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by

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A METHOD OF TEMPERATURE PREDICTION

by Gordon A. McKay

This evening I should like to present a temperature prediction method which has been applied successfully in Newfoundland and which, I believe, merits your consideration. Prediction aids are not too popular at Canadian offices for the simple reason that time is very much at a premium, and very few aids are so rewarding as to merit the use of this time. In the early thirties farm papers carried an advertisement offering a simple-to-operate guaranteed-to-perform fly killer. Each buyer received two blocks of wood; the fly was placed on one block and despatched by hitting him with the other. The method was simple and quite effective, but it was never popular since just as good results could be obtained from a well-directed swat. Many of our prediction aids have the same failings; they are time consuming in operation and may not yield better results than a well-directed estimate. The acceptance at Gander of the method which I shall describe suggests that it is worthwhile.

Temperature prediction methods directly or indirectly are based on the energy gains and losses experienced by the air near the ground, and the manner in which these energy changes are distributed in the vertical. Since air is constantly in motion, many methods employ trajectories. Commonly, temperature forecasts are made as follows: the maximum or minimum temperature which previously occurred in the air expected over the region is adjusted for the difference in normal temperatures between the source and terminus and for sky, wind, dew point or other factors. Most aids are merely refinements of this method, and are attempts to reduce the errors which may result from more arbitrary estimates.

As early as 1933 Gold (1) indicated how the tephigram could be used to determine the maximum temperature. In Canada, Washburn (7) used the tephigram in developing a method of maximum temperature prediction for the Maritimes; this was later modified by Holland (3) for use when a snow cover was present. Attempts have been made at Winnipeg by Muttit to relate the 850 mb temperature to the surface maximum and minimum.

Minimum temperature prediction aids show more variation. Many are based on Brunt's well-known formula for the nocturnal temperature drop. Modifications have been introduced to allow for the downward transport of energy through turbulence and for the formation of dew. Reuter's work centres about Brunt's equations. Other methods are statistical in approach: Knox has derived empirical equations relating deviation of forecast minimum temperature for Toronto from normal minimum to the difference between Malton and source temperatures at 0630 G.M.T. and to the departure of the source temperature from the normal source minimum. Saunders has introduced a more novel method which is currently in use at London. This is based on the cooling rates and the length of the cooling period. The discontinuity often apparent in the nocturnal cooling curve owes its origin to the formation of dew at the ground level - a process which Saunders observed to occur at a time dependent on the season. The temperature at the inflection point may be computed from regression equations while further cooling is computed from a series of experimentally obtained curves.

These are but a few of the methods available. Many of these are of restricted usage, requiring clear skies, light winds and no advective change. Some are based on few data which suggests their limited applicability. Data published on two methods suggests that the aids would yield results inferior to those obtained by routine methods. Klein, while checking on precipitation anomalies in U.S., found a relation which verified 66 percent on the history data, but only 25 percent on prognosis. Often, apparently promising techniques fail because it is more difficult to predict the variables employed in the equations than it is to predict the temperature directly.

The system which I shall now present suffers from defects as do the other methods; however, it has met with such success as to bring about its general acceptance at Gander. It is complex and incorporates directly or indirectly most of the factors which influence temperature; but it is rendered simple through the use of nomograms and by being based on parameters which are readily available from prognostic charts or current data. The method permits rapid assessment of the effects of deviations from forecast weather conditions, and prevents errors from inconsistent reasoning. By test, it has yielded results which were superior to the official forecasts.

The system was developed as follows: By statistical methods a selection was made of the weather elements which had a significant bearing on temperature and which were readily available to or could be estimated by the forecaster. The parameters selected were:

1. Thickness of the 1000-850 mb stratum (h).

2. Percent transmission of insolation by cloud (T).

3. Air-mass dew point at 1830 G.M.T. (T_d).

4. Geostrophic wind direction and speed(V).

These data were used in the derivation of regression equations relating maximum or minimum temperature to h,T and/or T_d. The effect of wind speed on the forecast temperature was determined graphically. To facilitate the practical application of these equations, a nomographic solution was prepared for each equation.

Because of the local geography, history data were divided into groups according to the geographic sector in which the source region was located. These sectors were selected on the following basis. Sea temperature isotherms are displaced southward off the east Newfoundland coast by the action of the Labrador current. Where this current meets the Gulf Stream, a high concentration of isotherms results. Consequently, southerly winds usually bring very stable maritime air to the island while northerly winds bring an unstable maritime variety. Westerly winds bring air not unlike that found over much of Eastern Canada. Because of the marked differences in these types of air, two sectors were used for the analysis of maximum temperatures and three sectors for minimum temperatures. The nomograms differ from month to month because of the seasonal changes in the relationship between temperature and the various parameters.

Examples of the nomograms are given in the figures. In Figure 1, a simple scale gives the forecast temperature, t_f, as a function of thickness, h. The effect of cloud was found to be small at this time of year. The most commonly used form of nomogram is illustrated in Figure 2. The forecast temperature is obtained by using a straight edge linking thickness to cloud transmission. Corrections for wind speed, wind direction and day of the month are given at the base of each nomogram. When another variable, such as the dew-point, is used, the nomogram is slightly more complex. Such a nomogram is illustrated in Figure 3. Here, the straight edge is used first to link thickness and dew-point, obtaining a point of intersection on a reference line, Q. This point is then linked to the value of cloud transmission and the forecast temperature read off on the temperature scale.

The variables used in the nomograms and graphs are obtained as follows. The thickness, cloud type and amount, and the geostrophic wind direction and speed are measured directly or inferred from the prognostic charts. The dew-point is taken directly from the current 1830 G.M.T. synoptic report. Haurwitz has measured average cloud transmission for overcasts of various cloud types and his figures are summarized in Table I.

Thickness is the most influential variable used, and much of the accuracy of this aid depends on the accuracy of prediction of this factor. With barotropic conditions there is usually no problem, but with strongly baroclinic conditions the problem may prove quite difficult. Thickness is directly proportional to the mean virtual temperature of the stratum. It is, therefore, a function of such processes as radiation, conduction, turbulence, subsidence, ascent, and phase changes of water substance. While the dependence on these varied processes undoubtedly accounts for the excellent relation between thickness and maximum or minimum temperature, it also complicates prediction. For, although the assumption of geostrophic advection provides a simple and frequently accurate method of predicting thickness, it must be remembered that in some cases the effects of advection may be completely nullified by the other processes. The thickness pattern has been found to be conservative relative to the surface frontal positions and this factor, along with knowledge of local radiative or dynamic effects, usually permits prediction with satisfactory accuracy. It is of interest to note that the U.S. Weather Bureau is experimenting with the use of total thickness (1,000 - 500 mb) for long range temperature prediction.

It may be shown that most of the significant factors affecting temperature are considered in this method through the variables. Moeller has found that 88% of the radiation returning to the ground comes from the lowest 500 metres. Through thickness, the temperature of this layer and possibly the temperature of the cloud base, are introduced.

The possible accuracy of the method was first suggested by the multiple correlation coefficients of .8 obtained for the partial regression equation, indicating that in "back-casting" 95% of the predictions would lie within 6 degrees of the actual observed values. Following a promising preliminary trial period, during which the duty forecaster tried the equations and then produced the official forecast by routine methods, tabulating both forecasts, equations were determined for all months and nomograms prepared. Over 3000 sets of data were processed and extensive smoothing was employed to dispose of spurious data.

The nomograms are easy to employ and may be used under any circumstances. They permit a rapid assessment of the effects of variations in the elements used. They have given results which compare favorably with those obtained through experience and which are consistent with atmospheric conditions. The system was developed for a sea-coast locality and in application elsewhere certain simplifications would be in order. At higher station elevations, for example, the surface to 700 mb thickness would be preferable to the 1000 - 850 mb thickness. For prairie stations, the greater convection present in summer suggests the desirability of using the 1000 - 700 mb thickness for maximum temperature forecasts, even for stations at low elevations. The most suitable thickness for any given locality could be determined experimentally.

Using this method the effects of land and sea breeze can be taken into account. A check on days when the sea breeze was quite active showed that there was a .92 correlation coefficient between maximum temperature and thickness. These investigations also showed that sea breezes were rare with geostrophic wind speeds of over 15 knots. By using the thickness, wind speed and direction, the sea breeze mechanism is well handled and ceases to be a problem to temperature prediction. Similarly the use of these parameters improves minimum temperature predictions under land breeze conditions.

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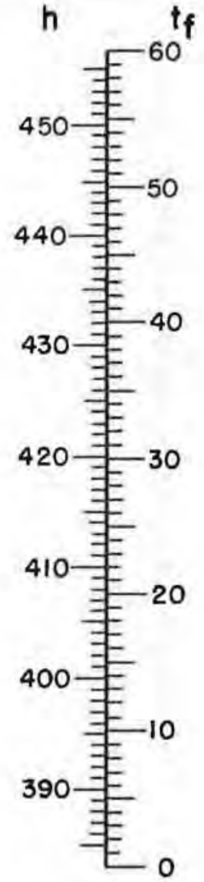
TABLE I

PERCENT TRANSMISSION OF INSOLATION BY CLOUDS (AFTER HAURWITZ).

These values of cloud transmission are for completely overcast skies. For scattered or broken cloud layers, fractional values are used.

Cloud Type	CI	CS	AC	AS	SC	ST	NS	FOG
Month								
JAN	82	72	48	41	32	25	24	18
FEB	84	78	50	41	34	25	19	17
MAR	84	81	51	41	34	25	17	17
APR	84	82	51	41	34	25	16	17
MAY	85	84	52	41	35	25	15	17
JUN	85	84	52	41	35	25	15	17
JUL	85	84	52	41	35	25	15	17
AUG	85	84	52	41	35	25	15	17
SEP	84	82	51	41	34	25	17	17
OCT	84	80	50	41	34	25	18	17
NOV	83	75	49	41	34	25	20	18
DEC	82	71	47	41	32	25	25	18

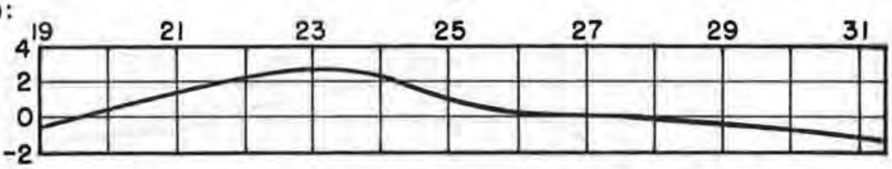


Corrections for:

Cloud Transmission: T < 25 -1° F

T > 75 +1° F

Wind Direction:



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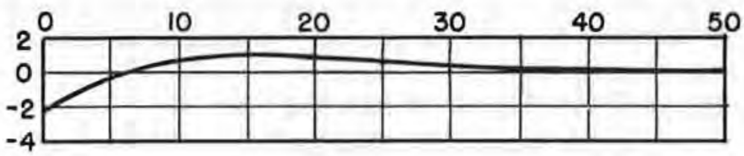
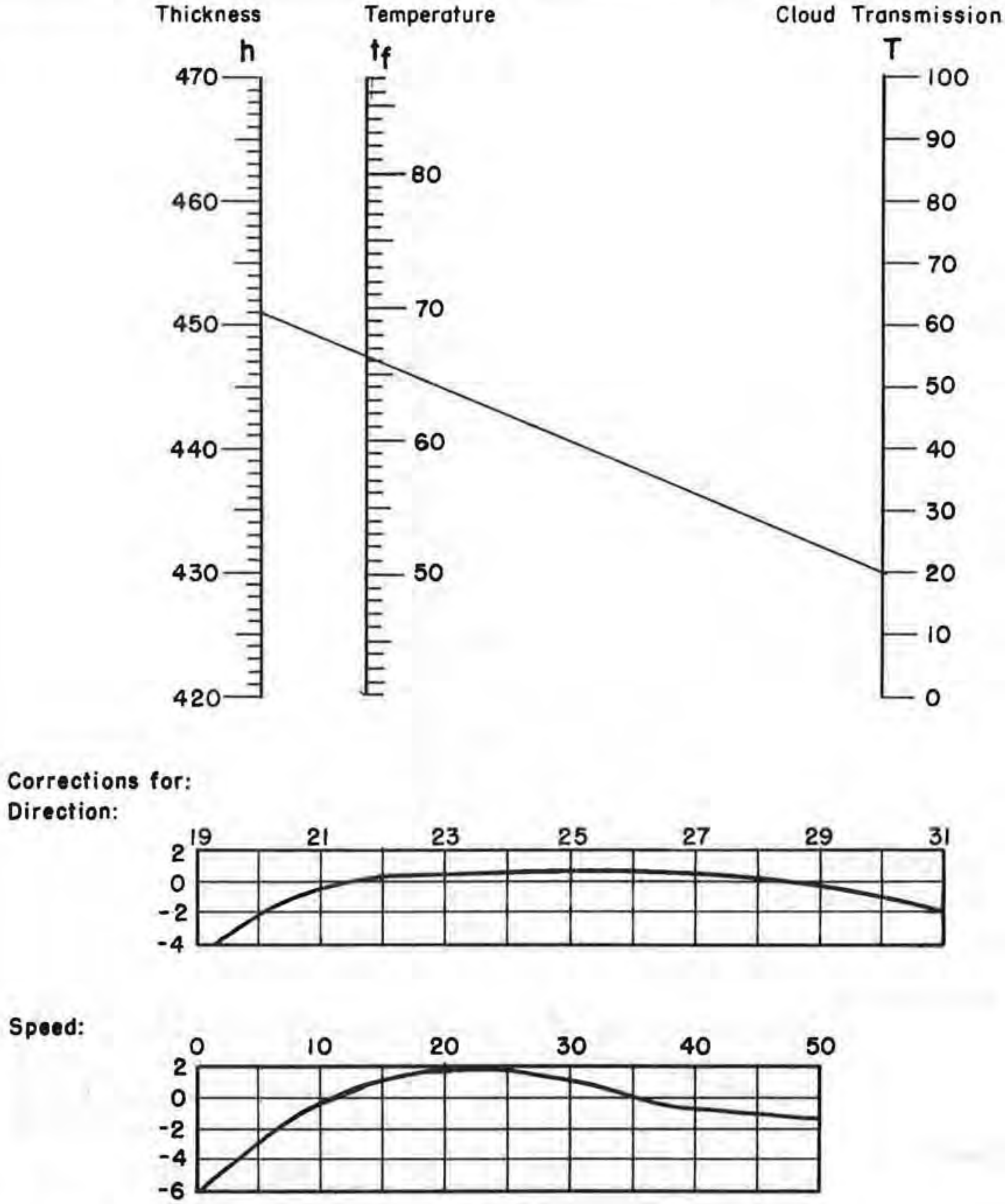


__Day of month:__ Nil

__Example:__ For a thickness value of 4100 the maximum temperature is 22° F.

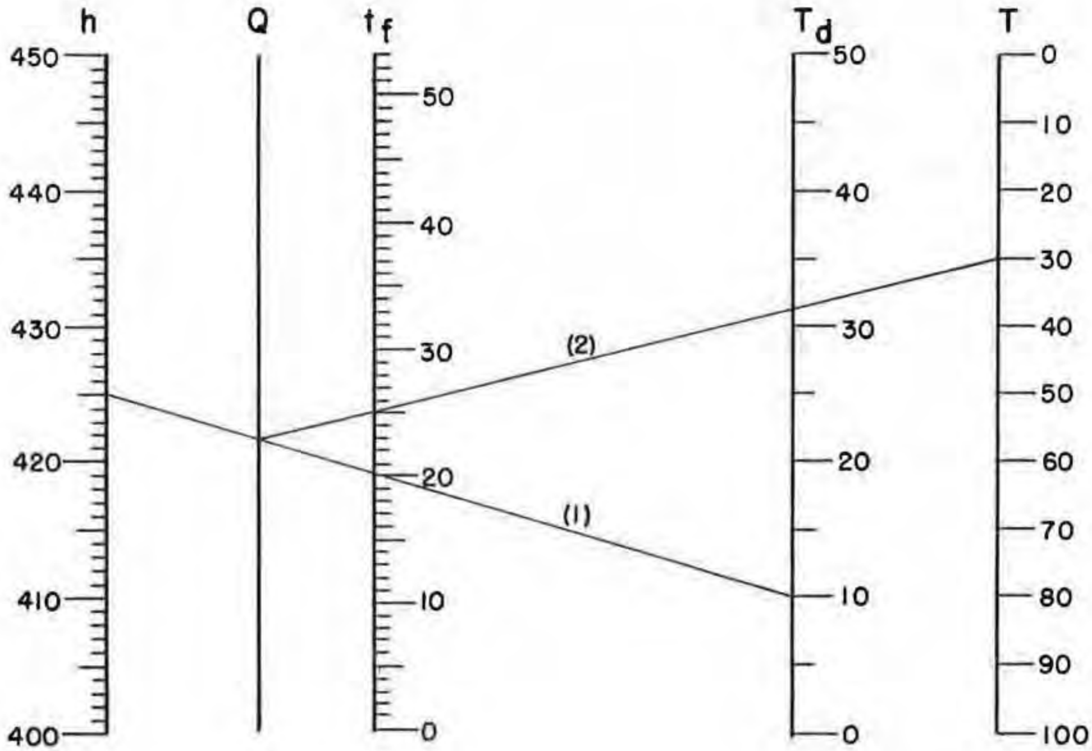
Fig. 1. Maximum Temperatures. Sector 190° - 310°.
JANUARY



<u>Day of month:</u> First day –: 1° too high
Last day –: 1° too low

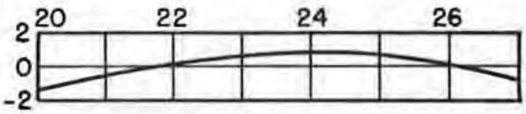
<u>Example:</u> Thickness is 4510, Cloud Transmission 20, the Maximum Temperature is 66°F.

Fig. 2. Maximum Temperatures. Sector 190° - 310°.
JUNE



Corrections for:

Direction:



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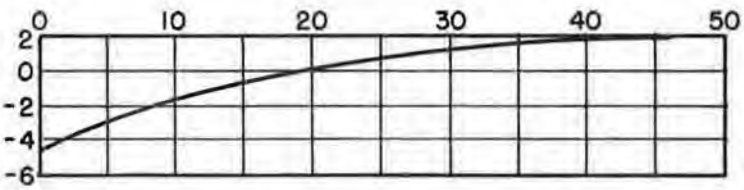

<u>Day of month:</u> **Negligible**

<u>Example:</u> **Thickness is 4,250, Dew Point 10°F**
Cloud Transmission 30%
the Minimum Temperature is 25°F

Fig. 3. Minimum Temperatures. Sector 200° - 270°.
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