TECHNICAL REPORT

A PRACTICAL METHOD OF PREDICTING
SEA ICE FORMATION AND GROWTH

OWEN S. LEE

and

LLOYD S. SIMPSON

*Applied Oceanography Branch
Division of Oceanography*

SEPTEMBER 1954

U. S. NAVY HYDROGRAPHIC OFFICE
WASHINGTON, D. C.

AC
/
TH3
no. TR-4

ABSTRACT

A technique for predicting ice formation and growth is presented. The ice potential calculations originally discussed by Zubov and Defant form part of the method, as do the standard heat budget equations developed by various authors. In addition, new formulas are derived for computing ice growth in terms of known or predicted oceanographic and meteorological data. The method is applied to the problem of predicting the general features of the ice distribution in the Baffin Bay-Davis Strait area for the season 1952-53. It is pointed out that use of this method must be limited to open-sea areas where winter and not polar ice is the dominating feature. However, the technique has important applications to estimating the general ice features of such areas several months in advance.

FOREWORD

The increasing importance of defense installations in northern areas has increased greatly the responsibilities of the U. S. Navy in supplying bases in Arctic waters, where sea ice is often an operating obstacle. The Hydrographic Office is charged with the responsibility of developing and testing techniques for observing and forecasting sea ice conditions. Standardized techniques for observing, charting, and reporting sea ice are now in operational use by the Navy, as described in publications issued by the Hydrographic Office. Heretofore, techniques for forecasting the formation, growth, and movement of sea ice have not been published by this Office. This publication describes a method of long-range forecasting of ice formation and growth. Since this technique is still in the developmental stage, the Hydrographic Office welcomes comments as to its operational value.

J. B. COCHRAN
Captain, U. S. Navy
Hydrographer

MBL/WHOI

0 0301 0040673 8

DISTRIBUTION LIST

CNO (Op-03, 03D3, 31, 316, 32, 33, 332, 04, 05, 533, 55)

BUAER (2)

BUSHIPS (2)

BUDOCKS (2)

ONR (Code 100, 102, 410, 416, 420, 430, 464, 466)

NOL (2)

NEL (2)

NRL (2)

COMOPDEVFOR (2)

COMSTS (2)

CODTMB (2)

AROWA

SUPNAVACAD (2)

NAVWARCOL (2)

NAVPOSTGRADSCOL, Monterey (2)

COMDT COGARD (IIP) (2)

USC&GS (2)

CG USAF (AFOOP)

CGAWS (2)

CGNEAC (2)

USAF CAMBRSCHLAB (2)

USWB (2)

CIA (2)

BEB (2)

SIPRE (2)

ASTIA (2)

ARTRANSCORP

CE (2)

INTLHYDROBU, Monaco (2)

ARCRSCHLAB, COL, Alaska

ARCINSTNA (2)

WHOI (2)

SIO (2)

UNIV WASH (2)

TEXAS A&M (2)

CBI (2)

CONTENTS

	Page
Foreword	iii
Distribution List.	iv
Figures.	v
Tables	vi
A. Introduction	1
B. The Ice Potential of a Water Column.	1
C. Method of Computing Date of Ice Formation.	5
D. Method of Computing Ice Growth	7
E. Use of the Ice Growth Tables in Forecasting.	10
F. Baffin Bay-Davis Strait Long-Range Ice Forecast for Season 1952-53	13
Conclusions.	13
Bibliography	27

FIGURES

1. Oceanographic Plot for Station #37	4
2. Ice-Potential Curve for Station #37.	6
3. Ice-Growth Forecast for Station #37.	12
4. Forecasted and Observed Ice Boundaries in Baffin Bay and Davis Strait for the Season 1952-53.	14

TABLES

	Page
1. Oceanographic Data for Station #37	3
2. Ice Potential Calculations for Station #37	15
3. Degree-days of Frost Associated with Given Ice Thickness and Heat Losses for Snow Cover = 0 cm.	16
4. Degree-days of Frost Associated with Given Ice Thickness and Heat Losses for Snow Cover = 2.5 cm.	17
5. Degree-days of Frost Associated with Given Ice Thickness and Heat Losses for Snow Cover = 5.0 cm.	18
6. Degree-days of Frost Associated with Given Ice Thickness and Heat Losses for Snow Cover = 7.5 cm.	19
7. Degree-days of Frost Associated with Given Ice Thickness and Heat Losses for Snow Cover = 10 cm.	20
8. Degree-days of Frost Associated with Given Ice Thickness and Heat Losses for Snow Cover = 15 cm.	21
9. Degree-days of Frost Associated with Given Ice Thickness and Heat Losses for Snow Cover = 20 cm.	22
10. Degree-days of Frost Associated with Given Ice Thickness and Heat Losses for Snow Cover = 30 cm.	23
11. Degree-days of Frost Associated with Given Ice Thickness and Heat Losses for Snow Cover = 40 cm.	24
12. Degree-days of Frost Associated with Given Ice Thickness and Heat Losses for Snow Cover = 50 cm.	25
13. Degree-days of Frost for Differing Heat Loss and Ice Thickness $\frac{(QT_i)}{2k_i}$	26

A. INTRODUCTION

The expanding program of ice observation and forecasting at the Hydrographic Office has emphasized the desirability of long-range ice forecasting. There are many phases of the ice program for which long range forecasts giving advance estimates of ice conditions of as much as 150 days are required. This paper deals with long-range forecasting of ice thickness in open seas whose salinity and density remain relatively constant, such as Baffin Bay and the Labrador Sea.

An operational method of forecasting for a long period must be easy to use, require a minimum number of involved calculations, and yield forecasts of reasonable accuracy. Most formulas previously developed have been complicated expressions which are not suited for operational use. In developing the following method, the goal has been to perfect a technique from which quantitative results can be derived with a minimum of computation and observation.

B. THE ICE POTENTIAL OF A WATER COLUMN

The severity of an ice season depends, among other things, upon the amount of thermal energy stored in the water mass and upon the rate at which convective mixing takes place. It is necessary to select a model of convective mixing which will explain the variation in the thermohaline conditions caused by heat removal and ice accretion. The method proposed by Defant (1949) and by Zubov (1938) of computing the ice potential and potential heat loss has been adopted as a basis for the present forecasting technique.

Before a forecast can be made, an analysis of the properties that inhibit ice formation and growth must be performed. Oceanographic measurements within the area in question must be secured in order to obtain information about salinity and thermal energy stored within the water mass. Unnecessary computation can be avoided by making the measurements at a time after the heat flux reverses, when thermal energy is being continually removed from the water. Otherwise the amount of heat which was added to the water column prior to the reversal of the heat flux would have to be computed before the method of Defant and Zubov could be utilized.

Establishing the ice potential of a given water column requires only the temperature and salinity at N levels within the column. The column is divided into $(N-1)$ layers and the mean temperature ($\bar{T}_n$), salinity ($\bar{S}_n$), and density ($\bar{\sigma}_n$), are computed for each layer. The mixing model, as defined by the method of Defant and Zubov is constructed by finding the mean temperature and salinity of the surface and second layers, i.e.,

$$\frac{\bar{S}_1 + \bar{S}_2}{2} = \bar{S}_{1,2} \quad , \quad \frac{\bar{T}_1 + \bar{T}_2}{2} = \bar{T}_{1,2} \quad .$$

The column is then said to be partially mixed down to the second level. Complete mixing is achieved by cooling the partially mixed column until its density, σ_1 , equals that of the original second layer, σ_2 . This mixing may be accomplished merely by changing the temperature of the partially mixed column, provided the water is not cooled below its freezing point. If the temperature change necessary for completely mixing the column requires a temperature below the freezing point, ice will form and the salinity of the remaining water in the column will be increased. The mixing process is carried out layer by layer until the potential heat loss is greater than the possible heat loss for a given ice season.

For convenience the expressions "partially mixed" and "completely mixed" have been used in connection with the ice potential computations. Two layers of water are termed "partially mixed" when the mixed column is defined completely by the means of the temperatures and salinities of the two original layers (i.e., no heat loss is involved). A "partially mixed" layer becomes "completely mixed" when the density of the partially mixed layer equals that of the original lower layer, with the density of the original lower layer remaining fixed throughout the process. In this latter case a heat loss is necessary, provided that the density distribution is stable. Temperature and salinity changes which result from this mixing model can be easily read from a T-S nomograph, or can be computed by use of standard hydrographic tables. (H.O. Pub. No. 615)

Complete mixing can be accomplished only by releasing q_t gram calories of sensible heat from the water column one square cm in cross section. Quantitatively, $q_{T(h)} = c \rho_w h \Delta T_w$ where c is the specific heat of sea water ρ_w is the density of sea water, h is the depth to which complete mixing reaches (or volume of $h \text{ cm}^3$), and ΔT_w is the amount of heat lost in changing the partially mixed column to a completely mixed column. When it is necessary to change the salinity of the column in order to achieve complete mixing, latent heat is involved in the process as well as sensible heat. Since a known percentage of the salt is frozen out of the ice, it is possible to write an expression for the latent heat as a function of the salinity change. Consequently, the ice accretion corresponding to a given salinity change can be expressed mathematically. As written by Defant, the ice thickness is given by

$$\xi_i = \frac{h \Delta S}{C \rho_w b S} \quad (1)$$

where S is the salinity of the partially mixed column and b is the percentage of the salts frozen out of the ice. The latent heat can now be evaluated from the well-known formula $q_f(Z) = K \xi(Z)$, where K is the latent heat of fusion, which decreases with increasing salinity of the ice. The total potential latent heat is given by

$$\int_0^h q_{\xi} dz = Q_l(h) \quad (2)$$

As the mixing model is developed, each layer will yield a certain amount of potential heat loss, q_T , and eventually, when the temperatures are low and the densities are high, each layer will yield a certain mass of potential ice (ξ) associated with convective mixing down through the corresponding layer. Thus it is possible to construct the very useful "potential curve" (Figure 2) from corresponding

$$\int_0^h \xi dz = l_i(h) \quad \text{and} \quad Q_T(h) = \tilde{Q}_T(h) - Q_0, \quad \text{where} \quad \tilde{Q}_T = \int_0^h q_T dz. \quad (3)$$

The potential curve is plotted, Q_T starting from zero within the layer where ice first appears. The remainder of the $\tilde{Q}_T, Q_0$, which is lost before ice is formed, determines the date of ice formation. The reason for taking Q_T as zero at this point becomes evident when one considers the lower limits of the integrals in equation (13). Obviously some question arises as to the exact quantity of heat that has been removed at the time ice is first formed. There is, of course, some error introduced, but it is not large as long as the water temperatures are near the freezing point and the water column is divided into layers of sufficiently small depth, for example five to ten meters. Recent work on the same type of model as Defant's has yielded exact values of the Q_T which must be removed before ice is formed, thus determining the proper point to start accumulating the Q_T for the potential curve (Brown, 1954).

In order to illustrate the computation of the ice potential and the drawing of the potential curve, a typical oceanographic station is used as an illustration. Station 37, at 66°N, 58°W, was occupied on 3 October 1952. A plot of the oceanographic variables at this station is given in Figure 1, and the complete numerical data are shown in Table 1.

TABLE 1
Oceanographic Data for Station #37
(66°N, 58°W), 3 October 1952

Depth m.	Temperature °C.	Salinity ‰	Density Anomaly (σ_t) gm/liter
0	0.56	32.37	25.98
5	0.10	32.36	26.00
10	0.61	32.39	25.99
20	0.73	32.47	26.05
30	-0.41	32.78	26.36
50	-1.65	33.08	26.64
75	-1.61	33.69	27.13
99	-2.13	33.69	27.14
148	-0.52	34.04	27.38
197	1.52	34.21	27.40
296	0.08	34.34	27.59
394	-1.71	34.52	27.81

FIG. 1 OCEANOGRAPHIC PLOT FOR STATION NO. 37, 66°N 58°W, 3 OCTOBER 1952.

From these data the ice potential has been calculated by the method of Defant and the results shown in Table 2A. Finally, the ice potential curve for Station 37 is shown in Figure 2. It will be noted that the ice potential curve is by no means a straight line or a smooth curve. In fact, for this station, the heat loss necessary to form a given amount of ice varies considerably. For this reason, the actual forecasting for this station is difficult, for a small additional heat loss at about 2 kg. cal. causes the formation of a large amount of ice. In this respect the example shown is not typical of many stations where the ice potential curve is quite regular and smooth; however, it is included to illustrate the kind of difficulties encountered in practice. In addition, the curve is atypical because Q_0 , the heat loss necessary to bring about formation of ice was found exactly at 25 meters when the temperature of the completely mixed layer (1-4, Table 2B) first dropped to -1.8°C . In general, Q_0 cannot be so easily determined.

C. METHOD OF COMPUTING DATE OF ICE FORMATION

There are two acceptable methods of computing the date of ice formation. Since the amount of heat that must be lost before ice is formed is known from the ice potential computations, it is only necessary to compute the time required to lose this heat. One method is to make actual observations of the heat loss per day per square cm. and thus to find the mean heat loss which is representative of a given area. The other method is to compute the total heat loss by consideration of the climatological data, the sun's altitude, and oceanographic data. For this purpose the only known formulas are those of Jacobs (1942), which yield rates of heat loss of the right order of magnitude in the Arctic, although they were specifically derived for middle latitudes.

Jacobs' formulas for computing heat losses are:

$$Q_{ab} = .025 \bar{\alpha} \left[.29 + .71 \left(1 - \frac{\bar{c}}{100} \right) \right] (1 - r) t, t \text{ in minutes} \quad (4)$$

$$Q_b = .94 \left[\text{eff. } Q_b (1 - .0083 \bar{c}) \right] t, \quad t \text{ in minutes} \quad (5)$$

$$Q_e = 145.4 \bar{w} (e_w - e_a) \left[1 + .01 \left\{ \frac{T_w - T_a}{e_w - e_a} \right\} \right] t, t \text{ in days,} \quad (6)$$

where

Q_{ab} = total incoming radiation in gm. cal/cm.²

Q_b = total back radiation in gm. cal/cm.²

Q_e = total heat loss due to evaporation in gm. cal/cm.²

$\bar{\alpha}$ = mean altitude of the sun in degrees,

$\bar{c}$ = mean cloud amount in percent,

$\bar{w}$ = mean wind velocity in knots,

FIG. 2 ICE-POTENTIAL CURVE FOR STATION NUMBER 37.

e_w = vapor pressure of the water in inches Hg.,

e_a = vapor pressure of the air in inches Hg.,

T_w = temperature of the water in degrees F.,

T_a = temperature of the air in degrees F.

eff. Q_b (effective back radiation) = difference between temperature radiation of the sea surface and long-wave radiation from the atmosphere,

t = time in units designated above, and

r = fractional part of the incoming radiation reflected from the sea surface.

The ice potential computations determine the amount of sensible heat which must be removed from the water column prior to the initial formation of ice. For example, let this value be Q_p . Then setting $Q_p = Q_b - Q_e - Q_{ab}$ and solving for t gives the number of days between the time that the oceanographic measurements were made and the time ice will form.

D. METHOD OF COMPUTING ICE GROWTH

From the time oceanographic observations are made until the time ice forms, it is assumed that the heat exchange results from incoming radiation, back radiation, and evaporation. After ice forms, the processes by which heat is removed from the water column are altered considerably. Any heat that is then removed from the water must be conducted through the solid layer of ice above it. Thus, the rate of further heat loss is determined by the temperature gradient through ice and snow. Hence, assuming steady-state conditions for finite increments of time,

$$\frac{d(Q_1 + Q_T)}{dt} = k_i \frac{\Delta T_i}{l_i} = k_s \frac{\Delta T}{l_s} \quad (7)$$

where, Q_T is the amount of sensible heat loss (in kg. cal.),

Q_1 is the amount of latent heat loss (in kg. cal.),

k_i is the heat conductivity coefficient of sea ice,

k_s is the heat conductivity coefficient of snow,

ΔT_i is the temperature difference between the upper surface of the ice and freezing point of sea water (in °C.),

ΔT_s is the temperature difference between the surface of the snow and the surface of the ice (in °C.),

l_i is the thickness of the ice in cm,

l_s is the thickness of the snow in cm, and

$\bar{l}_s$ is the mean snow cover over a finite period of time.

Since $\Delta T = \Delta T_i + \Delta T_s$, where ΔT is the temperature difference between the freezing point of sea water (taken at -1.8°C.) and the snow surface temperature, and from (7)

$$\frac{\Delta T_s}{\Delta T_i} = \frac{k_i \bar{l}_s}{k_s l_i} \quad (8)$$

then
$$\Delta T = \Delta T_i \left\{ 1 + \frac{k_i l_s}{k_s l_i} \right\} \quad \text{or} \quad \Delta T_i = \frac{\Delta T}{1 + \frac{k_i l_s}{k_s l_i}} \quad (9)$$

Then (7) becomes:
$$\frac{d(Q_i + Q_T)}{dt} = \frac{k_i \Delta T}{l_i \left\{ 1 + \frac{k_i l_s}{k_s l_i} \right\}} \quad (10)$$

Substituting $Q_i = \rho_i K l_i$ into (10) (ρ_o denotes ice density)

$$\rho_i K \frac{dl_i}{dt} + \frac{dQ_T}{dt} = \frac{k_i \Delta T}{l_i \left\{ 1 + \frac{k_i l_s}{k_s l_i} \right\}} \quad (11)$$

$$\rho_i K \left\{ 1 + \frac{k_i l_s}{k_s l_i} \right\} l_i dl_i + \left\{ 1 + \frac{k_i l_s}{k_s l_i} \right\} l_i dQ_T = k_i \Delta T dt \quad (12)$$

$$\rho_i K \int_0^{l_i(h)} l_i(Z) dl_i(Z) + \frac{\rho_i K k_i}{k_s} \int_0^{l_i(h)} l_s dl_i(Z) + \int_0^{Q_T(h)} l_i(Z) dQ_T(Z) +$$

$$\frac{k_i}{k_s} \int_0^{Q_T(h)} l_s dQ_T(Z) = k_i \int_{t_0}^t \Delta T dt \quad (13)$$

$$\frac{\rho_i K}{2} l_i^2(h) + \frac{\rho_i K k_i}{k_s} \bar{l}_s l_i(h) + \int_0^{Q_T(h)} l_i(Z) dQ_T(Z) + \frac{k_i}{k_s} \bar{l}_s Q_T(h) = k_i \int_{t_0}^t (T_F - T) dt \quad (14)$$

The right-hand expression in equation 14 is usually denoted by the title "degree-days of frost." A degree-day of frost is defined as a day with a mean temperature 1-degree Centigrade below the freezing point of sea water. While the freezing temperature of sea water varies with salinity, it is here assumed to be -1.8°C . A degree-day of frost is then 1 day with a mean temperature of -2.8°C . Degree-days of frost usually are accumulated for forecasting over periods of 15 or 30 days. By giving the following values to some of the terms in equation 14:

$$\begin{aligned}\rho_1 &= 0.9 \\ K &= .080 \frac{\text{Kg Cal}}{\text{gm}} \\ k_1 &= .389 \frac{\text{Kg Cal}}{\text{cm } ^{\circ}\text{C day}} \\ k_s &= .062 \frac{\text{Kg Cal}}{\text{cm } ^{\circ}\text{C day}},\end{aligned}$$

the formula can be used directly to forecast the ice in terms of degree-days of frost

$$\int_{t_0}^{\dagger} (T_F - T) dt.$$

Thus, for a given value of $\bar{l}_s$ all terms in the equation are known except l_1 and Q_T . A given l_1 and likewise the corresponding Q_T , can be selected from the potential curve. By substituting l_1 and Q_T into equation (14) and by evaluating the area under the potential curve between the proper limits for the expression

$$\int_0^{Q_T(h)} \bar{l}_1(Z) dQ_T(Z)$$

the number of degree-days of frost required to form l_1 centimeters of ice can be computed.

To eliminate the necessity of computation, the end results of the derivation have been presented in the form of tables (Tables 3-12). In addition the integral

$$\int_0^{Q_T(h)} \bar{l}_1(Z) dQ_T(Z)$$

had to be evaluated by approximation methods. It was found from the majority of potential curves that the integral could be approximated as

$$\frac{l_1}{2} Q_T(h),$$

The error introduced was found to be small unless the water temperature was unusually high, and in most cases ice will not form under such conditions. Since the potential curve $l_1(Q_T)$ must always be plotted, it is readily apparent when the above approximation is invalid; in this situation the formula can be used. In order to facilitate substitution of the actual integral for the approximation, an auxiliary table (Table 13) is included which gives the degree-days of frost associated with various values of l_1 and Q_T . If the potential curve is very irregular, Table 13 is entered, and by comparison with the degree-day figure computed from an average l_1 , one can determine the amount of error introduced into the total. Most frequently this will be found to be small, since the potential term is only one of four separate factors contributing to the total; however, the actual value can be added or subtracted and a more accurate figure secured.

The form of equation 14 which was used in the tables is

$$\int_{t_0}^t (T_F - T) dt = \frac{1}{k_i} \left[\frac{\rho_i K}{2} l_i^2 + \left\{ \frac{\rho_i K k_i l_s}{k_s} + \frac{Q_T}{2} \right\} l_i + \frac{k_i l_s}{k_s} Q_T \right]. \quad (15)$$

The degree-days of frost for fixed $l_s = 0, 2.5, 5, 7.5, 10, 15, 20, 30, 40,$ and 50 cm. are given in Tables 3 to 12. The concept of degree-days has an advantage over one of calendar days because of its versatility as far as forecasting is concerned. An ice forecast in days is difficult because it requires a forecast of air temperatures as well as ice growth, while the degree-day forecast permits ice growth forecasts which fit all conceivable temperature variations.

E. USE OF THE ICE GROWTH TABLES IN FORECASTING

Forecasting the ice growth in a given area requires the following information: (1) oceanographic data taken after the water mass begins to cool and prior to ice formation, (2) the date of ice formation, and (3) an expression relating ice growth to degree-days of frost for the given area. With this information the forecaster can then proceed to make a forecast for the entire season. The procedure is as follows: (1) the ice potential of each oceanographic station is calculated and the ice potential curve (example, Figure 2) is drawn; (2) from available meteorological and oceanographic data, the date of ice formation is determined; and (3) the forecast is made in terms of degree-days of frost.

Since the calculation of the ice potential, the date of first ice formation, and the ice potential curve have been previously explained, the remaining discussion will describe the preparation of an actual forecast. As before, Station #37 is used as an example. The ice potential curve for this station is given in Figure 2. In order to draw the ice forecast curves for this station it is necessary to read the ice thickness figures corresponding to integral values of Q_T from the ice potential curve. The degree-days of frost corresponding to each combi-

nation of l_i and Q_T values are read from each of the tables 3 to 12. A plot of ice thickness vs degree-days of frost is made from each set of values obtained from the graphs, and a smooth curve is drawn for each value of snow depth (l_s). An example of a completed forecast is given in Figure 3. In Figure 3, $Q_T = 1$ corresponds to an ice thickness of 27 cm. and $Q_T = 2$ to an ice thickness of 72 cm. on the ice potential curve of Figure 2. To convert the completed forecast into a time forecast the meteorologist must provide temperature and snow depth forecasts in order to secure an ice thickness forecast of 120 to 150 days for this station.

Now let us suppose that the date of first ice formation at Station #37 is 12 November and that the meteorologist provides a forecast, including the following data for the succeeding months:

Period	Mean Temperature (°C)	Degree-Days of Frost	Snow Depth (cm.)
12 - 15 Nov.	-5.8	16	0
16 - 30 Nov.	-4.8	45	0
1 - 15 Dec.	-8.8	105	2.5
16 - 31 Dec.	-7.8	96	2.5
1 - 15 Jan.	-9.8	120	7.5
16 - 31 Jan.	-18.8	272	7.5

The ice thickness for any given date may be found from the above data and the forecast curve.

During the period when the snow depth is zero, the growth of ice will be along the upper curve on Figure 3; on 30 November, the final day with no snow, the total of degree-days of frost is 16 + 45 or 61 and the ice thickness will be 17 cm. (point A on Figure 3).

During the month of December the ice grows under a snow depth of 2.5 cm. from a starting point of 17 cm. This point is marked A'. During December a total of 105 plus 96 or 201 degree-days of frost is counted, so that it is necessary to follow the curve $l_s = 2.5$ for 201 degree-days of frost beyond point A', or to point B. At point B, reached 31 December, the ice thickness will be 35 cm.

Similarly, during January the ice grows under a snow depth of 7.5 cm. for 120 plus 272 or 392 degree-days beyond the point B' corresponding to an ice thickness of 35 cm. On 31 January the point C is reached, and the ice thickness will be 53 cm. This constitutes an operational forecast, as the user of the forecast can determine the ice thickness on any day between 12 November and 31 January by counting the number of degree-days of frost and noting the snow depth applicable to the situation.

DEGREE -- DAYS OF FROST (°C.)

FIG. 3. ICE GROWTH FORECAST FOR STATION # 37

F. BAFFIN BAY-DAVIS STRAIT LONG-RANGE ICE FORECAST FOR SEASON 1952-53.

During early autumn, 1952, oceanographic observations were taken at the locations shown on Figure 4. The method explained previously was employed to forecast the ice formation and growth of these locations. The dates of ice formation were computed and are shown beside each station. Since the thermohaline structure at some of the stations was such that no ice would be formed, it was possible to delineate the theoretical extreme ice boundary shown as a heavy line in Figure 4. This boundary agrees very well with the boundary which was actually observed in late March and early April 1953, (shown as a dashed line in Figure 4) except for the occurrence of ice south of Stations 39 and 40. It is possible that ice which was observed at these two stations was not formed there, but had drifted from nearby areas of ice formation. The dispersion of ice near the observed boundary in this area indicates that the ice actually was formed outside the area.

CONCLUSIONS

The methods of Zubov and Defant for ice potential calculation have proved in practice to give reasonable answers for open seas and for in-shore areas where local variations in the physical properties of the water are not large. In harbors and areas where runoff is important, changes in salinity and density are so rapid that it is difficult to attach a meaning to an average value of these parameters. Hence any ice potential calculation based on one or a few observations in a harbor may give a potential ice growth which is unreasonably high or low for a single season.

The forecast of ice growth based on the ice potential can be used only during the period when ice thickness is increasing. No theory has been included which accounts for decreasing ice thicknesses during the breakup period. Indeed, no mathematical theory has yet been developed for the breakup of ice.

Many refinements of the method presented in this paper are possible. Some of them are discussed in a paper by Brown (1954). The method described here was used to forecast during the 1952-53 ice season; the forecast proved to be satisfactory. The most important advancement discussed in this report is the use of the ice potential as a basis for forecasting ice growth.

FIG. 4. FORECASTED AND OBSERVED ICE BOUNDARIES IN BAFFIN BAY AND DAVIS STRAIT FOR THE SEASON 1952-1953

TABLE 2A
ICE POTENTIAL CALCULATIONS FOR STATION #37
(66°N, 58°W), 3 OCTOBER 1952

Depth Meters	T °C	S ‰	σ_t	Layer No.	Depth (Meters)	T °C	Mean Values S ‰	σ_t
0	.56	32.38	25.98	1	0-10	.42	32.38	25.99
5	.10	32.36	26.00	2	10-15	.54	32.40	26.00
10	.61	32.39	25.99	3	15-20	.70	32.44	26.02
15	.67	32.41	26.00	4	20-25	.44	32.54	26.12
20	.73	32.47	26.05	5	25-30	-.13	32.70	26.28
25	.15	32.62	26.20	6	30-35	-.64	32.82	26.40
30	-.41	32.78	26.36	7	35-40	-1.02	32.90	26.45
35	-.86	32.86	26.43	8	40-45	-1.34	32.98	26.51
40	-1.18	32.94	26.48	9	45-50	-1.58	33.04	26.59
45	-1.50	33.01	26.54	10	50-55	-1.65	33.14	26.70
50	-1.65	33.08	26.64	11	55-60	-1.64	33.28	26.82
55	-1.65	33.20	26.76	12	60-65	-1.62	33.43	26.93
60	-1.62	33.36	26.88	13	65-70	-1.62	33.55	27.02
65	-1.62	33.50	26.98	14	70-75	-1.61	33.64	27.10
70	-1.61	33.60	27.07	15	75-80	-1.66	33.69	27.14
75	-1.61	33.69	27.13	16	80-85	-1.76	33.69	27.14
80	-1.72	33.69	27.14	17	85-90	-1.80	33.69	27.14
85	-1.80	33.69	27.14	18	90-95	-1.80	33.69	27.14
90	-1.80	33.69	27.14	19	95-100	-1.80	33.70	27.14
95	-1.80	33.69	27.14	20	100-150	-1.16	33.88	27.26
100	-1.80	33.70	27.14	21	150-200	.50	34.14	27.39
150	-0.51	34.06	27.38	22	200-300	.78	34.28	27.50
200	1.50	34.21	27.40	23	300-400	-.84	34.44	27.71
300	0.06	34.35	27.60					
400	-1.75	34.53	27.82					

TABLE 2B

Layer	Depth (m)	Before Mixing T °C S ‰	After Mixing T °C S ‰	ΔT	q_T	$\tilde{q}_T$	ΔS	ξ_i	l_i	Q_T
1-2	15	.46 32.39	26.00 .45 32.39	-.01	-.01	-.01				
1-3	20	.51 32.40	26.02 .30 32.40	-.21	.38	.39	0			
1-4	25	.33 32.44	26.12 -1.80 32.44	-2.13	4.79	5.18	0			
1-5	30	-1.52 32.48	26.28 -1.80 32.70	-.28	.76	5.94	.22	22.4	22.4	.76
1-6	35	-1.63 32.72	26.40 -1.80 32.79	-.17	.54	6.48	.07	8.2	30.6	1.30
1-7	40	-1.70 32.80	26.45 -1.80 32.86	-.10	.36	6.84	.06	8.0	38.6	1.66
1-8	45	-1.75 32.87	26.51 -1.80 32.93	-.05	.20	7.04	.06	9.0	47.6	1.86
1-9	50	-1.78 32.94	26.59 -1.80 33.01	-.02	.09	7.13	.07	11.7	59.3	1.95
1-10	55	-1.79 33.02	26.70 -1.80 33.15	-.01	.05	7.18	.13	23.8	83.1	2.00
1-11	60	-1.79 33.16	26.82 -1.80 33.30	-.01	.05	7.23	.14	27.7	110.8	2.05
1-12	65	-1.79 33.31	26.93 -1.80 33.43	-.01	.06	7.29	.12	25.6	136.4	2.11
1-13	70	-1.79 33.44	27.02 -1.80 33.54	-.01	.06	7.35	.10	23.0	159.4	2.17
1-14	75	-1.79 33.55	27.10 -1.80 33.65	-.01	.07	7.42	.10	24.5	183.9	2.24
1-19	100	-1.79 33.53	27.14 -1.80 33.70	-.01	.09	7.51	.17	55.4	239.3	2.33
1-20	150	-1.59 33.76	27.26 -1.80 33.86	-.21	2.83	10.34	.10	48.7	288.0	5.16
1-21	200	-1.22 33.93	27.39 -1.80 34.02	-.58	10.44	20.78	.09	58.2	346.2	15.60
1-22	300	-.94 34.11	27.50 -1.80 34.15	-.86	23.22	44.00	.04	38.7	384.9	38.82

TABLE 3

DEGREE-DAYS OF FROST ASSOCIATED WITH GIVEN ICE THICKNESS AND HEAT LOSSES FOR SNOW COVER = 0 cm.

Ice Thickness in cm. (I_i)	Heat Loss kg. cal. (Q_i)															
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
0	2	9	15	22	28	34	41	47	54	60	67	73	80	86	92	99
5	5	22	35	49	61	71	86	99	112	125	138	151	163	176	189	195
10	15	40	59	78	93	117	136	156	175	194	214	233	252	271	291	302
20	30	63	88	111	140	166	191	217	243	268	294	320	346	371	397	423
25	35	68	90	122	154	186	218	251	283	315	347	379	411	443	476	500
30	40	93	122	160	206	246	286	325	363	400	439	478	516	555	593	631
35	45	113	158	203	253	308	363	423	473	528	583	638	693	748	803	858
40	50	133	200	251	304	354	405	457	509	561	611	662	714	765	816	868
45	55	157	245	301	354	419	477	534	592	648	704	760	816	872	928	984
50	60	181	296	360	428	488	553	617	681	746	810	874	938	1003	1067	1131
55	65	205	351	421	492	563	633	704	775	846	916	987	1058	1128	1199	1270
60	70	230	381	451	525	602	679	756	832	907	982	1057	1132	1209	1286	1361
65	75	255	417	487	563	642	725	809	892	976	1059	1143	1226	1310	1394	1477
70	80	280	454	524	603	686	773	859	943	1028	1113	1197	1281	1365	1449	1532
75	85	305	491	561	643	730	820	909	1000	1090	1181	1271	1361	1451	1541	1631
80	90	330	521	591	676	768	862	957	1054	1151	1249	1347	1445	1543	1641	1739
85	95	355	551	621	710	806	904	1004	1106	1209	1312	1415	1517	1620	1722	1824
90	100	380	581	651	744	844	946	1050	1156	1262	1368	1474	1580	1686	1792	1898
 

TABLE 4

DEGREE-DAYS OF FROST ASSOCIATED WITH GIVEN ICE THICKNESSES AND HEAT LOSSES FOR SNOW COVER = 2.5 cm.
Heat loss kg. cal. (Q_i)

l_i cm	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	20	25	30
0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	17	64	110	157	204	250	297	344	391	438	484	531	578	624	671	718	836	1008	1210
10	33	91	148	206	264	321	378	436	494	551	608	665	722	779	836	893	1102	1368	1634
15	61	126	191	256	321	386	451	516	581	646	711	776	841	906	971	1036	1296	1584	1872
20	95	161	227	293	359	425	491	557	623	689	755	821	888	954	1020	1086	1406	1746	2076
25	130	203	275	348	420	493	565	638	710	782	855	927	1000	1072	1145	1217	1580	1962	2304
30	170	249	324	407	486	565	644	723	802	880	959	1038	1117	1196	1275	1354	1762	2212	2537
35	215	300	386	471	556	642	727	812	898	983	1068	1153	1239	1324	1409	1495	1921	2418	2774
40	264	356	448	539	631	723	815	906	998	1090	1182	1273	1365	1457	1548	1640	2099	2658	3016
45	318	416	514	612	711	809	907	1005	1103	1202	1300	1398	1496	1594	1692	1790	2391	2972	3363
50	377	481	586	687	795	905	1004	1109	1213	1318	1423	1527	1632	1736	1841	1945	2608	3291	3770
55	440	551	662	773	881	995	1106	1217	1328	1439	1550	1661	1772	1883	1994	2105	2860	3615	4141
60	507	625	742	860	977	1095	1212	1330	1447	1564	1682	1799	1917	2034	2152	2269	3156	3981	4566
65	580	704	827	951	1078	1199	1323	1447	1571	1694	1818	1942	2066	2190	2314	2438	3397	4306	4996
70	657	787	917	1048	1178	1308	1438	1569	1699	1829	1960	2090	2220	2351	2481	2611	3676	4674	5466
75	738	875	1012	1148	1285	1422	1559	1695	1832	1969	2106	2242	2379	2516	2653	2789	3973	5073	5962
80	825	968	1111	1254	1397	1540	1681	1827	1970	2113	2256	2399	2542	2686	2829	2972	4306	5545	6634
85	915	1065	1214	1364	1514	1663	1813	1962	2112	2262	2411	2561	2710	2860	3010	3159	4600	5982	7277
90	1011	1167	1323	1479	1635	1791	1947	2103	2259	2415	2571	2727	2883	3039	3195	3351	5000	6511	8013
95	1111	1273	1436	1598	1761	1923	2086	2248	2410	2573	2735	2897	3060	3223	3385	3547	5300	7037	8774
100	1215	1384	1553	1722	1891	2060	2229	2398	2567	2735	2904	3073	3242	3411	3580	3749	5600	7507	9404
110	1439	1621	1803	1984	2166	2348	2529	2711	2893	3075	3256	3438	3620	3802	3983	4165	6100	8257	10404
120	1681	1876	2070	2265	2459	2654	2848	3043	3238	3432	3627	3821	4016	4210	4405	4599	6700	9107	11504
130	1941	2149	2356	2564	2771	2978	3186	3393	3601	3808	4016	4223	4430	4638	4845	5053	7300	10007	12904
140	2220	2441	2661	2881	3102	3322	3542	3762	3982	4203	4423	4643	4864	5084	5304	5524	8000	11007	14404
150	2518	2751	2994	3217	3453	3691	3926	4166	4406	4646	4886	5126	5366	5606	5846	6086	8700	12007	16004
160	2834	3080	3326	3572	3818	4064	4310	4556	4802	5048	5294	5540	5786	6032	6278	6524	9400	13007	18004
170	3168	3427	3686	3945	4203	4462	4721	4980	5239	5498	5756	6015	6274	6533	6792	7050	10300	14007	19004
180	3522	3794	4065	4337	4609	4880	5151	5421	5696	5967	6238	6509	6780	7051	7322	7593	11000	15007	20004
190	3892	4177	4461	4747	5031	5315	5600	5884	6169	6453	6738	7022	7307	7592	7877	8162	12000	16007	21004
200	4282	4570	4857	5145	5432	5719	6006	6293	6580	6867	7154	7441	7728	8015	8302	8589	13000	17007	22004
210	4691	5001	5311	5622	5932	6242	6552	6863	7173	7483	7793	8103	8413	8723	9033	9343	14000	18007	23004
220	5113	5441	5761	6087	6415	6743	7070	7398	7726	8054	8382	8710	9038	9366	9694	10022	15000	19007	24004
230	5563	5909	6236	6571	6907	7243	7579	7915	8251	8587	8923	9259	9595	9931	10267	10603	16000	20007	25004
240	6037	6396	6735	7071	7407	7743	8079	8415	8751	9087	9423	9759	10095	10431	10767	11103	17000	21007	26004
250	6510	6882	7233	7575	7917	8259	8601	8943	9285	9627	9969	10311	10653	10995	11337	11679	18000	22007	27004
260	7011	7395	7760	8134	8509	8883	9257	9631	10005	10379	10753	11127	11501	11875	12249	12623	19000	23007	28004
270	7530	7935	8305	8680	9056	9432	9808	10184	10560	10936	11312	11688	12064	12440	12816	13192	20000	24007	29004
280	8063	8469	8869	9269	9669	10069	10469	10869	11269	11669	12069	12469	12869	13269	13669	14069	21000	25007	30004
290	8625	9038	9451	9864	10277	10690	11103	11516	11929	12342	12755	13168	13581	13994	14407	14820	22000	26007	31004
300	9203	9686	10052	10478	10904	11330	11756	12182	12608	13034	13460	13886	14312	14738	15164	15590	23000	27007	32004

Ice thickness in cm. (l_i)

TABLE 5

DEGREE-DAYS OF FROST ASSOCIATED WITH GIVEN ICE THICKNESSES AND HEAT LOSSES FOR SNOW COVER = 5 CM.

Heat Loss in kg. cal. (Q _T)																				
0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	20	25	30		
0	0	81	161	242	323	403	484	564	645	726	806	887	968	1049	1129	1210	1291	1372	1453	
5	31	118	206	292	380	467	554	641	728	815	902	989	1076	1163	1250	1337	1424	1511	1598	
10	67	161	254	348	441	535	628	722	815	909	1002	1096	1189	1283	1376	1470	1563	1656	1749	
15	108	208	308	408	508	608	708	807	907	1007	1107	1207	1307	1407	1507	1607	1706	1806	1906	
20	153	259	366	472	578	685	791	898	1004	1110	1217	1323	1429	1536	1642	1748	1854	1960	2066	
25	203	316	429	542	654	767	880	993	1106	1218	1331	1444	1556	1669	1782	1895	2008	2121	2234	
30	258	377	498	615	734	854	973	1092	1211	1330	1450	1569	1688	1807	1926	2046	2165	2284	2403	
35	316	442	568	693	819	945	1070	1195	1322	1447	1573	1698	1824	1950	2075	2201	2326	2452	2577	
40	380	512	644	776	909	1041	1173	1305	1437	1569	1701	1833	1965	2097	2229	2361	2493	2625	2757	
45	449	587	726	864	1003	1141	1280	1415	1557	1695	1834	1972	2110	2249	2388	2526	2665	2803	2941	
50	522	667	812	956	1101	1246	1391	1536	1681	1826	1971	2116	2261	2406	2550	2695	2840	2985	3130	
55	599	751	902	1053	1205	1356	1507	1659	1810	1961	2113	2264	2415	2567	2718	2869	3020	3171	3322	
60	682	839	997	1155	1313	1470	1628	1786	1944	2106	2259	2417	2575	2733	2890	3048	3206	3364	3522	
65	768	932	1097	1261	1425	1589	1754	1918	2082	2246	2410	2574	2739	2903	3067	3231	3395	3559	3723	
70	860	1031	1201	1372	1542	1713	1884	2054	2225	2396	2566	2737	2907	3078	3249	3419	3589	3759	3929	
75	956	1133	1310	1487	1664	1841	2018	2195	2372	2550	2726	2904	3081	3258	3435	3612	3789	3966	4143	
80	1057	1240	1424	1607	1791	1974	2158	2341	2525	2708	2892	3075	3258	3442	3625	3809	3992	4175	4358	
85	1162	1352	1542	1732	1922	2112	2302	2491	2681	2871	3061	3251	3441	3631	3821	4011	4201	4391	4581	
90	1272	1468	1665	1861	2056	2254	2450	2646	2843	3039	3235	3432	3624	3821	4021	4217	4419	4619	4819	
95	1387	1590	1792	1995	2198	2400	2603	2806	3009	3212	3415	3617	3820	4023	4225	4428	4636	4836	5036	
100	1506	1715	1926	2136	2346	2552	2761	2970	3180	3389	3598	3807	4016	4225	4434	4644	4853	5062	5271	
110	1758	1980	2203	2425	2647	2869	3091	3313	3535	3757	3979	4201	4423	4645	4867	5089	5311	5533	5755	
120	2029	2261	2493	2724	2956	3201	3439	3678	3918	4158	4398	4638	4878	5118	5358	5598	5838	6078	6318	
130	2319	2566	2814	3062	3310	3558	3805	4053	4301	4549	4797	5045	5292	5540	5788	6036	6284	6532	6780	
140	2627	2887	3148	3408	3669	3930	4190	4451	4712	4972	5233	5493	5754	6014	6275	6535	6795	7055	7315	
150	2953	3227	3500	3774	4047	4320	4594	4867	5141	5414	5688	5961	6235	6508	6782	7055	7328	7601	7874	
160	3298	3584	3871	4157	4443	4730	5016	5302	5589	5875	6161	6448	6734	7020	7306	7593	7879	8165	8451	
170	3662	3961	4260	4559	4858	5157	5457	5756	6055	6354	6653	6952	7252	7551	7850	8149	8448	8747	9046	
180	4044	4356	4668	4980	5292	5604	5916	6228	6540	6852	7164	7476	7788	8099	8411	8723	9035	9347	9659	
190	4444	4759	5074	5389	5704	6019	6334	6649	6964	7279	7594	7909	8224	8539	8854	9169	9484	9799	10114	
200	4863	5201	5538	5876	6214	6552	6890	7227	7565	7902	8240	8578	8916	9254	9592	9930	10268	10606	10944	
210	5301	5651	6002	6352	6703	7053	7403	7753	8103	8453	8803	9153	9503	9853	10203	10553	10903	11253	11603	
220	5757	6120	6483	6847	7211	7575	7939	8303	8667	9031	9395	9759	10123	10487	10851	11215	11579	11943	12307	
230	6231	6607	6984	7360	7736	8112	8489	8865	9241	9618	9994	10370	10746	11122	11498	11874	12250	12626	13002	
240	6724	7113	7502	7892	8281	8670	9059	9448	9837	10226	10615	11004	11393	11782	12171	12560	12949	13338	13727	
250	7236	7638	8040	8442	8844	9246	9648	10050	10452	10854	11256	11658	12060	12462	12864	13266	13668	14070	14472	
260	7766	8180	8595	9010	9425	9840	10254	10669	11084	11499	11914	12329	12744	13159	13574	13989	14404	14819	15234	
270	8314	8742	9172	9603	10025	10447	10869	11291	11713	12135	12557	12979	13401	13823	14245	14667	15089	15511	15933	
280	8881	9322	9763	10203	10643	11083	11523	11963	12403	12843	13283	13723	14163	14603	15043	15483	15923	16363	16803	
290	9467	9920	10374	10837	11299	11761	12223	12685	13147	13609	14071	14533	14995	15457	15919	16381	16843	17305	17767	
300	10071	10543	11015	11487	11959	12431	12903	13375	13847	14319	14791	15263	15735	16207	16679	17151	17623	18095	18567	

TABLE 6

DEGREE-DAYS OF FROST ASSOCIATED WITH GIVEN ICE THICKNESSES AND HEAT LOSSES FOR SNOW COVER = 7.5 cm.

Heat Loss in kg. cal. (Q_T)																				
0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	20	25	30		
0	121	212	363	544	766	1029	1331	1674	2059	2484	2948	3451	3992	4571	5188	5843	6536	7268	8039	
5	121	212	363	544	766	1029	1331	1674	2059	2484	2948	3451	3992	4571	5188	5843	6536	7268	8039	
10	121	212	363	544	766	1029	1331	1674	2059	2484	2948	3451	3992	4571	5188	5843	6536	7268	8039	
15	121	212	363	544	766	1029	1331	1674	2059	2484	2948	3451	3992	4571	5188	5843	6536	7268	8039	
20	121	212	363	544	766	1029	1331	1674	2059	2484	2948	3451	3992	4571	5188	5843	6536	7268	8039	
25	121	212	363	544	766	1029	1331	1674	2059	2484	2948	3451	3992	4571	5188	5843	6536	7268	8039	
30	121	212	363	544	766	1029	1331	1674	2059	2484	2948	3451	3992	4571	5188	5843	6536	7268	8039	
35	121	212	363	544	766	1029	1331	1674	2059	2484	2948	3451	3992	4571	5188	5843	6536	7268	8039	
40	121	212	363	544	766	1029	1331	1674	2059	2484	2948	3451	3992	4571	5188	5843	6536	7268	8039	
45	121	212	363	544	766	1029	1331	1674	2059	2484	2948	3451	3992	4571	5188	5843	6536	7268	8039	
50	121	212	363	544	766	1029	1331	1674	2059	2484	2948	3451	3992	4571	5188	5843	6536	7268	8039	
55	121	212	363	544	766	1029	1331	1674	2059	2484	2948	3451	3992	4571	5188	5843	6536	7268	8039	
60	121	212	363	544	766	1029	1331	1674	2059	2484	2948	3451	3992	4571	5188	5843	6536	7268	8039	
65	121	212	363	544	766	1029	1331	1674	2059	2484	2948	3451	3992	4571	5188	5843	6536	7268	8039	
70	121	212	363	544	766	1029	1331	1674	2059	2484	2948	3451	3992	4571	5188	5843	6536	7268	8039	
75	121	212	363	544	766	1029	1331	1674	2059	2484	2948	3451	3992	4571	5188	5843	6536	7268	8039	
80	121	212	363	544	766	1029	1331	1674	2059	2484	2948	3451	3992	4571	5188	5843	6536	7268	8039	
85	121	212	363	544	766	1029	1331	1674	2059	2484	2948	3451	3992	4571	5188	5843	6536	7268	8039	
90	121	212	363	544	766	1029	1331	1674	2059	2484	2948	3451	3992	4571	5188	5843	6536	7268	8039	
95	121	212	363	544	766	1029	1331	1674	2059	2484	2948	3451	3992	4571	5188	5843	6536	7268	8039	
100	121	212	363	544	766	1029	1331	1674	2059	2484	2948	3451	3992	4571	5188	5843	6536	7268	8039	
110	121	212	363	544	766	1029	1331	1674	2059	2484	2948	3451	3992	4571	5188	5843	6536	7268	8039	
120	121	212	363	544	766	1029	1331	1674	2059	2484	2948	3451	3992	4571	5188	5843	6536	7268	8039	
130	121	212	363	544	766	1029	1331	1674	2059	2484	2948	3451	3992	4571	5188	5843	6536	7268	8039	
140	121	212	363	544	766	1029	1331	1674	2059	2484	2948	3451	3992	4571	5188	5843	6536	7268	8039	
150	121	212	363	544	766	1029	1331	1674	2059	2484	2948	3451	3992	4571	5188	5843	6536	7268	8039	
160	121	212	363	544	766	1029	1331	1674	2059	2484	2948	3451	3992	4571	5188	5843	6536	7268	8039	
170	121	212	363	544	766	1029	1331	1674	2059	2484	2948	3451	3992	4571	5188	5843	6536	7268	8039	
180	121	212	363	544	766	1029	1331	1674	2059	2484	2948	3451	3992	4571	5188	5843	6536	7268	8039	
190	121	212	363	544	766	1029	1331	1674	2059	2484	2948	3451	3992	4571	5188	5843	6536	7268	8039	
200	121	212	363	544	766	1029	1331	1674	2059	2484	2948	3451	3992	4571	5188	5843	6536	7268	8039	
210	121	212	363	544	766	1029	1331	1674	2059	2484	2948	3451	3992	4571	5188	5843	6536	7268	8039	
220	121	212	363	544	766	1029	1331	1674	2059	2484	2948	3451	3992	4571	5188	5843	6536	7268	8039	
230	121	212	363	544	766	1029	1331	1674	2059	2484	2948	3451	3992	4571	5188	5843	6536	7268	8039	
240	121	212	363	544	766	1029	1331	1674	2059	2484	2948	3451	3992	4571	5188	5843	6536	7268	8039	
250	121	212	363	544	766	1029	1331	1674	2059	2484	2948	3451	3992	4571	5188	5843	6536	7268	8039	
260	121	212	363	544	766	1029	1331	1674	2059	2484	2948	3451	3992	4571	5188	5843	6536	7268	8039	
270	121	212	363	544	766	1029	1331	1674	2059	2484	2948	3451	3992	4571	5188	5843	6536	7268	8039	
280	121	212	363	544	766	1029	1331	1674	2059	2484	2948	3451	3992	4571	5188	5843	6536	7268	8039	
290	121	212	363	544	766	1029	1331	1674	2059	2484	2948	3451	3992	4571	5188	5843	6536	7268	8039	
300	121	212	363	544	766	1029	1331	1674	2059	2484	2948	3451	3992	4571	5188	5843	6536	7268	8039	

TABLE 7

DEGREE-DAYS OF FROST ASSOCIATED WITH GIVEN ICE THICKNESSES AND HEAT LOSSES FOR SNOW COVER = 10 cm.

Ice thickness in cm. (l_i)	Heat Loss in kg. cal. (Q_i)														
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14
0	0	161	323	484	645	806	967	1129	1290	1452	1613	1774	1936	2097	2258
5	60	223	396	564	731	899	1067	1234	1402	1570	1738	1905	2073	2241	2408
10	125	376	646	914	1182	1450	1717	1984	2251	2519	2786	3053	3320	3587	3854
15	195	456	756	1056	1356	1656	1956	2256	2556	2856	3156	3456	3756	4056	4356
20	265	566	866	1166	1466	1766	2066	2366	2666	2966	3266	3566	3866	4166	4466
25	335	635	935	1235	1535	1835	2135	2435	2735	3035	3335	3635	3935	4235	4535
30	405	705	1005	1305	1605	1905	2205	2505	2805	3105	3405	3705	4005	4305	4605
35	475	775	1075	1375	1675	1975	2275	2575	2875	3175	3475	3775	4075	4375	4675
40	545	845	1145	1445	1745	2045	2345	2645	2945	3245	3545	3845	4145	4445	4745
45	615	915	1215	1515	1815	2115	2415	2715	3015	3315	3615	3915	4215	4515	4815
50	685	985	1285	1585	1885	2185	2485	2785	3085	3385	3685	3985	4285	4585	4885
 

TABLE 8

DEGREE-DAYS OF FROST ASSOCIATED WITH GIVEN ICE THICKNESSES AND HEAT LOSSES FOR SNOW COVER = 15 cm.

Ice Thickness in cm. (1)	Heat Loss in kg. cal. (2)														
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14
0	0	212	474	726	968	1210	1452	1694	1936	2177	2419	2661	2903	3145	3387
5	99	338	586	834	1083	1331	1580	1828	2076	2325	2573	2821	3069	3317	3565
10	183	438	693	947	1202	1458	1713	1967	2222	2476	2731	2986	3241	3496	3750
15	252	543	805	1085	1366	1648	1931	2211	2492	2772	3051	3330	3609	3888	4167
20	305	653	921	1198	1476	1754	2031	2309	2587	2864	3141	3418	3695	3972	4249
25	353	747	1042	1345	1642	1939	2236	2532	2828	3124	3419	3714	4009	4304	4599
30	406	806	1147	1487	1822	2158	2494	2829	3164	3500	3835	4170	4505	4840	5175
35	463	910	1297	1692	2078	2465	2851	3237	3623	4009	4395	4781	5167	5552	5937
40	525	1018	1452	1883	2312	2740	3168	3596	4023	4450	4877	5304	5731	6158	6585
45	591	1121	1597	2068	2538	3007	3476	3944	4412	4880	5348	5816	6283	6750	7217
 

TABLE 9

DROPLETS-DAYS OF FROST ASSOCIATED WITH CROWN AND TWIG DISEASES AND LEAF LOSSES PER SNOW COVER = 20 cm.

Ice Thickness in cm. (I_2)	C	1	2	3	4	5	6	Vegetation Loss kg. cal. (I_1)										20	25	30
								7	8	9	10	11	12	13	14	15	16			
10	118	333	423	460	1250	1613	1836	2253	2381	2993	3226	3548	3871	4191	4516	4839	5162	4652	3864	2677
15	202	577	775	1005	1434	1763	2092	2422	2750	3079	3408	3738	4066	4395	4724	5054	5383	4680	3801	2502
20	502	950	1193	1245	1583	1919	2254	2580	2925	3260	3596	3931	4267	4602	4938	5273	5608	4950	3929	10004
30	780	1211	1502	1564	1985	2243	2591	2940	3288	3636	3984	4333	4681	5029	5378	5726	6073	5357	4209	
40	1077	1451	1825	1929	2356	2596	2947	3308	3669	4030	4391	4751	5111	5471	5831	6191	6551	5787	4547	
50	1393	1780	2156	2252	2680	2927	3321	3714	4107	4500	4893	5286	5679	6072	6465	6858	7251	6451	5147	
60	1717	2136	2526	2626	3056	3326	3729	4128	4527	4926	5325	5724	6123	6522	6921	7320	7719	6880	5527	
70	2079	2522	2904	3006	3436	3736	4139	4542	4945	5348	5751	6154	6557	6960	7363	7766	8169	7290	5907	
80	2510	2966	3391	3497	3926	4236	4639	5042	5445	5848	6251	6654	7057	7460	7863	8266	8669	7750	6327	
90	3043	3529	3951	4059	4488	4808	5209	5612	6015	6418	6821	7224	7627	8030	8433	8836	9239	8270	6807	
100	3675	4189	4603	4713	5142	5462	5881	6299	6718	7137	7556	7975	8394	8813	9232	9651	10070	9051	7547	
110	4410	4956	5393	5504	5932	6252	6671	7089	7508	7927	8346	8765	9184	9603	10022	10441	10860	9791	8237	
120	5263	5829	6266	6377	6804	7124	7543	7962	8381	8800	9219	9638	10057	10476	10895	11314	11733	10604	9000	
130	6243	6829	7266	7377	7804	8124	8543	8962	9381	9800	10219	10638	11057	11476	11895	12314	12733	11544	9880	
140	7359	7956	8393	8504	8932	9252	9671	10090	10509	10928	11347	11766	12185	12604	13023	13442	13861	12612	10908	
150	8612	9229	9666	9777	10204	10524	10943	11362	11781	12200	12619	13038	13457	13876	14295	14714	15133	13824	12080	
 	

TABLE 10

DEGREE-DAYS OF FROST ASSOCIATED WITH GIVEN ICE THICKNESSES AND HEAT LOSSES FOR SNOW COVER = 30 cm.

		Heat Loss kg. cal. (Q_T)																		
		0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	20		
Ice Thickness in in. (L_1)	0	0	164	368	1152	1936	2412	2903	3487	3871	4355	4839	5323	5806	6290	6774	7258	9677		
	5	176	667	1157	1644	2138	2628	3118	3609	4099	4589	5080	5570	6060	6550	7041	7531	9982		
	10	353	854	1351	1848	2344	2841	3338	3835	4341	4828	5325	5822	6318	6815	7312	7808	10292		
	20	734	1243	1753	2262	2772	3282	3791	4301	4810	5320	5830	6339	6849	7358	7868	8377	9565		
	30	1128	1651	2173	2696	3218	3741	4263	4786	5308	5830	6353	6875	7398	7920	8442	8965	9571		
	40	1542	2077	2612	3147	3683	4218	4753	5289	5824	6359	6894	7430	7965	8500	9036	9571	10195		
	50	1973	2522	3070	3618	4166	4714	5262	5810	6358	6906	7455	8003	8551	9099	9647	10195	10819		
	60	2424	2981	3545	4109	4673	5237	5801	6365	6929	7493	8057	8621	9185	9749	10313	10877	11541		
	70	2892	3466	4053	4641	5228	5816	6403	6990	7578	8165	8752	9340	9927	10515	11103	11691	12379		
	80	3372	3966	4573	5180	5786	6393	6999	7606	8213	8820	9427	10034	10641	11248	11855	12462	13169		
	90	3885	4485	5091	5696	6301	6906	7512	8118	8724	9330	9936	10542	11148	11754	12360	12966	13672		
	100	4409	5022	5634	6247	6859	7472	8085	8698	9311	9924	10537	11150	11763	12376	12989	13602	14215		
	110	4952	5577	6203	6828	7453	8078	8703	9328	9953	10578	11203	11828	12453	13078	13703	14328	14953		
	120	5513	6151	6789	7428	8066	8704	9342	9980	10618	11256	11894	12532	13170	13808	14446	15084	15722		
	130	6093	6744	7395	8046	8697	9348	9999	10650	11301	11952	12603	13254	13905	14556	15207	15858	16509		
	140	6691	7355	8019	8683	9347	10011	10674	11338	12001	12664	13327	13990	14653	15316	15979	16642	17305		
	150	7308	7985	8661	9338	10015	10692	11369	12046	12723	13400	14077	14754	15431	16108	16785	17462	18139		
	160	7943	8633	9322	10001	10680	11359	12038	12717	13396	14075	14754	15433	16112	16791	17470	18149	18828		
	170	8597	9300	10002																
	180	9270	9985																	
	190	9960	10688																	
	200	10670																		

TABLE 11
DEGREE-DAYS OF FROST ASSOCIATED WITH GIVEN ICE THICKNESSES AND HEAT LOSSES FOR SNOW COVER = 10 cm.

Ice Thickness in cm. (L_i)	Heat Loss kg. cal. $\cdot$ g (Q_i)															
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
0		615	1290	1936	2591	3226	3871	4516	5161	5806	6452	7097	7742	8387	9032	9677
5	235	896	1538	2189	2841	3492	4144	4796	5447	6099	6750	7402	8054	8705	9357	10008
10	474	1132	1790	2448	3106	3764	4422	5080	5738	6396	7054	7712	8370	9028	9686	
20	966	1637	2308	2979	3649	4320	4991	5662	6333	7004	7675	8346	9016	9687	10358	
30	1477	2161	2844	3528	4212	4895	5579	6263	6947	7630	8314	8998	9681	10365		
40	2006	2703	3399	4096	4792	5489	6186	6882	7579	8275	8972	9669	10365			
50	2554	3264	3973	4682	5392	6101	6811	7520	8229	8939	9648	10358				
60	3120	3843	4565	5287	6009	6732	7454	8176	8899	9621	10343					
70	3705	4446	5185	5910	6646	7381	8116	8851	9586	10321						
80	4308	5056	5804	6552	7300	8048	8796	9544	10292							
90	4930	5691	6452	7213	7974	8734	9495	10256								
100	5571	6344	7118	7892	8665	9439	10213									
110	6230	7015	7803	8589	9376	10162										
120	6907	7706	8506	9305	10104											
130	7603	8415	9227	10040												
140	8317	9142	9967													
150	9050	9888	10726													
160	9802	10652														
170	10571															

TABLE 12
DEGREE-DAYS OF FROST ASSOCIATED WITH GIVEN ICE THICKNESSES AND HEAT LOSSES FOR SNOW COVER = 50 cm.

Ice thickness in in. (I_1)	Heat Loss kg. cal. (Q_T)												
	0	1	2	3	4	5	6	7	8	9	10	11	12
0	806	1612	2419	3226	4032	4839	5645	6452	7258	8064	8871	9677	10484
5	293	1105	1918	2731	3544	4357	5170	5983	6796	7608	8421	9234	10047
10	590	1109	2228	3048	3867	4686	5506	6325	7144	7964	8783	9602	
20	1198	2030	2837	3695	4527	5359	6191	7023	7856	8688	9520	10352	
30	1825	2670	3515	4360	5205	6050	6895	7740	8585	9430	10275		
40	2471	3328	4186	5044	5902	6760	7618	8476	9334	10191			
50	3135	4005	4876	5747	6618	7488	8359	9230	10100				
60	3817	4701	5584	6468	7351	8235	9118	10002					
70	4513	5414	6311	7207	8104	9000	9896						
80	5238	6147	7056	7965	8875	9784	10693						
90	5975	6898	7820	8742	9664	10586							
100	6732	7667	8602	9537	10472								
110	7507	8455	9403	10350									
120	8300	9261	10222										
130	9112	10086											
140	9943												
150	10792												

TABLE 13

DEGREE-DAYS OF FROST FOR DIFFERING HEAT LOSS AND ICE THICKNESS $\left(\sum_{t=1}^n \frac{1}{2k_i}\right)$

Ice Thickness (in.)	Heat Loss (kg. Cal.)														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	110	141	283	424	566	707	848	990	1131	1272	1414	1555	1697	1838	1979
2	120	154	308	463	617	771	925	1080	1234	1388	1542	1697	1851	2005	2159
3	130	167	334	501	668	835	1003	1170	1337	1504	1671	1838	2005	2172	2339
4	140	180	360	540	720	900	1080	1260	1440	1620	1799	2159	2339	2519	2699
5	150	193	386	578	771	964	1157	1350	1542	1735	1928	2121	2314	2506	2699
6	160	206	411	617	823	1029	1234	1440	1645	1851	2057	2262	2468	2674	2879
7	170	219	437	656	874	1093	1311	1530	1748	1967	2185	2404	2622	2841	3059
8	180	231	463	694	925	1157	1388	1620	1851	2082	2314	2545	2776	3008	3239
9	190	244	488	733	977	1221	1465	1710	1954	2198	2442	2686	2931	3175	3419
10	200	257	514	771	1028	1285	1542	1799	2057	2314	2571	2828	3085	3342	3599
11	210	270	540	810	1080	1350	1620	1889	2159	2429	2699	2969	3239	3509	3779
12	220	283	566	848	1131	1414	1697	1979	2262	2545	2828	3111	3393	3676	3959
13	230	296	591	887	1183	1478	1774	2059	2345	2631	2916	3202	3487	3772	4057
14	240	308	617	925	1234	1542	1851	2159	2448	2736	3024	3312	3600	3888	4176
15	250	321	643	964	1285	1607	1928	2219	2510	2800	3090	3380	3670	3960	4250
16	260	334	668	1003	1347	1671	2005	2309	2604	2900	3196	3492	3788	4084	4380
17	270	347	694	1041	1388	1735	2082	2429	2726	3024	3321	3618	3915	4212	4509
18	280	360	720	1080	1440	1799	2159	2519	2819	3119	3419	3719	4019	4319	4619
19	290	373	746	1118	1491	1864	2237	2609	2982	3355	3728	4100	4473	4846	5219
20	300	386	771	1157	1542	1928	2314	2699	3085	3470	3855	4242	4627	5013	5398

BIBLIOGRAPHY

BROWN, A. L. An analytical method of ice potential calculation. U. S. Hydrographic Office, Technical Report 5. Washington. September 1954. 13p.

DEFANT, A. Konvektion und Eisbereitschaft in polaren Schelfmeeren (Convection and ice formation in polar shelf seas), Geografiska Annaler, Arg. 31, pp. 25-35, 1949.

JACOBS, W. C. On the energy exchange between sea and atmosphere, Journal of Marine Research, Vol. 5, pp. 37-66, 1942.

ZUBOV, N. N. Morskie vody i l'dy (Marine water and ice). Moskva: Gidrometeorologicheskoe Izdatel'stvo, 1938. 451p.

<p>U. S. Navy Hydrographic Office A PRACTICAL METHOD OF PREDICTING SEA ICE FORMATION AND GROWTH, by Owen S. Lee and Lloyd S. Simpson, September 1954. 9 p., 4 charts, 13 tables. (H. O. TR-4).</p> <p>A technique for predicting ice formation and growth is presented. Using the ice potential calculations and heat budget equations of various authors, new formulas are derived for computing ice growth in terms of known or predicted oceanographic and meteorological data. The technique is applied to forecasting ice conditions in Baffin Bay-Davis Strait area for 1952-53.</p> <p>i. title: A Practical Method of Predicting Sea Ice Formation and Growth</p> <p>ii. authors: Owen S. Lee and Lloyd S. Simpson</p> <p>iii. H. O. TR-4</p>	<p>U. S. Navy Hydrographic Office A PRACTICAL METHOD OF PREDICTING SEA ICE FORMATION AND GROWTH, by Owen S. Lee and Lloyd S. Simpson, September 1954. 9 p., 4 charts, 13 tables. (H. O. TR-4).</p> <p>A technique for predicting ice formation and growth is presented. Using the ice potential calculations and heat budget equations of various authors, new formulas are derived for computing ice growth in terms of known or predicted oceanographic and meteorological data. The technique is applied to forecasting ice conditions in Baffin Bay-Davis Strait area for 1952-53.</p> <p>i. title: A Practical Method of Predicting Sea Ice Formation and Growth</p> <p>ii. authors: Owen S. Lee and Lloyd S. Simpson</p> <p>iii. H. O. TR-4</p>
<p>U. S. Navy Hydrographic Office A PRACTICAL METHOD OF PREDICTING SEA ICE FORMATION AND GROWTH, by Owen S. Lee and Lloyd S. Simpson, September 1954. 9 p., 4 charts, 13 tables. (H. O. TR-4).</p> <p>A technique for predicting ice formation and growth is presented. Using the ice potential calculations and heat budget equations of various authors, new formulas are derived for computing ice growth in terms of known or predicted oceanographic and meteorological data. The technique is applied to forecasting ice conditions in Baffin Bay-Davis Strait area for 1952-53.</p> <p>i. title: A Practical Method of Predicting Sea Ice Formation and Growth</p> <p>ii. authors: Owen S. Lee and Lloyd S. Simpson</p> <p>iii. H. O. TR-4</p>	<p>U. S. Navy Hydrographic Office A PRACTICAL METHOD OF PREDICTING SEA ICE FORMATION AND GROWTH, by Owen S. Lee and Lloyd S. Simpson, September 1954. 9 p., 4 charts, 13 tables. (H. O. TR-4).</p> <p>A technique for predicting ice formation and growth is presented. Using the ice potential calculations and heat budget equations of various authors, new formulas are derived for computing ice growth in terms of known or predicted oceanographic and meteorological data. The technique is applied to forecasting ice conditions in Baffin Bay-Davis Strait area for 1952-53.</p> <p>i. title: A Practical Method of Predicting Sea Ice Formation and Growth</p> <p>ii. authors: Owen S. Lee and Lloyd S. Simpson</p> <p>iii. H. O. TR-4</p>

<p>U. S. Navy Hydrographic Office. A PRACTICAL METHOD OF PREDICTING SEA ICE FORMATION AND GROWTH, by Owen S. Lee and Lloyd S. Simpson, September 1954. 9 p., 4 charts, 13 tables. (H. O. TR-4).</p> <p>A technique for predicting ice formation and growth is presented. Using the ice potential calculations and heat budget equations of various authors, new formulas are derived for computing ice growth in terms of known or predicted oceanographic and meteorological data. The technique is applied to forecasting ice conditions in Baffin Bay-Davis Strait area for 1952-53.</p>	<ol style="list-style-type: none"> 1. Sea Ice Forecasting 2. Oceanography 3. Meteorology 4. Sea Ice Potential 5. Heat 6. Convection 7. Baffin Bay-Sea Ice <p>i. title: A Practical Method of Predicting Sea Ice Formation and Growth</p> <p>ii. authors: Owen S. Lee and Lloyd S. Simpson</p> <p>iii. H. O. TR-4</p>
<p>U. S. Navy Hydrographic Office. A PRACTICAL METHOD OF PREDICTING SEA ICE FORMATION AND GROWTH, by Owen S. Lee and Lloyd S. Simpson, September 1954. 9 p., 4 charts, 13 tables. (H. O. TR-4).</p> <p>A technique for predicting ice formation and growth is presented. Using the ice potential calculations and heat budget equations of various authors, new formulas are derived for computing ice growth in terms of known or predicted oceanographic and meteorological data. The technique is applied to forecasting ice conditions in Baffin Bay-Davis Strait area for 1952-53.</p>	<ol style="list-style-type: none"> 1. Sea Ice Forecasting 2. Oceanography 3. Meteorology 4. Sea Ice Potential 5. Heat 6. Convection 7. Baffin Bay-Sea Ice <p>i. title: A Practical Method of Predicting Sea Ice Formation and Growth</p> <p>ii. authors: Owen S. Lee and Lloyd S. Simpson</p> <p>iii. H. O. TR-4</p>
<p>U. S. Navy Hydrographic Office. A PRACTICAL METHOD OF PREDICTING SEA ICE FORMATION AND GROWTH, by Owen S. Lee and Lloyd S. Simpson, September 1954. 9 p., 4 charts, 13 tables. (H. O. TR-4).</p> <p>A technique for predicting ice formation and growth is presented. Using the ice potential calculations and heat budget equations of various authors, new formulas are derived for computing ice growth in terms of known or predicted oceanographic and meteorological data. The technique is applied to forecasting ice conditions in Baffin Bay-Davis Strait area for 1952-53.</p>	<ol style="list-style-type: none"> 1. Sea Ice Forecasting 2. Oceanography 3. Meteorology 4. Sea Ice Potential 5. Heat 6. Convection 7. Baffin Bay-Sea Ice <p>i. title: A Practical Method of Predicting Sea Ice Formation and Growth</p> <p>ii. authors: Owen S. Lee and Lloyd S. Simpson</p> <p>iii. H. O. TR-4</p>
<p>U. S. Navy Hydrographic Office. A PRACTICAL METHOD OF PREDICTING SEA ICE FORMATION AND GROWTH, by Owen S. Lee and Lloyd S. Simpson, September 1954. 9 p., 4 charts, 13 tables. (H. O. TR-4).</p> <p>A technique for predicting ice formation and growth is presented. Using the ice potential calculations and heat budget equations of various authors, new formulas are derived for computing ice growth in terms of known or predicted oceanographic and meteorological data. The technique is applied to forecasting ice conditions in Baffin Bay-Davis Strait area for 1952-53.</p>	<ol style="list-style-type: none"> 1. Sea Ice Forecasting 2. Oceanography 3. Meteorology 4. Sea Ice Potential 5. Heat 6. Convection 7. Baffin Bay-Sea Ice <p>i. title: A Practical Method of Predicting Sea Ice Formation and Growth</p> <p>ii. authors: Owen S. Lee and Lloyd S. Simpson</p> <p>iii. H. O. TR-4</p>

<p>U. S. Navy Hydrographic Office A PRACTICAL METHOD OF PREDICTING SEA ICE FORMATION AND GROWTH, by Owen S. Lee and Lloyd S. Simpson, September 1954. 9 p., 4 charts, 13 tables. (H. O. TR-4).</p> <p>A technique for predicting ice formation and growth is presented. Using the ice potential calculations and heat budget equations of various authors, new formulas are derived for computing ice growth in terms of known or predicted oceanographic and meteorological data. The technique is applied to forecasting ice conditions in Baffin Bay-Davis Strait area for 1952-53.</p>	<ol style="list-style-type: none">1. Sea Ice Forecasting2. Oceanography3. Meteorology4. Sea Ice Potential5. Heat6. Convection7. Baffin Bay-Sea Ice <p>i. title: A Practical Method of Predicting Sea Ice Formation and Growth</p> <p>ii. authors: Owen S. Lee and Lloyd S. Simpson</p> <p>iii. H. O. TR-4</p>
<p>U. S. Navy Hydrographic Office A PRACTICAL METHOD OF PREDICTING SEA ICE FORMATION AND GROWTH, by Owen S. Lee and Lloyd S. Simpson, September 1954. 9 p., 4 charts, 13 tables. (H. O. TR-4).</p> <p>A technique for predicting ice formation and growth is presented. Using the ice potential calculations and heat budget equations of various authors, new formulas are derived for computing ice growth in terms of known or predicted oceanographic and meteorological data. The technique is applied to forecasting ice conditions in Baffin Bay-Davis Strait area for 1952-53.</p>	<ol style="list-style-type: none">1. Sea Ice Forecasting2. Oceanography3. Meteorology4. Sea Ice Potential5. Heat6. Convection7. Baffin Bay-Sea Ice <p>i. title: A Practical Method of Predicting Sea Ice Formation and Growth</p> <p>ii. authors: Owen S. Lee and Lloyd S. Simpson</p> <p>iii. H. O. TR-4</p>
<p>U. S. Navy Hydrographic Office A PRACTICAL METHOD OF PREDICTING SEA ICE FORMATION AND GROWTH, by Owen S. Lee and Lloyd S. Simpson, September 1954. 9 p., 4 charts, 13 tables. (H. O. TR-4).</p> <p>A technique for predicting ice formation and growth is presented. Using the ice potential calculations and heat budget equations of various authors, new formulas are derived for computing ice growth in terms of known or predicted oceanographic and meteorological data. The technique is applied to forecasting ice conditions in Baffin Bay-Davis Strait area for 1952-53.</p>	<ol style="list-style-type: none">1. Sea Ice Forecasting2. Oceanography3. Meteorology4. Sea Ice Potential5. Heat6. Convection7. Baffin Bay-Sea Ice <p>i. title: A Practical Method of Predicting Sea Ice Formation and Growth</p> <p>ii. authors: Owen S. Lee and Lloyd S. Simpson</p> <p>iii. H. O. TR-4</p>
<p>U. S. Navy Hydrographic Office A PRACTICAL METHOD OF PREDICTING SEA ICE FORMATION AND GROWTH, by Owen S. Lee and Lloyd S. Simpson, September 1954. 9 p., 4 charts, 13 tables. (H. O. TR-4).</p> <p>A technique for predicting ice formation and growth is presented. Using the ice potential calculations and heat budget equations of various authors, new formulas are derived for computing ice growth in terms of known or predicted oceanographic and meteorological data. The technique is applied to forecasting ice conditions in Baffin Bay-Davis Strait area for 1952-53.</p>	<ol style="list-style-type: none">1. Sea Ice Forecasting2. Oceanography3. Meteorology4. Sea Ice Potential5. Heat6. Convection7. Baffin Bay-Sea Ice <p>i. title: A Practical Method of Predicting Sea Ice Formation and Growth</p> <p>ii. authors: Owen S. Lee and Lloyd S. Simpson</p> <p>iii. H. O. TR-4</p>