{31}/_{5}$	1934	,,	$^{27}/_{5}$	,,	$^{1}/_{6}$	1923	6	
25.	$^{12}/_{4}$	,,	$^{14}/_{4}$	1933	,,	$^{16}/_{4}$	,,	$^{18}/_{4}$	1922	3	
26.	$^{13}/_{5}$	,,	$^{15}/_{5}$	1931	,,	$^{11}/_{5}$	,,	$^{13}/_{5}$	1925	3	
27.	$^{19}/_{5}$	,,	$^{23}/_{5}$	1934	,,	$^{20}/_{5}$	,,	$^{24}/_{5}$	1923	5	
28.	$^{22}/_{5}$	,,	$^{25}/_{5}$	1929	,,	$^{16}/_{5}$	,,	$^{19}/_{5}$	1925	4	
29.	$^{22}/_{5}$	,,	$^{27}/_{5}$	1936	,,	$^{20}/_{5}$	,,	$^{25}/_{5}$	1935	6	
30.	$^{1}/_{6}$	,,	$^{8}/_{6}$	1933	,,	$^{3}/_{6}$	,,	$^{10}/_{6}$	1925	8	
31.	$^{19}/_{6}$	,,	$^{23}/_{6}$	1936	,,	$^{14}/_{6}$	,,	$^{18}/_{6}$	1930	5	
32.	$^{19}/_{6}$	,,	$^{25}/_{6}$	1935	,,	$^{3}/_{6}$	,,	$^{9}/_{6}$	1925	7	
33.	$^{19}/_{6}$	,,	$^{25}/_{6}$	1935	,,	$^{1}/_{6}$	,,	$^{7}/_{6}$	1933	7	
34.	$^{14}/_{6}$	,,	$^{20}/_{6}$	1935	,,	$^{31}/_{5}$	,,	$^{6}/_{6}$	1924	7	
35.	$^{15}/_{6}$	,,	$^{18}/_{6}$	1937	,,	$^{24}/_{6}$	,,	$^{27}/_{6}$	1926	4	
36.	$^{26}/_{6}$	,,	$^{28}/_{6}$	1938	,,	$^{28}/_{6}$	,,	$^{30}/_{6}$	1928	3	
37.	$^{25}/_{6}$	,,	$^{28}/_{6}$	1931	,,	$^{24}/_{6}$	,,	$^{27}/_{6}$	1921	4	
38.	$^{8}/_{7}$	,,	$^{14}/_{7}$	1923	,,	$^{14}/_{7}$	,,	$^{20}/_{7}$	1921	7	
39.	$^{4}/_{7}$	,,	$^{6}/_{7}$	1939	,,	$^{3}/_{7}$	,,	$^{5}/_{7}$	1932	3	
40.	$^{15}/_{7}$	,,	$^{22}/_{7}$	1934	,,	$^{11}/_{7}$	,,	$^{18}/_{7}$	1923	8	
41.	$^{16}/_{7}$	,,	$^{26}/_{7}$	1933	,,	$^{27}/_{7}$	,,	$^{6}/_{8}$	1922	11	
42.	$^{28}/_{7}$	,,	$^{1}/_{8}$	1938	,,	$^{29}/_{7}$	,,	$^{2}/_{8}$	1927	5	
43.	$^{29}/_{7}$	,,	$^{2}/_{8}$	1921	,,	$^{17}/_{7}$	,,	$^{21}/_{7}$	1920	5	
44.	$^{22}/_{7}$	,,	$^{23}/_{7}$	1939	,,	$^{22}/_{7}$	,,	$^{23}/_{7}$	1924	2	
45.	$^{27}/_{7}$	,,	$^{28}/_{7}$	1939	,,	$^{6}/_{8}$	,,	$^{7}/_{8}$	1928	2	
46.	$^{2}/_{8}$	,,	$^{4}/_{8}$	1938	,,	$^{3}/_{8}$	,,	$^{5}/_{8}$	1927	3	
47.	$^{9}/_{8}$	,,	$^{12}/_{8}$	1938	,,	$^{4}/_{8}$	,,	$^{7}/_{8}$	1927	4	
48.	$^{1}/_{8}$	,,	$^{9}/_{8}$	1937	,,	$^{18}/_{8}$	,,	$^{26}/_{8}$	1921	9	
49.	$^{8}/_{8}$	,,	$^{15}/_{8}$	1938	,,	$^{1}/_{8}$	,,	$^{8}/_{8}$	1937	8	
50.	$^{7}/_{8}$	,,	$^{15}/_{8}$	1938	,,	$^{17}/_{8}$	,,	$^{25}/_{8}$	1921	9	

	Weather situation					Weather situation				Permanence	
51.	6/8	,,	14/8	1938	is tangent to	21/8	till	29/8	1937	9	24^h periods.
52.	15/8	,,	19/8	1933	,,	15/8	,,	19/8	1922	5	,,
53.	18/8	,,	22/8	1939	,,	29/7	,,	2/8	1937	5	,,
54.	19/8	,,	21/8	1939	,,	21/8	,,	23/8	1937	3	,,
55.	13/8	,,	21/8	1939	,,	31/7	,,	8/8	1938	9	,,
56.	22/8	,,	29/8	1937	,,	17/8	,,	24/8	1921	8	,,
57.	23/8	,,	26/8	1939	,,	20/8	,,	23/8	1921	4	,,
58.	23/8	,,	26/8	1939	,,	25/8	,,	28/8	1937	4	,,
59.	24/8	,,	26/8	1939	,,	4/8	,,	6/8	1937	3	,,
60.	24/8	,,	27/8	1939	,,	11/8	,,	14/8	1938	4	,,
61.	20/8	,,	23/8	1936	,,	28/8	,,	31/8	1925	4	,,
62.	10/9	,,	13/9	1936	,,	27/9	,,	30/9	1920	4	,,
63.	14/9	,,	17/9	1935	,,	14/9	,,	17/9	1924	4	,,
64.	17/9	,,	22/9	1921	,,	21/9	,,	26/9	1920	6	,,
65.	26/9	,,	29/9	1938	,,	28/9	,,	1/10	1920	4	,,
66.	28/9	,,	30/9	1929	,,	28/9	,,	30/9	1925	3	,,
67.	25/9	,,	1/10	1936	,,	10/9	,,	16/9	1936	7	,,
68.	27/9	,,	30/9	1935	,,	4/10	,,	7/10	1924	4	,,
69.	8/10	,,	9/10	1938	,,	6/10	,,	7/10	1938	2	,,
70.	7/10	,,	10/10	1922	,,	7/10	,,	10/10	1920	4	,,
71.	14/10	,,	16/10	1938	,,	3/11	,,	5/11	1936	3	,,
72.	15/10	,,	20/10	1922	,,	15/10	,,	20/10	1920	6	,,
73.	8/10	,,	10/10	1935	,,	10/10	,,	12/10	1924	3	,,
74.	16/10	,,	22/10	1926	,,	13/10	,,	19/10	1925	7	,,
75.	25/10	,,	31/10	1939	,,	10/10	,,	16/10	1928	7	,,
76.	29/10	,,	30/10	1938	,,	30/9	,,	1/10	1922	2	,,
77.	10/11	,,	15/11	1932	,,	21/11	,,	26/11	1920	6	,,
78.	9/11	,,	11/11	1935	,,	29/11	,,	1/12	1924	3	,,
79.	12/11	,,	17/11	1924	,,	22/11	,,	27/11	1920	6	,,
80.	19/11	,,	26/11	1933	,,	11/11	,,	18/11	1932	8	,,
81.	19/11	,,	22/11	1933	,,	22/11	,,	25/11	1920	4	,,
82.	17/11	,,	22/11	1933	,,	10/11	,,	15/11	1924	6	,,
83.	16/11	,,	22/11	1933	,,	12/11	,,	18/11	1921	7	,,
84.	19/11	,,	22/11	1936	,,	24/11	,,	27/11	1934	4	,,
85.	22/11	,,	26/11	1926	,,	20/11	,,	24/11	1937	5	,,
86.	24/11	,,	30/11	1934	,,	13/11	,,	19/11	1922	7	,,
87.	19/11	,,	23/11	1936	,,	13/11	,,	17/11	1922	5	,,
88.	7/11	,,	16/11	1924	,,	10/11	,,	19/11	1921	10	,,
89.	6/12	,,	15/12	1939	,,	5/12	,,	14/12	1920	10	,,
90.	11/12	,,	14/12	1939	,,	1/12	,,	4/12	1927	4	,,
91.	12/12	,,	13/12	1937	,,	12/11	,,	13/11	1934	2	,,
92.	11/12	,,	14/12	1939	,,	19/12	,,	22/12	1931	4	,,
93.	18/12	,,	22/12	1931	,,	30/11	,,	4/12	1927	5	,,
94.	1/12	,,	8/12	1927	,,	10/12	,,	17/12	1920	8	,,
95.	19/12	,,	22/12	1931	,,	10/12	,,	13/12	1920	4	,,
96.	7/12	,,	13/12	1931	,,	30/11	,,	6/12	1922	7	,,
97.	22/12	,,	27/12	1931	,,	12/12	,,	17/12	1922	6	,,
98.	25/12	,,	27/12	1931	,,	12/12	,,	14/12	1931	3	,,
99.	26/12	,,	29/12	1935	,,	28/12	,,	31/12	1922	4	,,
100.	28/11	,,	5/12	1931	,,	16/12	,,	23/12	1920	8	,,

These tangencies have collectively a duration of 12,000 hours, a mean of 120 hours each. The longest tangency lasted 288 hours.

The procedure for the selection of tangencies has been nearly the same as for the selection of analogy charts (page 17). By aid of the clue diagrams those situations were first selected which evinced any possibility at all for tangencies. A second examination of the charts aimed at making certain that the definitions on page 16 were satisfied. The main object for utilising the clue diagrams here was, as elsewhere in the forecasting, to eliminate a vast amount of "impossible" situations and limit attention to a few only.

It may be assumed that the 100 tangencies, which are mentioned above, represent approximately half the total amount of the tangencies which have occurred during the twenty years 1920–39 (1940 had such deficient weather charts that this year is not included). We have namely chiefly considered tangencies for the same month, and not attempted comparison to preceding or following months, and it seems reasonable to assume that such a comparison might reveal at least the same number of tangencies.

In the periods which were covered by the tests (section 12), the preceding and following months were examined with great accuracy. Seven tangencies were then discovered. Three of them occurred in the same month, one at the transition from one month to the next, and three in the adjacent months. According to the tests, about 15 % of the time is covered by tangencies when charts for 20 years are the basis for the examination. As the archives of well analysed maps increase, the tangencies will cover a steadily increasing percentage of the time. Even now the percentage is sufficiently large to justify attempts on extended forecasting in cases where circumstances seem to be favourable.

The following rules for extended forecasting by the clue diagrams method may be indicated according to experience gained through the selection and examination of tangencies.

i) A tolerably good harmony between the actual chart and the analogy chart is required.

ii) Among the good analogies, those should be preferred where the two weather situations have previously evinced similarity to each other; a stepwise approximation ought to be perceptible.

iii) Analogies to weather situations with high pressure over or in the vicinity of the prognosis area ought to be preferred.

iiii) Among the good analogies one should preferably choose for extended forecasting those which range within approximately the same phase of the 11-year period.

Remarks to rule i: One may as a preliminary estimate, assume that of 100 forecasting days, about 30 are found with eligible analogies (see page 22). Of these about 15 days are included in the tangency periods, which must have good analogies as long as they last. (See above.) The number of eligible analogies which commence are then about 15. If the duration of each of the tangency periods is from 2 to 4 days and nights, then one may estimate being among the 15 eligible commencing analogies between 7 and 4 tangencies, respectively.

Remarks to rule ii: According to empirical studies a tangency generally commences in the following manner: at first certain points of resemblance appear, for example, an analogy which must be termed medium or poor, then the series may diverge from each other for a couple of days, but then a new similarity may occur. Thus approximations may stepwise appear, until the tangency is established. The time interval between two such points of resemblance are often not of equal length on the two series.

This rule must be examined more closely both physically and statistically. To this end, however, much labour and a long time is needed, before the number of tests is sufficiently large. The stepwise approximation was more or less pronounced for the greater number of the tangencies I have found.

Remarks to rule iii: This rule is fairly obvious. By previous attempts at extended forecasting one has also preferentially chosen stable weather situations upon the recognition that it is exceedingly more difficult to predict future development when the weather situation changes rapidly, than when it remains stabile. To ascertain which types of weather most frequently cause tangencies in respect of the prognosis area round Oslo, I have grouped the 100 tangencies according to the situation of the most

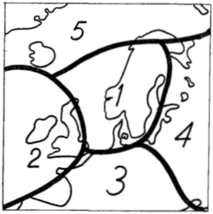


Fig. 9. Situation of high pressure system.

conspicuous high pressure system. Group 1) comprises cases with high pressure over Scandinavia, 2) high pressure over the British Isles and/or North Atlantic, 3) high pressure over Central Europe, 4) high pressure over Russia, 5) high pressure over Iceland and/or Greenland, 6) comprises cases where no pronounced high pressure is found within the region of the path-charts. The boundaries of groups 1–5 are found on figure 9.

The result is as follows:—

Groups	1	2	3	4	5	6
Distribution of tangencies	44%	15%	14%	17%	6%	4%

Nearly half of the tangencies occured in group 1).

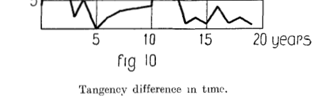
Remarks to rule iiii: The basis for this rule is apparent from figure 10, where the frequency of tangency is ordinate, and the difference in time is abscissa.

I had, as a matter of fact, expected such a distribution, according to the distribution of analogies on figure 8, which was previously discovered. It was therefore natural that special attention was paid to the search for tangency round the 11-year period. The following assumption is justified, namely, that if all the tangencies which may have been overlooked, had been taken into account, the curve on figure 10 would have been smoothed somewhat, but I consider it beyond question that its main features would not alter appreciably even though all the tangencies had been included. The clue diagrams were so critically examined, that it is legitimate to assume that only a negligible number of tangencies during the same month has escaped attention. Tangencies with the adjacent months have not been sought, but there is no reason to expect any materially different grouping of them.

The 11-year period is so conspicuous, that it suggests the idea of examining the relation between the tangencies and the proportionate number of the sunspots. The problem appears, according to some preliminary work which has been done, to be rather complicated. It is, however, beyond the scope of this investigation, and will therefore not be treated here.

It may be assumed that the clue diagrams method does not furnish the basis for extended forecasting at any time, but in cases where the conditions satisfy the requirements stated in rules in this section (page 26), or at least some of them, the method should be tried.

Also with a view to the wording of the extended forecasts, one should keep in mind that the clue diagrams method must not be slavishly dependent on the analogies. The latter are to furnish the basis for the physical considerations of the similarities and the differences which exist, and which might be expected to appear during the coming period. In extended forecasting special attention should be paid to climatological data, especially the probability of the reappearance of the weather phenomena found on the analogies. If the phenomenon in question is an extremum, one should, at any rate, ascertain whether a minute analysis might not suggest a wording of the forecast modified towards more average conditions.



Tangency difference in time.

The numbers for the percentage of success for extended forecasting are, as for current forecasting, to a high degree, dependent on the wording of the forecast and of the rules for verification. Such percentages reveal, however, very little if they are not compared to similar numbers for other forecasting methods for the same weather period. If, therefore, a rational test is to be obtained, rules for the computation must be agreed upon, and these rules must have general validity. One may, no matter how these rules may be formed, in advance take for granted, that the percentage of success will exceed the percentage of correctly foreseen tangencies. To predict a tangency is equivalent to indicating the character of the weather chart for the coming days, even in detail for the prognosis area, and on a large scale for the adjacent areas. A number of cases will certainly occur where the wording of the forecast will harmonize more or less with the development of the weather, at least in respect of certain elements, even though the actual synoptic situation recedes from the analogy in such a way that the prediction of tangency is in error.

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