ANALYSIS OF THE RECORDED DATA ON THE DRIFT OF ICEBERGS

PRITAM SINGH CHEEMA

ANALYSIS OF THE RECORDED DATA
ON THE DRIFT OF ICEBERGS

by

© Pritam Singh Cheema , M.A.

A Thesis submitted in Partial Fulfillment
of the Requirement for the Degree of
Master of Engineering

Faculty of Engineering and Applied Science
Memorial University of Newfoundland

June 1976

St. John's Newfoundland

TABLE OF CONTENTS

APPENDIX		PAGE

LIST OF TABLES

LIST OF FIGURES

PREFACE

With the development of offshore explorations and onshore refining facilities in the eastern coast of Canada, it seemed obvious a pipeline from the Grand Banks to the refining facilities would be a logical alternative for transportation of crude oil. This region is frequented by hundreds of icebergs annually which present a serious threat to the drilling operations and the pipeline. It was at this juncture that Prof. H. N. Ahuja made me aware of this problem in January 1973.

It was therefore planned to research the method for selection of the safest pipeline route for transportation of oil and gas from the Grand Banks to the onshore refining facilities. The approach was to predict the iceberg hazard for the alternative pipeline routes by determining the probability of iceberg grounding along the routes. The objective was to select the pipeline route along which the probability of iceberg grounding was minimum. It was intended to use the International Ice Patrol iceberg data for the period 1950 - 56 for this analysis. Considerable time was spent in obtaining information on tracked icebergs from the International Ice Patrol reports. It was observed from these reports that no information was available on the iceberg drafts and therefore the data was not suitable for this analysis. Therefore it became necessary to change the direction of research. It was decided to analyse the data collected by the International Ice Patrol and to suggest the possibility of improvements in its system for collecting data on drifting icebergs.

Consequently the data collected by the International Ice Patrol for the period 1950 - 56 was analysed and conclusions were derived from this analysis. A seminar based on the findings of this analysis on data collection by the International Ice Patrol was given in April, 1976 at Memorial University of Newfoundland, St. John's.

The thesis is made up of four parts, namely an introduction to the problem area, drifts of icebergs into the Atlantic Ocean, analysis of the drifts of icebergs, and conclusions.

Before presenting the research in the final form it was decided to contact International Ice Patrol to obtain information on present method of data collection on drifting icebergs. A reply was received in May, 1976 that described the improvements being implemented about the timing of sighting of an iceberg and the accuracy of the positional system by the International Ice Patrol. It was encouraging to find that the modifications to data collection implemented by the International Ice Patrol are in line with some of the conclusions of this study. Further discussion was held with LTJG Neill and LTJG Knutson, Senior Ice Observers with the International Ice Patrol subsequent to the above letter to ascertain the time when the said modifications were introduced by the

International Ice Patrol. According to their statement the changes were introduced not earlier than March, 1976.

Although some of the conclusions obtained in this study are similar to the modifications already implemented there is a likelihood that the decision to implement the modifications may have been prompted by dissimilar analysis. It is therefore considered that apart from the conclusions of this study, the analysis from which these conclusions are derived should be of significant interest. Other conclusions that pertain to future research areas are included.

I express my sincere thanks and gratitude to Professor H. N. Ahuja who introduced me to this area and who provided many hours of instruction and guidance. I would like to express my gratitude to Dean R. T. Dempster for his time and guidance about the drifts of icebergs. I am also indebted to my wife and family who tolerated many hours of absence from home and for their patience and encouragement.

P. S. Cheema

ABSTRACT

The basic problem of sightings of icebergs off Newfoundland and Labrador coasts has been of special interest because of the sinking of the Titanic and hazards icebergs present to the North Atlantic Shipping. Drifting icebergs pose a serious problem to those who search for hydrocarbons on Canada's eastern continental shelf. In view of the extension of the hazard to oil exploration activities, it is important to investigate the possibility of improvement in the present techniques of collecting data on the drifts of icebergs by the International Ice Patrol.

A kinematic model has been developed to analyse the drifts of icebergs. In this model, the berg velocity is expressed as a function of the resultant surface current velocity averaged over the draft of an iceberg. An analysis of the data on the sightings of icebergs in successive locations published by the International Ice Patrol for the period 1950 - 56 has been made. Suggested improvements in the reports of sightings of icebergs based on the analysis are:

1. First order approximation of the draft.
2. Precise locations of icebergs in degrees, minutes and seconds.
3. Timings of successive sightings of icebergs.

4. Estimation of errors in locating icebergs and positioning the observation vessels.
5. Detailed measurements of ocean currents.
6. Data for tidal currents.

With these improvements in data collection and more rigorous analysis, a closer correlation between the computed and observed drifts of icebergs can be obtained. The knowledge gained can be useful in mitigating the severity of their hazards.

CHAPTER I

INTRODUCTION

Canada's eastern continental shelf has been the focal point of an extensive search for hydrocarbons in recent years. International petroleum companies have spent millions of dollars in explorations during this time. Off the Newfoundland and Labrador coasts, 42 wildcat wells have been drilled. One of the major hostile elements to the oil drilling rig operators in this region is the threat of drifting icebergs.

State-of-the-Art

The general drift pattern of icebergs under the influence of ocean currents and wind-generated currents from Davis Strait to the tail of the Grand Banks has been provided by Smith (19). Post (13) has described that the drifts of icebergs in the North Atlantic are mainly due to the relative strengths of the Labrador Current and the Gulf Stream. Schell (18) estimated the drifts of icebergs due to ocean currents and wind-generated currents and indicated that wind has a significant effect on the drift of an iceberg if the wind continues from one direction over a long period. Schell (18) also obtained a linear regression equation to predict the berg count south of latitude 48° N. Kollymeyer et al (9) observed the drift of an iceberg under the combined influence of ocean currents and wind-generated currents. Murray (11) discussed the factors that effect the drifts of icebergs and suggested a statistical approach as the best solution to determine the drifts of icebergs. Cochkanoff et al (4) developed a mathematical dynamic model to determine the motion of icebergs in which inertial force, wind force, Coriolos force, and damping force were considered. Bruneau and Dempster (2) suggested modifications to the structures to be used in the berg infested North Atlantic and observed that the motion of an iceberg is controlled by the wind action on the portion above water and by the current action on the submerged portion. Dempster (6) tracked more than one hundred icebergs in the North Atlantic and has observed that icebergs respond mainly to the ocean currents. Sodhi and Dempster (20) derived dynamic equations of motion for the drift of an iceberg by assuming that the water drag force is proportional to the square of relative velocity of water with respect to the iceberg.

Research Methodology

Among several techniques, there are two significant methods to analyse the drifts of icebergs. First is to use sophisticated instruments and highly trained personnel to collect field data on the following:

1. Ocean Currents
2. Tidal currents
3. Wind velocities
4. Sizes, shapes, and drafts of icebergs
5. Hourly drifts of icebergs

These data can then be analysed. It is no doubt a reliable research methodology but data collection costs are prohibitive. To be of statistical significance, extensive data have to be collected over long periods, the cost of which can be phenomenal.

An alternative research methodology which can be figuratively described by "incrementalism" is to analyse less sophisticated but already available data on icebergs and derive conclusions from the data to upgrade future reporting. The data so collected can be analysed subsequently. Improved data collection and increasingly rigorous analysis can alternate in repeated cycles. The strength of the latter methodology lies in the fact that as the extensive data become available for analysis, statistical significant conclusions can be derived in each iteration. The sophistication can be introduced gradually to take advantage of the development in technology such as development of remote sensor technique to determine iceberg profile and to estimate the size of the submerged portion of an iceberg. This methodology has been adopted in the present research.

Collection of Iceberg Drift Data

The International Ice Patrol has been established since 1913. Its major missions have been to disseminate information on ice and icebergs, maintain cognizance of ice and iceberg conditions and to direct preseason and postseason oceanographic cruises and flights as necessary in the Northwest Atlantic. The sightings of icebergs tracked in the Grand Banks and other regions have been published by the International Ice Patrol for the last several years.

Factors that Effect the Drift of Icebergs

The system of ocean currents in Baffin Bay, Davis Strait, and Labrador Sea is the major factor for the transportation of icebergs from Baffin Bay to the Grand Banks as shown in Figure 1. The influence of wind is small in comparison to the effect of the ocean currents. However, when high winds continue from a given direction over a long period, the effect of the winds is more marked. Tidal currents have also been reported (17) to have influence on the drifts of icebergs.

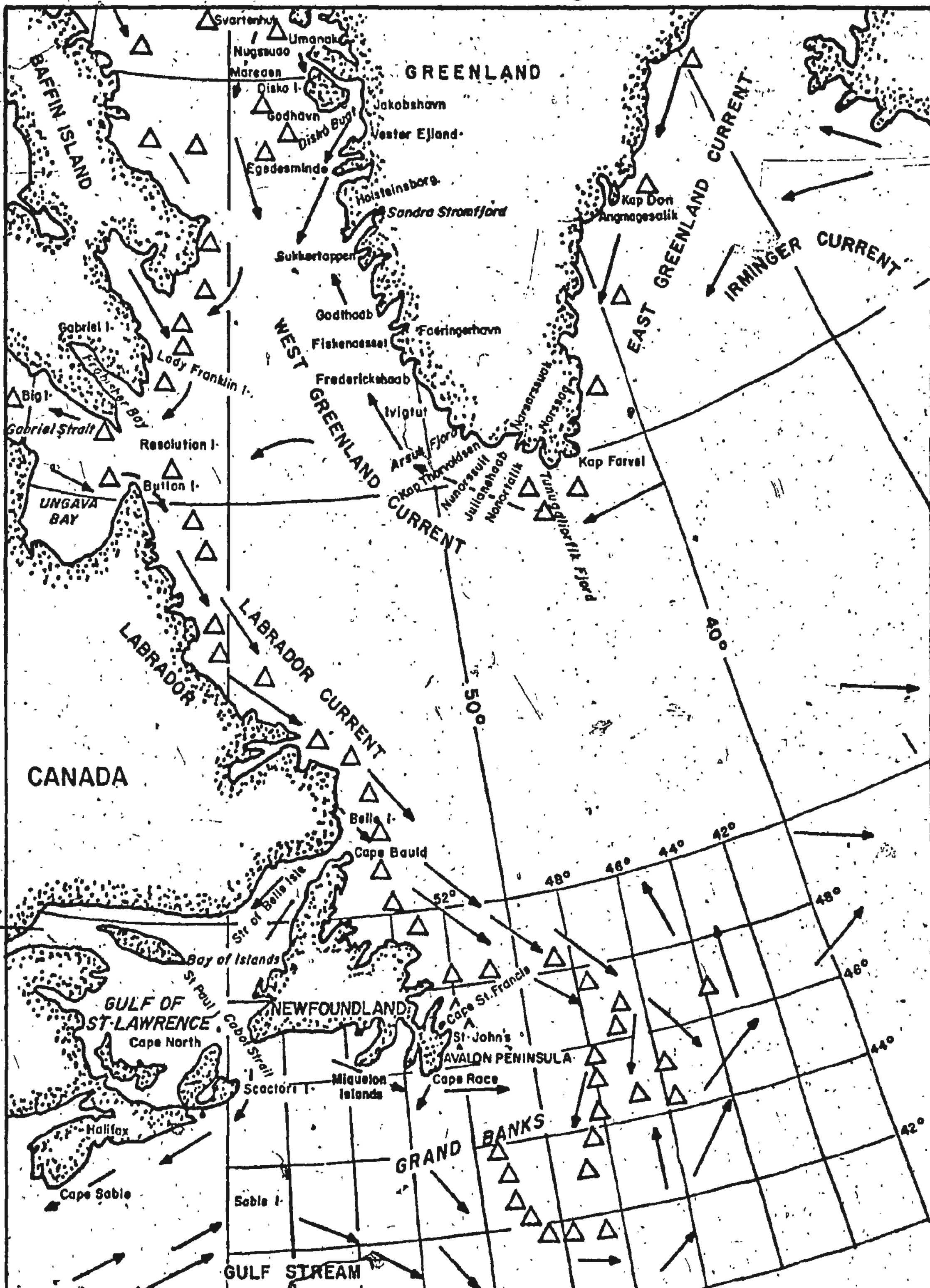


FIG. I DRIFT OF ICEBERGS FROM THEIR SOURCE INTO THE NORTH ATLANTIC OCEAN (ADAPTED FROM REFERENCE # 7)

The drift of an iceberg depends considerably on the shape and draft of its submerged portion. But the shape of the submerged portion ~~of an i~~ceberg varies markedly from one iceberg to another. The above water portion of an iceberg is no doubt measurable but it cannot be extrapolated to estimate its draft. The ratio of height to the draft varies considerably according to Robe (14) who has studied the relationship between height and draft of icebergs in the Davis Strait. Besides the above water portion of an iceberg, the other measurable characteristic is its velocity. Can this be related to draft? An iceberg responds mainly to the ocean currents (6) which act on its submerged part indicating a relationship between berg velocity and its draft. The best approach seems to make the first order approximation of the draft from the berg velocity expressed as a function of the surface current averaged over its draft. With the improvement of technology and collection of more reliable data on the drifts of icebergs successively alternated with increasingly rigorous analysis, more realistic approximation of the draft will become possible in the future.

Sources and Quality of Data

Records gathered over the Grand Banks of a large number of sightings of icebergs tracked by the International

Ice Patrol during the period 1950-56 and published by it (22) have been analysed. The main purpose of collecting the data on the drifts of icebergs has been to warn ships of the dangerous presence of these drifting icebergs. These sightings data have been reported by commercial vessels, naval vessels, and by the International Ice Patrol planes and ships using different instruments obviously varying in precision from one to the other.

Because the primary role of the International Ice Patrol has been to warn ships of the presence of icebergs in different locations, the data (22) are reported in degrees and minutes. But even a difference of 1 minute in latitude of the location of an iceberg means an error of 1 nautical mile in observed distance.

More scientific data on the drifts of icebergs have been collected by using sophisticated instruments and highly skilled personnel by research teams at Memorial University of Newfoundland. But these researches having been funded by oil companies and the Defence Research Board the collected data are classified and unfortunately are not available for analysis.

The objective of this study is not to trace the iceberg trajectory but to determine whether the data being collected are adequate in view of the need to protect the oil exploration facilities from the dangers of the drifting icebergs. Since the analysis has to reflect upon the adequacy of the

International Ice Patrol data, the data collected by it are more pertinent to this study than the information collected by other agencies.

The precise ocean currents data for different periods at different locations in the Northwest Atlantic are not available. However, the ocean currents data separately for two periods--summer and winter for intervals of nearly three degrees longitude are available for the Grand Banks in the Sailing Directions for Newfoundland (17). The ocean currents for the intermediate points have been interpolated. Environment Canada has provided the wind data for each day for the period 1950-56 for Sable Island which is the nearest weather station to the Grand Banks for which the data are available. Wind-generated currents have been computed for each day from these data.

Kinematic Model

A kinematic model has been developed to analyse the drifts of icebergs. In this model, the drifts of icebergs under the influence of ocean currents, wind-generated currents and other variables have been analysed. The berg velocity has been expressed as a factor K times the resultant surface current averaged over the draft of the berg. The resultant current has been obtained by adding vectorially the ocean current and wind-generated current.

Factor K takes into account the effect on the drifts of icebergs of tidal currents and other variables viz waves, continuous deterioration, periodic calving, and atmospheric pressure.

Objective of the Study

The primary role of the International Ice Patrol has been to warn ships of the hazardous presence of drifting icebergs in the Northwest Atlantic. But these drifting icebergs pose equally serious problems to oil exploration facilities and bottom installations that may be installed in the near future in this region. A new dimension has been added to the usefulness of the data. It is imperative to ascertain whether the quality of the data on icebergs collected by the International Ice Patrol is adequate to meet the new demands. The purpose of this research is to analyse the available data on the drifts of icebergs and to suggest improvements in the future data collection activities.

Scope of the Study

The drifts of icebergs are subject to numerous factors. Presently only qualitative effects of the atmospheric pressure differences, temperature variations, waves, continuous deterioration, and periodic calving on the drifts of icebergs are known. Also the data on the tidal currents in the Northwest Atlantic are not available. Their effects are taken into account in the factor K. Daily variations of the ocean currents are not known and hence have not been considered. Some records (22) do not indicate the daily location of an iceberg but show its location after two or more days. In this analysis the daily distance travelled by an iceberg has been interpolated.

A dynamic model takes into account the effect of all forces on the drift of an iceberg. Some of these forces are Coriolos force, water force, and wind force. All these forces, and there are more, must be determined in order to understand how much of the total drift of an iceberg can be attributed to each of the forces. The effect of some of these forces on the drift of an iceberg is not known yet and hence a dynamic model cannot be effectively applied in this research.

Analysis Criterion

A kinematic model has been developed for computer analysis of the drifts of icebergs. In each step of the analysis, comparison is made between the observed and computed drifts of icebergs. The objective in each step is to select a variable of interest. The criterion used for this selection is the minimization of the mean of the errors between the computed and observed drifts of icebergs. Those values of the variable of interest are accepted which minimize the mean of the errors in each step.

CHAPTER II

DRIFTS OF ICEBERGS INTO THE ATLANTIC OCEAN

In this chapter the drifts of icebergs from the origin to the tail of the Grand Banks, monitored by the International Ice Patrol, are investigated. Their source, drift and frequency are described. The effect of the winds, ocean currents, tidal currents and other variables on the drifts of icebergs are dealt with.

Source, Drift and Frequency of Icebergs

The principal origin of icebergs which reach the North Atlantic are glaciers of West Greenland where approximately 15,000 bergs are calved every year as reported by Dinnsmore (7). It has been observed by the International Ice Patrol that these account for 85 per cent of the average 400 icebergs which reach the Grand Banks each year from March to July. East Greenland and Northern Ellesmere Island glaciers are the other sources of iceberg origin. It is estimated that only 10 per cent of the number of icebergs reaching the North Atlantic are calved from the glaciers of East Greenland and the remaining 5 per cent from the glaciers of northern Ellesmere Islands.

Icebergs from East Greenland drift southward along the coast to Kap Farvel as shown in Figure 1. They round that cape and then drift northward under the influence of the West Greenland Current. Some of these bergs from East Greenland under the influence of wind or in the absence of the strong Irminger Current may continue drifting past Kap Farvel reaching as far as 100 - 200 nautical miles to the south or southwest. The warm West Greenland Current disintegrates those icebergs drifting northward. They seldom drift north of latitude 65° N along the West Greenland coast. A few of them drift westward where they join the mainstream of icebergs drifting southward.

Icebergs from West Greenland drift along the west coast of Greenland and around the western side of Baffin Bay. The majority of these icebergs as they start their journey southward are concentrated within 20 nautical miles on the West Greenland side and 60 nautical miles on the Canadian side.

It has been observed by Smith (19) that drifts of icebergs from Baffin Bay to the Newfoundland coast displays the same pattern as the sea ice stream of the Arctic pack indicating that they are under the influence of the same currents. Their drift season also corresponds with the arrival of winter pack ice along the Labrador and the Newfoundland coasts.

It is estimated that about 1,000 bergs each year reach the region offshore from Belle Isle and about 400 bergs drift south of latitude 48° N. Here the velocity of an iceberg increases from about 10-15 nautical miles per day along the Newfoundland and Labrador coasts to 25-30 nautical miles per day along the slopes of the Grand Banks.

The International Ice Patrol has been keeping records of the drifts of icebergs in the Northwest Atlantic since 1913. From these records it can be seen that the number of icebergs reaching the Grand Banks varies from year to year. Their annual cycle is shown in Figure 2. Unusual sightings at different locations and at different times of the year have been reported on the entire North Atlantic north of latitude 38° N. Figure 3 represents these unusual sightings of icebergs.

Effects of Winds on the Drifts of Icebergs

The relative importance of currents and winds for the drifts of icebergs is discussed by Mecking (10). He has observed that in regions where slope currents prevail, the current is a dominant factor for the drifts of the icebergs, while in regions of weak currents the wind determines the course of the icebergs. It has been observed by the International Ice Patrol (22) that the continuous off-shore winds along the coast of West Greenland determine the number of icebergs reaching the Labrador current and thus the number of icebergs off Newfoundland in the following spring.

The effect of wind is made up of two parts: (1) the direct force of the wind exerted on the exposed surface of the iceberg above water; and (2) movement of the floating

MARKS ON ORIGINAL

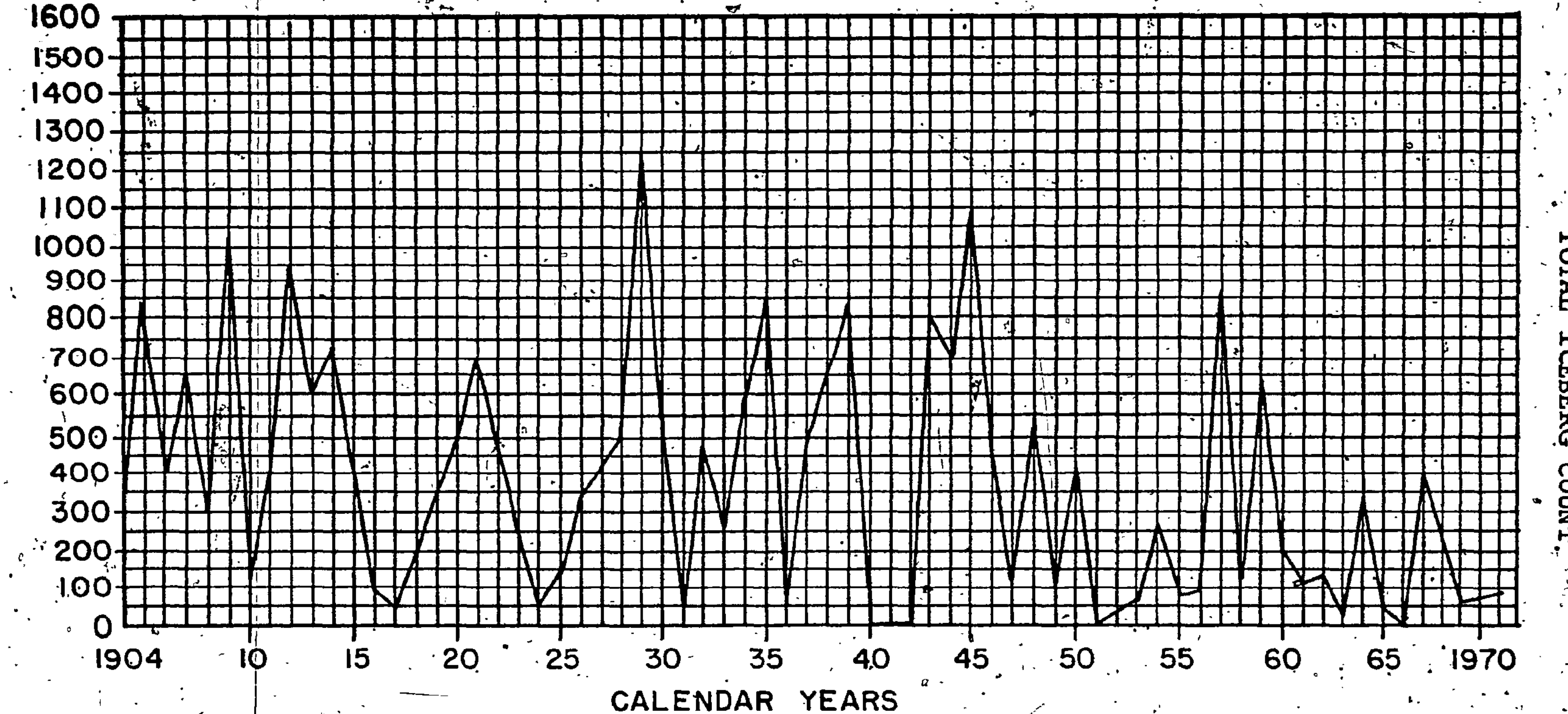


FIG. 2. YEARLY COUNT OF ICEBERGS CROSSING THE 48TH PARALLEL OF LATITUDE OFF NEWFOUNDLAND. (REPRODUCED FROM REFERENCE #3).

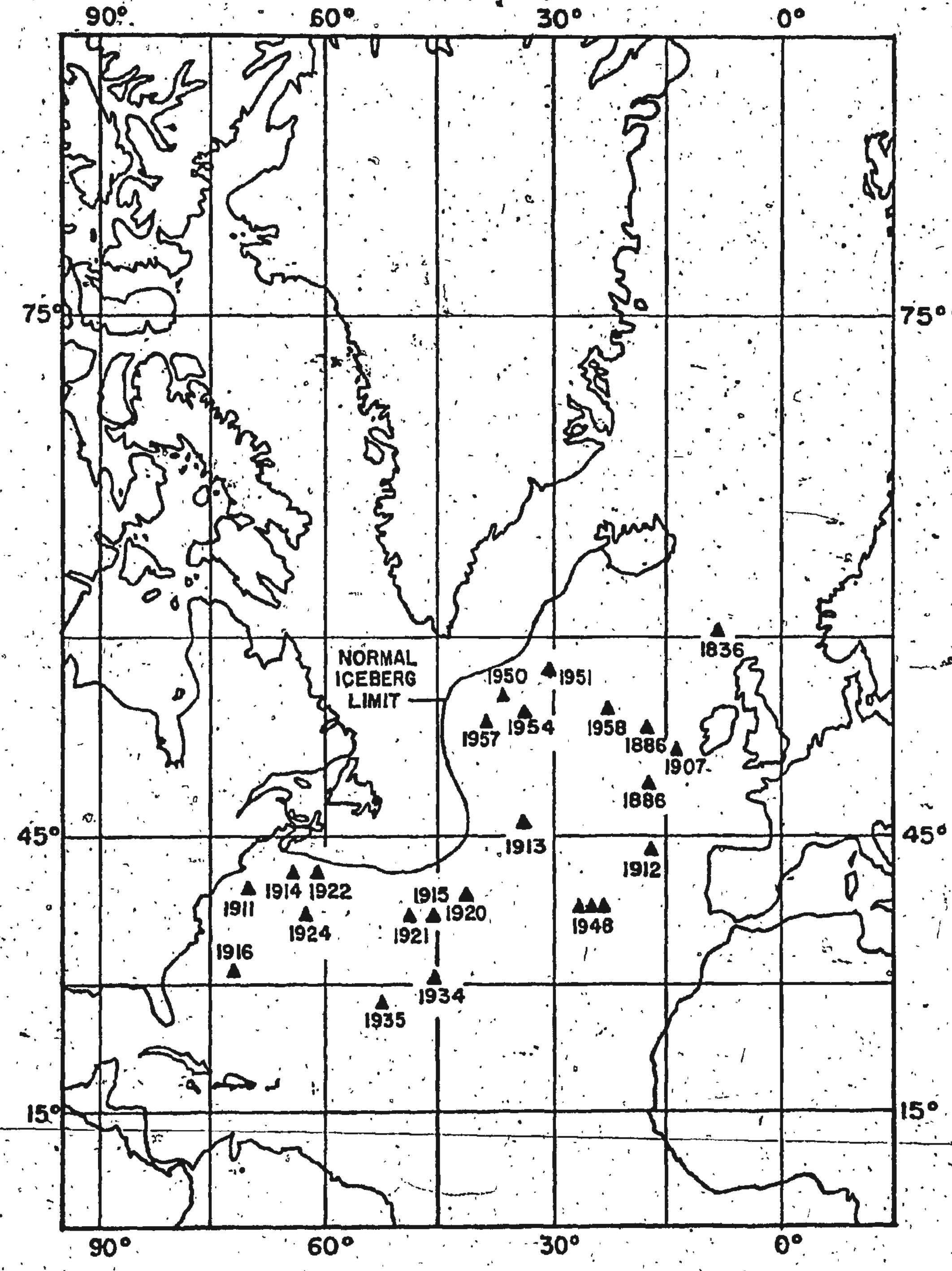


FIG 3 UNUSUAL ICEBERG SIGHTINGS (REPRODUCED FROM REFERENCE #3)

iceberg with wind-drift current set up in the top layer of the ocean. The exposed portion of the iceberg is much smaller than its underwater portion, the effect of the wind on it is almost negligible. Even if the exposed portion is of the same size as the submerged portion, the drag force of the wind is very small compared to that of the water movement.

The frictional force of wind exerted on the surface of the sea is significantly responsible for maintaining the large-scale currents of the open ocean. The energy of the wind system is transmitted to the water through friction, depending on the roughness or smoothness of the water surface. The stress of the wind on the water is proportional to the square of the wind velocity for moderate and strong winds. The wind stress can be expressed in terms of the velocity of the surface winds by $\tau_o = \rho y^2 w^2$

where τ_o = wind stress

ρ = density of air

w = wind velocity

y = a constant depending on the height at which the wind is measured and the smoothness or roughness of the sea surface

The resulting transport of water is given by

$$T = f/\tau_o$$

where T = the transport of water

f = Coriolos force

τ_o = wind stress

As the Coriolos force is a deflecting force acting at right angles to the mean motion, the water will be directed to the right of the direction of the wind stress in the northern hemisphere and to the left of the direction of the wind stress in the southern hemisphere.

In 1902, Ekman (8), in his paper on wind currents, confirmed by mathematical treatment the effects of the deflecting force and of the eddy viscosity on the generation of the wind currents. Ekman (8) considered a non-accelerated current in a homogeneous ocean, unbounded in the horizontal direction and infinitely deep.

The equations of motion for this steady case are (21)

$$2\omega \sin\phi u = \frac{A}{\rho} \frac{\partial^2 v}{\partial z^2}$$

$$2\omega \sin\phi V = \frac{A}{\rho} \frac{\partial^2 u}{\partial z^2}$$

where A = eddy viscosity coefficient, assumed as constant

u = velocity in +ve x-direction

v = velocity in +ve y-direction

ϕ = latitude

ω = angular velocity of the earth = .00007292 rad/sec.

ρ = density of air

Writing $\pi\sqrt{A/\rho\omega\sin\phi}$ = D and integrating the equations directly one obtains

$$u = C_1 e^{\frac{\pi}{D}z} \cos\left(\frac{\pi}{D}z + C_2\right) + C_3 e^{-\frac{\pi}{D}z} \cos\left(\frac{\pi}{D}z + C_4\right)$$

$$v = C_1 e^{\frac{\pi}{D}z} \sin\left(\frac{\pi}{D}z + C_2\right) - C_3 e^{-\frac{\pi}{D}z} \sin\left(\frac{\pi}{D}z + C_4\right)$$

where C_1, C_2, C_3 and C_4 are constants to be determined from the boundary conditions and z is the depth of the ocean measured +ve downward.

If the depth of the ocean is so great that one can assume the velocity near the bottom to be zero, then C_1 in the equations is zero. Also assuming that the stress of the wind τ_0 is directed along y-axis, we have

$$-A\left(\frac{dv}{dz}\right) = \tau_0$$

and $$A\left(\frac{du}{dz}\right) = 0$$

From these equations C_3 and C_4 can be determined. Let v_0 be the velocity at the surface, the velocity components of a pure drift current as a function of depth becomes

$$u = v_0 e^{-\frac{\pi}{D}z} \cos\left(45^\circ - \frac{\pi}{D}z\right)$$

$$v = v_0 e^{-\frac{\pi}{D}z} \sin\left(45^\circ - \frac{\pi}{D}z\right)$$

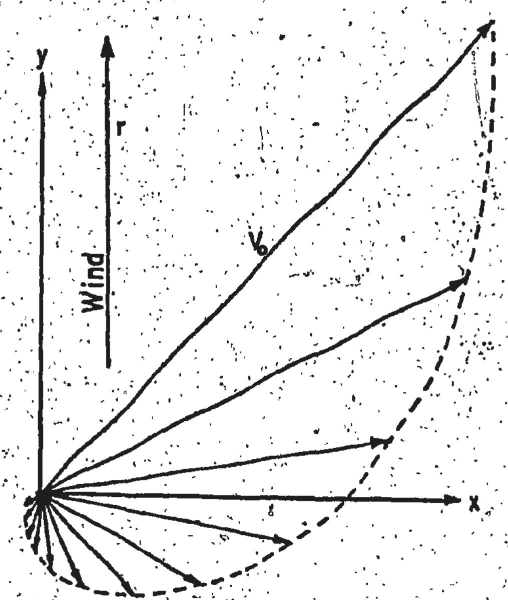
$$v_0 = \frac{\pi \tau_0}{D \rho \omega \sin\phi \sqrt{2}}$$

From the above equations it is seen that for the sea surface i.e. $z = 0$,

$$u = v_0 \cos 45^\circ$$

$$v = v_0 \sin 45^\circ$$

Hence the wind current is directed 45° cum sole from the direction of the wind. The angle of deflection increases with the depth and at depth $z = D$, the current is opposite in direction to the surface current. The velocity of the wind current decreases regularly with the increasing depth and at $z = D$ it is 4.3 per cent times the surface current. Ekman called the depth above $z = D$ "the depth of frictional resistance". Ekman has represented the pure wind drift current as a function of the depth as shown in Figure 4.



FIG·4 Ekman spiral for pure wind-driven currents projected on a horizontal plane· V_0 is the surface velocity vector deviated by 45° to the right of the wind vector· (Northern Hemisphere)· After Ekman (1905)· (Reproduced from reference # 12)

The arrows indicate the velocity and the direction of current vectors at depths of equal intervals. Projected on a horizontal plane, the end points of the current vectors form a logarithmic spiral, the Ekman spiral. According to Ekman's theory, the angle of deflection of the wind current should remain constant at 45° and the wind factor should be equal to 0.025 at lat. 15° and 0.0136 at lat. 60°.

Rossby and Montogomery (15) formed tables according to which the deflection of the wind current in lat. 5° increases from 35° at a wind velocity of 5 m/sec to 43° at a wind velocity of 20 m/sec. In the same latitude the wind factors decrease from 0.0317 at a wind velocity of 5 m/sec to 0.0266 at a velocity of 20 m/sec. From the empirical results, the Ekman theory seems to give better results than that of Rossby and Montogomery (15).

It has been estimated by Smith (19) that a moderate to fresh wind blowing for a day or two in the ice regions of the North Atlantic will establish a movement of the water layers to a depth of 200 ft. and a strong breeze to moderate gale in the same interval to a depth of 300 ft. The mean velocity of movement will be that at 80 ft. and 120 ft. levels, respectively, and the direction of the icebergs will be 72° to the right of the wind. Thus for winds blowing at 25 to 38 knots and 13 to 24 knots, the icebergs will move at the rate of 3.7 miles per day and at 2.5 miles per day, ~~respectively, 72° to the right of the wind ignoring the~~ effect of the ocean currents. The wind effect on the drift of larger, deep draft icebergs, 500 to 600 ft. which exceeds the depth of wind current, is less than that of a smaller iceberg of lesser draft for which the wind force and the force due to wind drift current act more closely. For deep

MARKS ON ORIGINAL

immersing icebergs, the deflection from the direction of the wind is only 20° - 40° (19). For deep draft icebergs and smaller bergs, the effect of the wind force and the force due to wind drift currents are given in Table I.

TABLE I

Direct wind force and force due to wind drift on icebergs (According to Smith.) a, deep-immersing large icebergs; b, smaller icebergs.

	Wind Velocity Beaufort	Direct wind force in the wind direction	Wind drift deflection 70° to the right of wind (km/day)	Resultant icebergs drift: Speed (km/day)	Resultant icebergs drift: Direction, to the right of wind direction
a	4 - 5	2.6	3.2	4.5	40°
	6 - 7	4.0	4.8	6.9	40°
b	4 - 5	8.8	4.0	10.8	18°
	6 - 7	13.7	6.0	16.4	21°

The values listed in Table I are plotted in Figure 5.

MARKS ON ORIGINAL

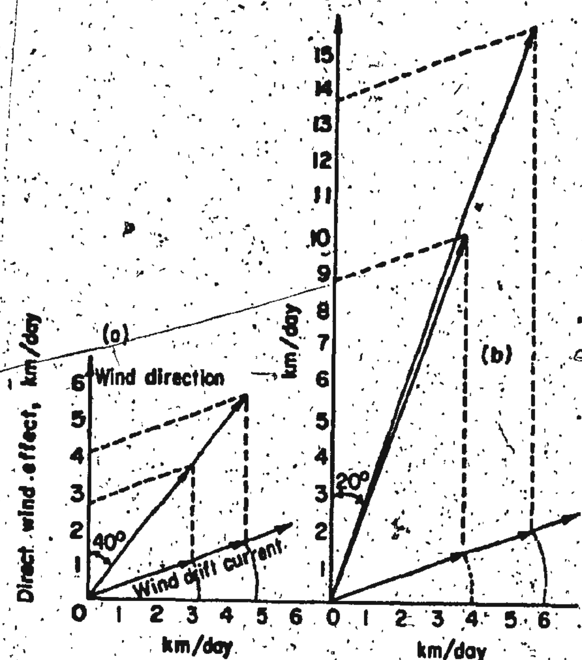


FIG. 5 Diagram of the forces affecting the drift of icebergs (according to Smith) · (a) Effect of wind on large icebergs ; (b) Effect of wind on small icebergs · (Reproduced from reference # 5)

One of the major factors for transportation of icebergs in the North Atlantic Ocean is the system of ocean currents. In the next section, the effect of ocean currents on the drifts of icebergs is discussed.

Effect of Ocean Current on the Drifts of Icebergs

Generally the drifts of icebergs are governed by the rate of flow and direction of the ocean currents. The system of ocean currents in Baffin Bay, Davis Strait and the Labrador Sea is the major factor for the transportation of icebergs from Baffin Bay to the Grand Banks. Figure 6 shows the general circulatory pattern of the ocean currents in this area (11).

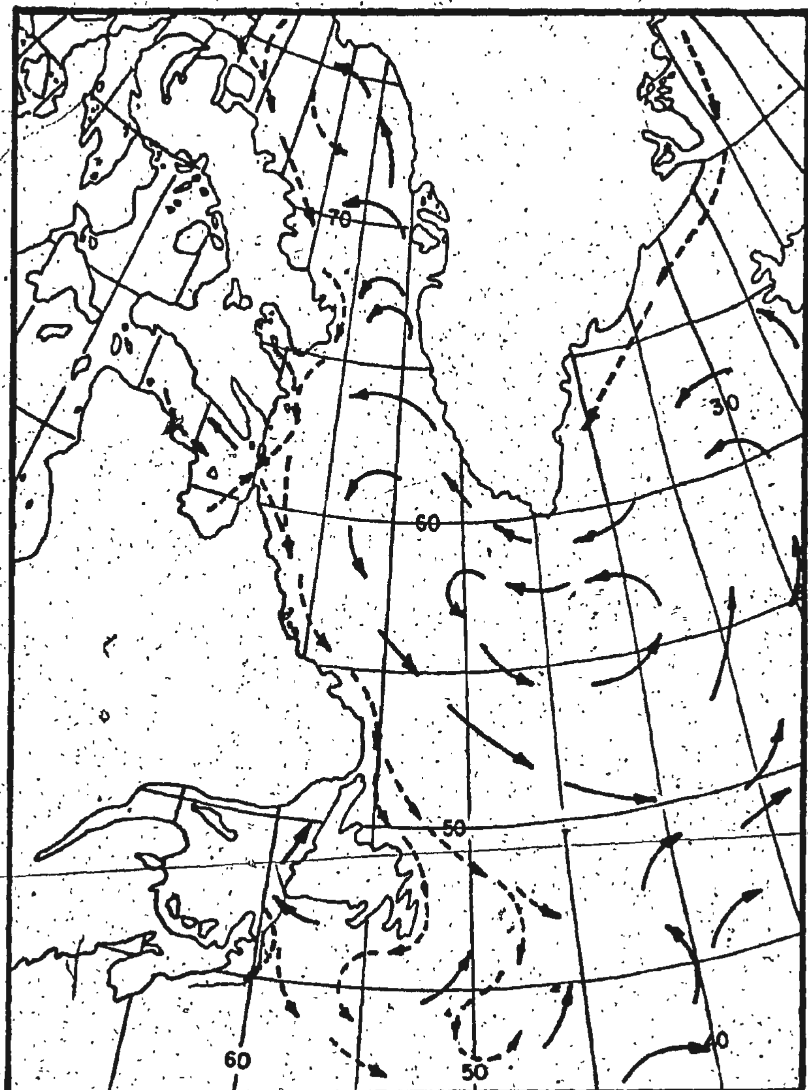


FIG. 6 The ocean currents affecting the drift and deterioration of ice (Reproduced from reference # 11)

The Labrador Current along the east coast of Newfoundland to the north slope of the Grand Banks is one of the significant factors for transporting icebergs to the south of 48° N. During March to April the flooding Labrador Current flows quite closely to the eastern slope of the Grand Banks and curls around the tail and extends north-westward along the south-western slope. The minor branch of this current goes south along the Avalon Peninsula making the icebergs drift westward off the southern coast of Newfoundland. Around the tail of the Grand Banks, one part of the Labrador Current curves to the east parallel to the Atlantic Current and the other part turns towards west and mixes along the southern side of the current in large eddies with warm water of the Gulf Stream. There is no detailed information available about the currents over the Grand Banks (11). The Labrador Current forms the channel along which the icebergs pass 48° N. The main iceberg tracks as given by Smith (19) are shown in Figure 7.

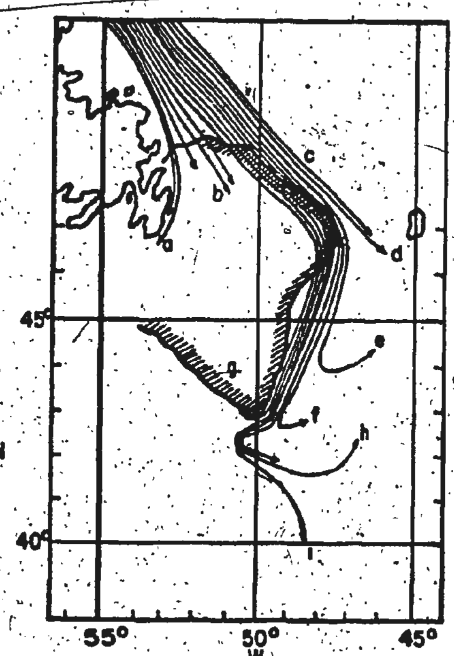


FIG. 7 Main iceberg tracks off Newfoundland and the Grand Banks. (Reproduced from reference # 5)

Russell in his thesis (16) investigated the drift pattern of icebergs due to currents at longitude 52° 30' W and latitude 50° 30' N. He studied the currents at horizontal positions over a spatial length scale of several miles and at depths of approximately 15m, 28m, 65m, and 218m.

Effect of Tidal Currents and Other Variable on the Drifts of Icebergs

The rise and fall of sea level associated with the tides imparts important motions to the sea water. In the open ocean tidal currents follow paths that are usually rotary in form, which means the flow continuously changes direction during the tidal cycle as shown in Figure 8.

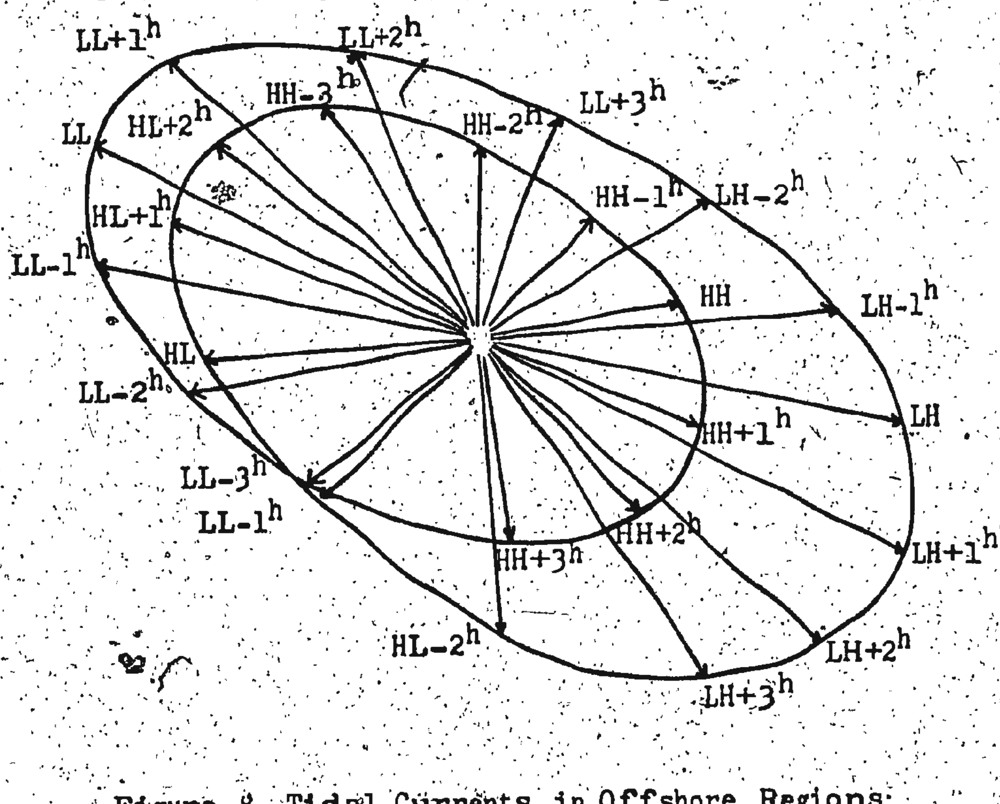


Figure 8 Tidal Currents in Offshore Regions
(Reproduced from reference #4)

Sodhi and Dempster (20) have described the effects of rotary tidal currents on the drifts of icebergs.

Some effects of low pressure on the drifts of icebergs as observed by Dempster (6) are shown in Figure 9. Presently only the qualitative effect of the waves, variations of temperatures and the daily variations of the currents on the drifts of icebergs are known.

Figure 9 Low Pressure effects on drift
(Reproduced from reference #5)

CHAPTER III

ANALYSIS OF THE DRIFTS OF ICEBERGS

A kinematic model has been developed in which the effects of the ocean currents, wind-generated currents, and other variables on the drifts of icebergs has been considered. Data collected by the International Ice Patrol (~~22~~) have been utilised to compare the computed drifts with observed drifts.

Kinematic Model

In the kinematic model, the drifts of icebergs under the influence of ocean currents, wind-generated currents, and other variables have been analysed. The berg velocity is expressed as

$$\overline{U} = K\,(\overline{\overline{V} + \overline{W}})$$

where $\overline{U}$ = berg velocity in knots

$\overline{V}$ = ocean current vector in knots (Atlantic currents)

$\overline{W}$ = wind-generated current vector in knots

K = a factor which takes into account the effect of tidal currents and other variables

$\overline{\overline{V} + \overline{W}}$ = averaged resultant current vector over the draft of an iceberg.

The computed drifts of icebergs obtained from this model are compared with the observed drifts. The data for the observed drifts have been obtained from the records of sightings published by the International Ice Patrol for the period 1950 - 1956 (22). The observations which represent the sightings of icebergs at two or more locations on different days during the period are summarized in Appendix A. Some typical values from this appendix are shown in Table II.

TABLE II

Sightings of Icebergs from International Ice Patrol Reports

No.	Latitude N (Degrees)	Longitude W (Degrees)	Duration (Days)	Observed Distance (Nautical Miles)
1	47.3833	47.0833	1	25.62
	47.0000	46.9167		
2	46.2500	46.6667	4	44.00
	46.4000	45.9667		
3	49.0000	52.0000	7	41.00
	48.7333	51.3333		
4	47.7000	52.6500	1	11.50
	47.6333	52.4667		
5	47.4333	52.6333	1	7.50
	47.4000	52.5167		

The following comments on the data reported by the International Ice Patrol are made:

1. Average drift of ~~icebergs in the~~ Grand Banks is known to be 25-30 nautical miles per day and some icebergs have been observed to travel up to 36 nautical miles per day (17). Rounding off this figure to 40 nautical miles, observations indicating distance travelled by an iceberg in excess of 40 nautical miles per day have been rejected.
2. The draft and shape of an iceberg which have significant effect on the berg velocity are not specified.
3. Timings of the sightings are not recorded. The duration between successive sightings can be 24 hours or more or less. Duration is quite important when comparing the daily computed distance with the observed distance.

Wind-generated current velocity required in the kinematic model is obtained from the available wind data for each day. This velocity in nautical miles per day with berg drift 30 degrees to the right of the wind is determined by multiplying the wind velocity in knots by the corresponding wind factors. The wind factors (11) used in these calculations are shown in Table III.

TABLE III

Wind Factors for Computing Wind-Generated Currents

Wind Velocity/Knots	Factor
0——5	negligible
6——14	.025
15——29	.030
30 +	.035

The draft and shape of icebergs are not ~~mentioned in~~ the International Ice Patrol reports. The average berg vector obviously depends on these factors. In view of the nonavailability of this vital information there seems to be two possible courses. One alternative is to ignore altogether the effect of the draft. This will mean that each iceberg is being propelled by the surface currents and that there is no effect of variation of current from the surface to the bottom of the ocean. This assumption being illogical is not used. The other alternative is to assign ratio of draft to depth of the ocean to each iceberg. The shortcoming in this course is that its verification against collected data is not possible. This method allows the use of average current rather than the surface current. Because the hypothesis that berg velocity has a relationship with its draft cannot be tested, no conclusion can be derived which can effect future data collection and reporting. However this procedure can provide strong indication about the relationship between the berg velocity and its draft pinpointing future areas of research. The variation of ocean current from the surface to the bottom has been assumed logarithmically by most researchers although this has not been verified experimentally. Logarithmic variation of the current has been used in this study.

The velocity of an iceberg is given by the product of factor K and the average current velocity over the draft of the iceberg. The average current velocity is obtained from the resultant of the ocean and the wind-generated current velocities. If $\overline{V}_o + \overline{W}_o = \overline{U}_o$ is the resultant surface current velocity which varies logarithmically with respect to the depth of the ocean, then the current velocity at any depth is given by

$$\overline{U}_z = (1 - 1.443 \ln (1 + z/d)) \overline{U}_o \qquad (1)$$

where $\overline{U}_z$ = current velocity at any depth

d = average depth of the ocean for the trajectory of an iceberg

From equation (1), the average current velocity $\overline{\overline{V} + \overline{W}} = \overline{U}_a$ over the draft of an iceberg is given by

$$\overline{U}_a = 1/\ell d \int_o^{\ell d} (1 - 1.443 \ln (1 + z/d)) \overline{U}_o dz$$

$$\overline{U}_a = (2.443 - 1.443 (1 + 1/\ell) \ln (1 + \ell)) \overline{U}_o \qquad (2)$$

$$\bar{U}_a = XA \times \bar{U}_o$$

where XA = averaging factor = $2.443 - 1.443\,(1 + 1/\ell)\ \ell n\,(1 + \ell)$ (3)

ℓ = ratio of draft of an iceberg to average depth of the ocean for its trajectory.

System Flow Chart

The system flow chart illustrated in Figure 10 represents three steps of the kinematic model for which a computer program is listed in Appendix B. It computes the drift of each iceberg, examines its correlation with the observed data and determines the absolute difference between the computed and observed distance. The mean of such differences for all icebergs is denoted by E. As stated under analysis criterion, each step selects that variable of interest which minimizes this E.

Step 1. The timings of successive sightings of icebergs are not given by the International Ice Patrol (22). The duration of 24 hours for successive sightings of an iceberg has been assumed in this step. The Grand Banks is surrounded by 50-fathom contour. The maximum draft of an iceberg reaching Grand Banks can be 100m because the iceberg with larger draft will be grounded. The minimum draft of an iceberg reaching this region can be 20m because the

MARKS ON ORIGINAL

iceberg having a smaller draft is termed as a growler which does not present any hazard. Taking into account these values of maximum and minimum drafts of icebergs reaching the Grand Banks region the range of the ratios of the draft to the average ocean depth has been assumed to be 0.20 to 1.00. The values of the averaging factor XA in equation (3) have been determined for ℓ = 0.20 to 1.00 with an increment of 0.01. The distance travelled by an iceberg depends upon the average velocity of the surface currents. The average current velocity is a product of the averaging factor XA and the resultant surface current velocity. An averaging factor has been assigned to each iceberg which in effect ascribes a draft/depth ratio ℓ corresponding to the distance travelled by it. In the absence of the validation of these results it was not possible to derive firm conclusions. Value of K = 1 has been assumed in this step. K = 1 implies negligible effect of tidal currents and other variables. Values of K less than one implies that the tidal currents and other variables are opposing the combined effect of the ocean and wind-generated currents and value of K greater than one indicates that these are supporting the ocean and wind-generated currents in the movement of an iceberg. Distance travelled per day by an iceberg has been computed and compared with its observed distance. The results are listed in Appendix B1. Some typical values are shown in Table IV.

TABLE IV

Comparison of Computed and Observed Distances of Icebergs

OBD	XA	CPD	ERR
16.00	0.61	12.00	4.00
11.25	0.55	11.22	0.03
8.00	0.53	9.03	1.03
4.50	0.50	4.80	0.30
2.00	0.45	2.48	0.48

where OBD = observed distance in nautical miles

XA = averaging factor

CPD = computed distance in nautical miles

ERR = absolute difference between the observed and computed distance of an iceberg in nautical miles

The mean and standard deviation of the errors are:

1. Mean of the errors = 2.73 nautical miles
2. Standard deviation of the errors = 2.59 nautical miles

Rejecting those observations of icebergs whose errors are not

$$\bar{U}_a = \left[2{\cdot}443 - 1{\cdot}443\left(1+\frac{1}{\ell}\right)\ln(1+\ell)\right](\bar{V}+\bar{W})$$

$$\bar{U} = K\bar{U}_a$$

$$D_1 = T\bar{U}$$

$(T = 24 \text{ hrs}, K = 1)$

set of bergs whose errors are not in the 95 per cent confidence interval

$$\bar{U} = K\bar{U}_a$$

$$D_2 = T\bar{U}$$

(T simulated between 14 to 34hrs, K=1)

set of 'T' selected to minimize E

$$\bar{U} = K\bar{U}_a$$

$$D_3 = TU_{b3}$$

(K simulated between ·70 to 1·30)

set of 'K' selected to minimize E

D_1, D_2, D_3 = distances travelled per day by an iceberg

Figure 10· System Flow Chart

in the 95% confidence interval of the mean, the mean and the standard deviation of the remaining 237 observations listed in Appendix B1.A are:

1. Mean of the errors = 2.27 nautical miles
2. Standard deviation of the errors = 1.92 nautical miles

Step 2. As stated earlier the timings of the sightings of icebergs are not mentioned (22). The durations of drifts of icebergs between successive sightings could be anywhere between 14 to 34 hours as the averaged visibility in the Grand Banks during March to July is 10 hours (1). Monte Carlo simulation technique is used to randomly assign a duration to each observation. One hundred and forty-four simulations based on 95 per cent probability are made. In each simulation run distance travelled by each iceberg is computed ignoring the effect of the tidal currents and other variables and it is compared with its observed distance. The results are listed in Appendix B2. Some typical output values are shown in Table V.

TABLE V

Comparison of Computed and Observed
Distances of Icebergs - Simulating Time

Simulation No.	Mean Error	Std. Dev.	Seed No.	Mean T
1	2.58	2.18	5.00	23.44
10	2.79	2.31	77.00	23.40
15	2.58	2.28	125.00	23.63
91	2.34	1.96	725.00	23.67
144	2.72	2.42	1149.00	23.38

Mean error and standard deviation are in nautical miles and mean time T is in hours.

The set of durations in simulation number 91 minimizes the mean of the errors. This set of durations has been used for further analysis in the next step.

Step 3. To take into account the effect of the tidal currents and other variables on the drift of an iceberg the value of K is to be determined. It is assumed that each iceberg is subjected to the same effect on account of the tidal currents and other variables, a value of 0.5 is assigned to K for each iceberg in the set selected in the previous step. The distance travelled by each iceberg as computed from this value of K is used to determine E. The value of K is varied from 0.5 to 1.50 in increments of 0.01 recording the value of E in each step. For K = 1.10, the mean of errors E is minimum. The assumption made earlier in this step to assign the same value of K to each iceberg is not realistic because the icebergs are at different locations and the effect of tidal currents and other variables cannot be same on all of them. Therefore, the value of K should be different for all of them. Previous analysis indicates the value of K is in the vicinity of 1.10. It is required to investigate the range of values of K on either side of this value. The values of E obtained earlier are more for K less than 0.9 and for K more than 1.30 indicating the range of values of K for which E is minimum. This range for K is 0.90 to 1.30. Values of K between 0.90 to 1.30 are simulated 144 times. As stated earlier, durations selected in step 2 have been used to compute the distances travelled by the icebergs in each simulation. The computed distances of icebergs have been compared with the observed distances in each simulation and results are listed in Appendix B3. Typical values from this appendix are shown in Table VI.

TABLE VI

Comparison of Computed and Observed
Distances of Icebergs (Simulating K)

Simulation No.	Mean Error	Std. Dev.	Seed No.	Mean K
1	2.12	1.65	565.00	1.09
20	2.04	1.68	717.00	1.11
55	2.08	1.76	997.00	1.10
100	2.06	1.57	1357.00	1.09
118	1.98	1.77	1493.00	1.09

Mean error and the standard deviation of the errors are in nautical miles.

The set of values of K in simulation number 118 minimizes the mean error.

Outputs of steps 1, 2, and 3 are summarized in Appendix B4. Some of the typical values from this appendix are shown in Table VII.

TABLE VII

Comparison of Computed and Observed
Distances of Icebergs (Summarizing Steps 1, 2, and 3)

OBD	XA	FACTOR K	TIME	CPD	ERR
6.88	0.52	1.18	22.33	5.21	1.67
10.00	0.55	1.11	16.30	7.75	2.25
16.50	0.61	1.19	25.43	16.63	0.13
11.25	0.55	0.98	23.60	10.83	0.42
20.00	0.66	1.06	25.89	17.21	2.79

The mean of the errors is 1.98 nautical miles and the mean of the observed distances is 12.25 nautical miles. The ratio of the mean of the errors to the mean of the observed distance is 1 to 6.

The errors in the computed and observed distances caused by the errors in the positioning of vessels and in sightings of icebergs can be considerable. Therefore, more rigorous analysis of these data is not justified.

The distribution of the errors obtained from the kinematic model is shown in Figure 11.

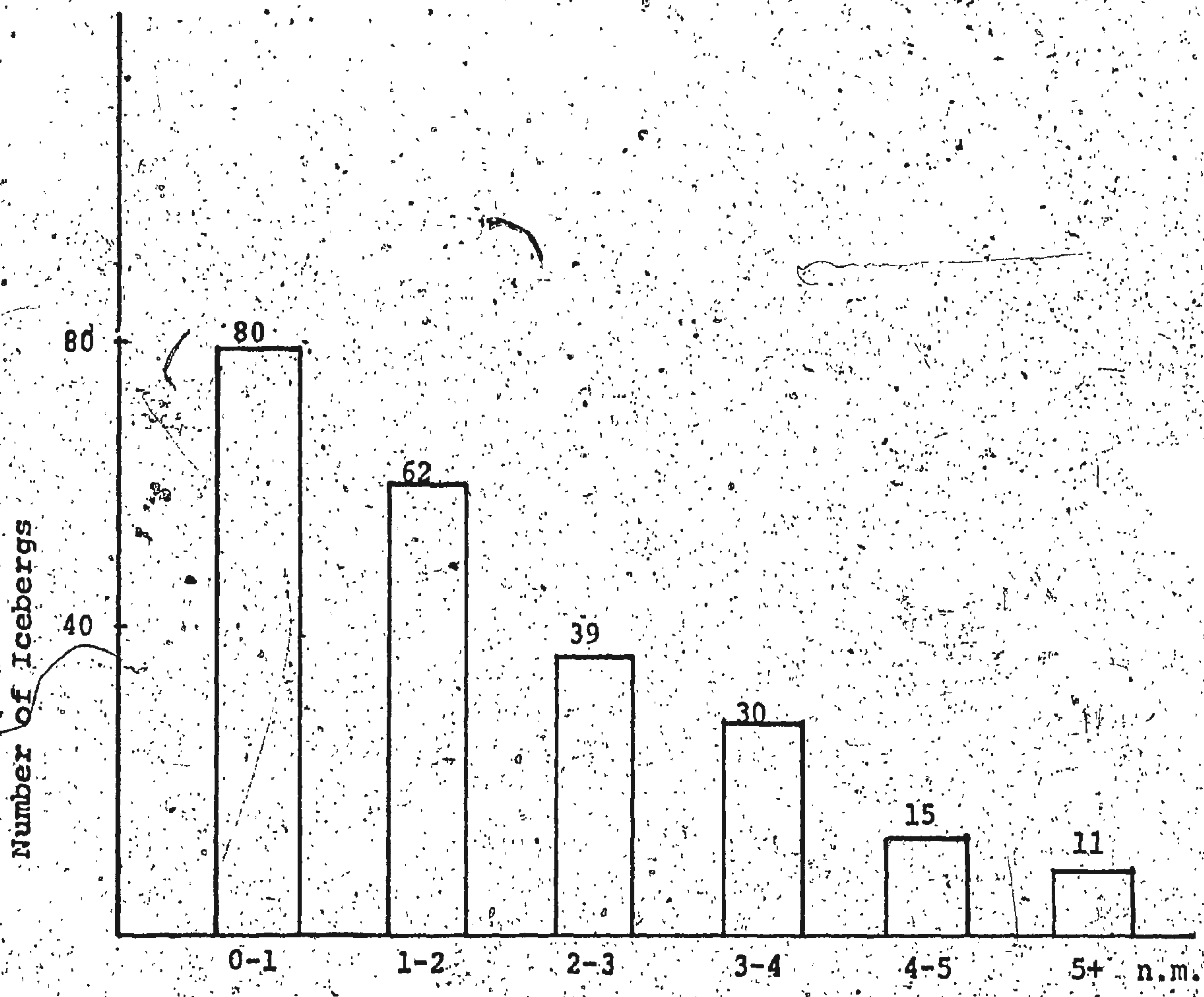


FIG. 11 Number of Icebergs with Errors between the Computed and Observed Drifts in the Given Ranges

Conclusions obtained from this analysis are described in the next chapter.

CHAPTER IV

CONCLUSIONS

The following conclusions have been obtained from the analysis:

1. Draft and shape of an iceberg have considerable influence on its velocity (5,6). The shape of the submerged portion of an iceberg cannot be ascertained reasonably with the present technology. However a first order approximation of the draft may be obtained from equation (2). An analysis of the relationship between ~~the~~ berg velocity and its draft and validation of the results with field data is a very promising area for future research.

2. It is important to know the precise location of a tracked iceberg. In the International Ice Patrol reports, the locations have been reported in degrees and minutes. But a difference of 1 minute in latitude could result in an error of 1 nautical mile in the observed distance. The locations of icebergs should be recorded and plotted more precisely correct to seconds.

3. The timings of successive sightings should also be reported.

4. The errors caused by instruments used in sighting icebergs and in positioning the vessels used in making the observations should be estimated.

5. There is a need to record detailed measurements of ocean currents for arriving at more reliable estimates of the values of K.

6. Other compenents of factor K pertaining to the effect of the tidal currents, atmospheric pressure, waves, etc. can be identified if the data for the tidal currents, atmospheric pressures, waves, etc. are also obtained.

7. Data on the detailed ocean currents and tidal currents are being collected by different agencies. These data when available can be used for developing more rigorous methods of future analysis.

APPENDIX A

SIGHTINGS OF ICEBERGS OBTAINED FROM THE INTERNATIONAL ICE PATROL REPORTS: 1950-1956

****YEAR 1950****

LAT/DEG	LONG/DEG	TIME/DAYS	OBD/NM
48,4167	47,3500	7,0000	60,0000
47,9500	46,4667	3,0000	76,2500
47,7500	45,2500		
48,2333	48,2500	5,0000	85,0000
48,0333	46,8333		
48,7167	47,0000	5,0000	31,2500
48,2000	46,8333		
46,7667	47,0333	5,0000	76,0000
46,5000	45,8000	1,0000	30,0000
46,6167	45,3167	1,0000	24,0000
46,6167	45,8333		
47,3833	47,0833	1,0000	25,6200
47,0000	46,9167		
46,2500	46,6667	4,0000	44,0000
46,4000	45,9667		
47,8667	48,4500	1,0000	6,8800
47,8667	48,3333		
45,5000	46,1667	3,0000	25,0000
45,3333	48,5500	1,0000	20,0000
45,0000	48,5000	2,0000	17,5000
44,7167	48,4667		
45,6333	48,1500	3,0000	21,2500
45,4667	48,4500	3,0000	41,8800
44,7833	48,6000	4,0000	34,3800
44,3667	49,0000		

LAT/DEG	LONG/DEG	TIME/DAYS	QBD/NM
46.6333	47.0333	1.0000	5.0000
46.5833	46.8500		
46.5833	46.8333	1.0000	3.7500
46.6333	46.8500		
45.2500	47.7000	3.0000	27.5000
44.8000	47.6667		
45.9500	47.5333	10.0000	125.6200
44.1833	48.6667		
44.2167	48.8000	4.0000	68.8000
45.3667	48.8667	2.0000	49.4000
44.5833	49.1667		
45.4500	48.5000	2.0000	41.2500
44.7833	48.8833	3.0000	9.3800
44.6333	48.8667		
45.5667	48.3833	2.0000	43.7500
44.9333	48.7500	3.0000	26.2500
44.5333	48.8500		
44.4500	48.8667	1.0000	22.5000
44.0833	48.8000	1.0000	10.0000
43.9500	48.6833	2.0000	8.7500
44.0833	48.7167	1.0000	12.5000
44.1167	48.5167		
44.2333	48.6833	2.0000	16.8800
44.0000	48.8333		
45.6833	48.8000	5.0000	61.8800
44.6667	48.6000		
46.3000	47.2667	2.0000	25.6200
46.1667	47.6667		

LAT/DEG	LONG/DEG	TIME/DAYS	OBD/NM
46,2500	47,3833	2,0000	21,2500
46,1000	47,7000		
47,4000	47,3833	1,0000	11,2500
47,2833	47,4000		
46,8833	46,8500	1,0000	16,0000
46,7167	46,6667		
48,0167	45,3833	1,0000	10,6200
48,0000	45,2167		
47,5333	48,6000	4,0000	73,1200
46,9167	47,5500	4,0000	36,8800
46,3333	47,3333		
46,7500	48,4000	1,0000	14,3800
46,8000	48,6333		
47,6333	51,6500	1,0000	22,5000
47,3500	51,8833		
45,3833	45,0833	1,0000	29,3800
45,3500	44,6000		
43,7000	45,0667	5,0000	72,5000
43,9500	42,6000		
47,0833	44,5333	1,0000	16,8800
47,3500	44,6167		
46,9333	47,4833	2,0000	16,0000
47,2167	46,9500		
47,3167	47,4667	1,0000	31,2500
43,2167	46,9500		

LAT/DEG	LONG/DEG	TIME/DAYS	OBD/NM
48,4167	50,2333	1,0000	25,6200
48,2833	49,8333		
46,9333	47,4833	5,0000	60,0000
45,9333	47,5833	2,0000	53,7500
45,4500	48,3333	1,0000	18,1200
45,1833	48,4833	1,0000	28,1200
44,7500	48,6500	1,0000	9,3800
44,8833	48,7333	1,0000	9,3800
44,9333	48,6167	1,0000	9,3800
44,8167	48,6667	1,0000	15,6200
44,5833	48,5500	1,0000	14,3800
44,4500	48,3500	1,0000	11,2500
44,3167	48,4833	1,0000	7,5000
44,4167	48,5333	1,0000	10,6200
44,5667	48,6000		
45,2167	48,5000	2,0000	22,5000
44,9000	48,7167		
47,3333	50,5833	1,0000	4,3800
47,2833	50,6333		
47,3667	51,1500	3,0000	25,6200
47,2167	51,5500	1,0000	27,5000
46,9500	51,9167	1,0000	6,2500
47,0333	51,9667	1,0000	13,7500
46,9167	52,1667		
47,0667	51,2667	3,0000	8,1200
46,9167	51,3000	1,0000	25,6200
46,7833	51,6167		
46,9167	48,3000	1,0000	5,6200
46,8333	48,3333		
47,9167	52,5833	1,0000	13,7500
47,7500	52,4167		

LAT/DEG	LONG/DEG	TIME/DAYS	OBD/NM
47,0833	52,7833	2,0000	30,0000
46,6667	52,5000		
47,9167	52,8167	2,0000	9,3800
47,8000	52,7167	1,0000	8,1200
47,6833	52,6500		
47,8667	51,4333	3,0000	25,0000
47,5167	51,6500	1,0000	16,2500
47,2833	51,7833	2,0000	23,7500
47,1167	51,5833	2,0000	4,3800
47,1833	51,4000		
47,7833	52,6500	1,0000	17,5000
47,7500	52,9333		
48,3833	51,6667	3,0000	40,0000
47,9500	51,6667		
47,0833	51,7500	3,0000	30,0000
46,9167	52,2167		
46,6333	49,3333	2,0000	30,6200
46,4333	48,8667	1,0000	5,0000
46,3500	48,8833	1,0000	5,0000
46,3533	48,6667	1,0000	20,0000
46,3167	48,5000		
47,1833	51,6333	4,0000	30,0000
46,9333	52,0667	1,0000	12,5000
46,8167	52,2333		
46,8667	52,2500	1,0000	10,0000
46,8000	52,4000		

****YEAR 1951****

LAT/DEG	LONG/DEG	TIME/DAYS	OBD/NM
48.0000	50.1667	12.0000	59.0000
47.5833	51.0500	2.0000	19.5000
47.6500	51.3667	9.0000	81.0000
46.3333	51.1000		
49.0000	52.0000	7.0000	41.0000
48.7333	51.3333		
48.5833	49.1500	1.0000	4.0000
48.5833	49.0833	11.0000	67.0000
48.3500	48.0000	3.0000	61.5000
47.4167	48.8167		

****YEAR 1952****

LAT/DEG	LONG/DEG	TIME/DAYS	OBD/NM
48,9167	52,6333	1,0000	15,0000
48,8500	52,5500		
49,4833	52,2000	1,0000	19,0000
49,1833	52,1833		
48,5000	53,0000	1,0000	10,0000
48,3333	52,9667		
48,5500	51,8667	3,0000	23,0000
48,4167	52,3333		
48,6000	51,5833	3,0000	42,0000
48,3333	52,2000		

****YEAR 1953****

LAT/DEG	LONG/DEG	TIME/DAYS	OBD/NM
49.5000	51.3333	2.0000	29.0000
49.1833	51.7000	4.0000	97.5000
48.1667	50.4333		
48.7167	50.2500	4.0000	33.0000
47.8333	50.3000		
47.7667	51.5833	2.0000	32.0000
47.3000	51.8333		
46.6667	51.0333	1.0000	8.5000
46.7000	50.9000	2.0000	47.0000
46.0000	50.9167		
47.6667	52.1667	1.0000	12.0000
47.5500	52.3167		
47.7000	52.6167	1.0000	9.5000
47.6167	52.4833		
47.7000	52.6500	1.0000	11.5000
47.6333	52.4667		
48.1333	49.4500	8.0000	99.0000
47.1833	51.1000		
49.8333	51.1667	7.0000	62.5000
48.8000	51.3167	9.0000	40.0000
48.1667	51.1333	1.0000	5.8000
48.1167	51.1500	4.0000	42.5000
47.4000	51.2167	1.0000	5.0000
47.3333	51.2500	2.0000	24.0000
47.2333	51.7833	1.0000	5.5000
47.2500	51.7000	1.0000	18.0000
46.8333	52.0000		

LAT/DEG	LONG/DEG	TIME/DAYS	OBD/NM
50.6667	51.7333	9.0000	95.0000
49.8000	50.4167	13.0000	120.0000
47.8167	50.2333		
47.6333	51.5833	1.0000	6.5000
47.7000	51.6667	5.0000	64.5000
46.7500	52.1500	1.0000	6.5000
46.7333	52.2500		
47.2167	52.6667	1.0000	8.0000
47.1167	52.6667	1.0000	6.0000
46.9167	52.8167	1.0000	16.5000
46.6500	52.9667	1.0000	4.0000
46.6667	52.9167	1.0000	20.0000
46.5333	53.2167	2.0000	9.5000
46.6167	53.3500		
47.6667	51.9167	1.0000	6.5000
47.7500	51.8667	1.0000	7.5000
47.6667	51.9167	4.0000	47.5000
46.8667	51.9167	1.0000	3.0000
46.8167	52.0833	1.0000	10.0000
46.8000	52.1833	2.0000	9.0000
46.6833	51.7167		
48.2000	52.1667	6.0000	72.5000
47.0833	52.3500	1.0000	11.5000
47.0167	52.5333	1.0000	11.0000
47.0000	52.7333	1.0000	14.0000
46.8833	52.6667		
48.3000	52.1500	1.0000	11.5000
48.1500	52.2667	2.0000	22.0000
47.7833	52.2500	4.0000	49.5000
47.1833	52.8000	2.0000	3.0000
47.1833	52.7500	1.0000	27.0000
46.7500	52.8333		
48.4167	52.7833	1.0000	9.0000
48.2667	52.7667		

LAT/DEG	LONG/DEG	TIME/DAYS	OBD/NM
48.4500	51.6667	4.0000	81.0000
47.1500	52.0333	2.0000	18.0000
47.4000	52.1833	2.0000	25.0000
47.2833	52.5833	2.0000	14.0000
47.0500	52.6333		

****YEAR 1954****

LAT/DEG	LONG/DEG	TIME/DAYS	ODD/NM
46.6667	48.1667	12.0000	169.0000
43.9833	48.9167	13.0000	342.0000
47.9333	53.0000		
47.8333	53.0833	1.0000	10.0000
47.9167	52.9500		
47.5167	50.7667	1.0000	10.0000
47.5167	50.9333	2.0000	7.0000
47.4167	50.8833	3.0000	7.0000
47.3333	50.9500	3.0000	17.5000
47.2333	51.2500	4.0000	20.0000
47.4833	51.0000	6.0000	15.0000
47.2500	51.0833	9.0000	27.0000
47.3833	51.5000		
46.5000	53.4500	1.0000	17.5000
46.4333	53.7333	2.0000	20.0000
46.4833	53.4167	1.0000	3.5000
46.4333	53.4167	5.0000	14.5000
46.3833	53.6500		
47.4167	47.5833	3.0000	37.0000
46.9333	47.1667	1.0000	28.0000
46.9333	47.6333	2.0000	20.0000
46.6667	47.8333	1.0000	20.0000
46.4000	47.7000	2.0000	29.0000
46.0000	48.0000	4.0000	66.5000
45.2167	48.7667	3.0000	52.0000
44.7833	48.3833	2.0000	27.5000
44.8000	48.5833	2.0000	37.0000
45.0833	48.0333	2.0000	26.0000
45.5167	48.0333	4.0000	65.0000
44.8667	47.1667	15.0000	49.0000
44.8167	46.3500	1.0000	11.0000
45.0000	46.3333	16.0000	57.5000
45.9333	46.5000		

LAT/DEG	LONG/DEG	TIME/DAYS	OBD/NM
46,9333	51,7000	1,0000	11,0000
47,9500	51,5167	1,0000	25,5000
47,8667	51,9333		
47,8333	52,7167	1,0000	3,0000
47,7833	52,7333		
47,4833	48,3833	4,0000	53,0000
47,0833	47,6000		
46,6833	52,2833	1,0000	4,5000
46,7667	52,3500	1,0000	12,5000
46,5667	52,4167	1,0000	4,5000
46,5500	52,4833	3,0000	2,5000
46,5667	52,5167	1,0000	3,5000
46,6167	52,4833	1,0000	15,0000
46,4833	52,7000	1,0000	7,5000
46,3500	52,7500	1,0000	19,0000
46,3333	53,0667	2,0000	16,0000
46,3500	53,3333	1,0000	10,0000
46,3000	53,1833		

****YEAR 1955****

LAT/DEG	LONG/DEG	TIME/DAYS	OBD/NM
47.9500	52.8333	3.0000	33.0000
47.4667	52.5667	3.0000	52.5000
47.2333	51.7333	5.0000	34.0000
46.6667	51.6833		
47.4333	52.6333	1.0000	7.5000
47.4000	52.5167		
47.9167	51.9167	2.0000	36.0000
47.4167	51.6167	3.0000	33.0000
46.8667	51.5333		
46.9333	52.6000	2.0000	11.5000
46.9000	52.7833		
47.0667	52.5000	2.0000	20.0000
47.1500	52.8167		
47.8167	52.2333	1.0000	18.0000
47.6000	52.4333		
47.8667	52.4167	1.0000	21.0000
47.6000	52.5000		
47.5333	52.3167	5.0000	27.0000
47.3333	52.7167	2.0000	30.0000
46.8333	52.7667	2.0000	15.0000
46.6000	52.6667	3.0000	43.5000
46.0000	53.0167		
47.5667	52.6333	1.0000	4.5000
47.6333	52.1667		
45.1667	52.7500	1.0000	23.5000
45.2500	52.3667	1.0000	21.5000
45.1500	52.0000		

LAT/DEG	LONG/DEG	TIME/DAYS	OBD/NM
46.0667	51.0833	2.0000	42.0000
45.9333	50.4000	1.0000	27.0000
45.6333	50.0667	1.0000	19.0000
45.3833	49.8500	1.0000	15.0000
45.1667	49.7500		
44.9333	50.4667	1.0000	13.0000
44.7500	50.3667		
47.8167	52.7000	3.0000	7.0000
47.7167	52.6333	6.0000	50.0000
46.9667	52.8000		
47.9500	52.7833	2.0000	34.0000
47.5333	52.4000	8.0000	38.0000
46.9000	52.3500	1.0000	26.5000
46.9167	52.8167	4.0000	11.0000
46.7500	52.8833	2.0000	10.0000
46.8333	52.7333	1.0000	7.0000
46.8667	52.8500	2.0000	26.0000
46.4333	52.8500	2.0000	28.5000
46.2833	53.2833	1.0000	29.0000
46.3333	53.7667	5.0000	10.0000
46.5000	53.7167	3.0000	7.5000
46.6000	53.7833	1.0000	8.0000
46.4833	53.7333	4.0000	8.4000
46.4333	55.2667		
45.8833	49.7500	1.0000	8.0000
45.9833	49.6667	2.0000	22.5000
45.6167	49.6500	6.0000	9.0000
46.0833	49.7167	4.0000	70.0000
45.0333	50.6333	7.0000	67.5000
44.5667	51.6500	1.0000	27.5000
45.8833	49.7500		
46.4167	50.8333	1.0000	31.0000
46.5667	50.4667	2.0000	17.0000
46.5500	50.7500	3.0000	16.0000
46.4667	50.5000	1.0000	15.5000
46.4333	50.7500	1.0000	23.5000
46.3000	50.3833	1.0000	11.0000
46.4167	50.2500	4.0000	100.5000
45.7500	51.7833	1.0000	19.0000
45.7167	52.1000	4.0000	80.0000
44.5833	52.7833		

****YEAR 1956****

LAT/DEG	LONG/DEG	TIME/DAYS	OBD/NM
47.8667	47.1667	1.0000	14.5000
47.6333	47.8333	3.0000	72.0000
46.4000	47.5833		
47.8167	47.5333	1.0000	22.0000
47.8167	47.1000		
47.4167	46.9167	3.0000	35.0000
47.8167	47.1000		
48.8000	49.4500	3.0000	62.5000
47.8500	48.0333		
47.3667	48.3000	2.0000	27.5000
47.1000	47.9333	2.0000	29.0000
47.0000	48.4000	3.0000	60.0000
46.0667	48.7500		
47.5500	48.8000	2.0000	37.0000
47.3167	48.2333	2.0000	9.0000
47.2167	48.3500	2.0000	24.0000
46.8333	48.2333		
48.0167	48.7667	2.0000	40.0000
47.5000	48.3333	2.0000	16.0000
47.3333	48.5333	2.0000	36.0000
46.8500	48.7833		
47.7667	50.4000	2.0000	23.5000
47.4833	50.6667	1.0000	38.0000
47.4667	50.0333	1.0000	19.0000
47.3667	50.3333		
47.2167	48.6667	2.0000	32.5000
46.6833	48.7667	4.0000	19.0000
46.6000	48.4667		

LAT/DEG	LONG/DEG	TIME/DAYS	OBD/KM
48,0000	50,1833	2,0000	12,0000
47,8167	50,2500	2,0000	21,5000
47,7500	50,6000	1,0000	10,0000
47,6167	50,5167		
47,9667	52,0167	2,0000	13,0000
47,7833	52,1333		
47,6500	47,9167	1,0000	7,5000
47,5333	47,8667		
47,8333	50,9167	3,0000	45,0000
47,3000	50,4000	1,0000	17,0000
47,2333	50,1333	1,0000	15,0000
47,1833	49,8833	2,0000	19,0000
46,9167	49,7167		
47,1667	47,7833	3,0000	22,5000
46,9500	47,4500	1,0000	27,0000
46,7833	47,0333		
47,6000	48,3333	3,0000	45,0000
46,9667	48,6667		
47,9667	50,8833	4,0000	36,5000
47,4500	51,2000		
48,0000	51,6333	3,0000	18,0000
47,9167	51,9167		

APPENDIX B

Source Listing of the Computer Program for the Kinematic Model

```
      DIMENSION CP(253),ER(253),AM(253)
      DIMENSION XKB(41),CFK(41),OBD(253),CU(253),XA(253),
     1CPD(253),ERR(253),XKA(253)
      DIMENSION R(253),CPDA(253),ERRA(253),XMERA(144)
      DIMENSION ZX(61)
      DIMENSION XL(99),Y(99)
      DIMENSION OBAD(253),CAU(253),XAU(253)
      DIMENSION XKAA(253),ERRAA(253),CPDAA(253)
      DIMENSION DIFF(253)
      DIMENSION TX(21),CFY(21),T(253)
      DIMENSION CPX(253),ERX(253)
      DIMENSION XMERR(144),STERR(144),XM(144),SEERR(144)
      DIMENSION YY(144)
      DIMENSION XX(253),K1(144)
      DIMENSION TB(253)
      DIMENSION XMT(144)
      DIMENSION XMK(144),AS(144),YYY(144)
      J=5
      K=6
C     XL=RATIO OF DRAFT TO OCEAN DEPTH
C     XA=FACTOR WHICH AVERAGED THE CURRENT OVER THE DRAFT
      XL(1)=.20
      DO 50 I=1,80
      XL(I+1)=XL(I)+0.01
   50 CONTINUE
      DO 51 I=1,81
       Y(I)=2.443-1.443*(1.+1./XL(I))*ALOG(1.+XL(I))
   51 CONTINUE
      WRITE(K,53)
   53 FORMAT(1H1,////4X,'DRAFT/DEPTH',8X,'AVERAGING FACTOR'
     1,//)
      DO 54 I=1,81
      WRITE(K,55)XL(I),Y(I)
   55 FORMAT(4X,F11.2,8X,F10.2)
   54 CONTINUE
      READ(J,117) TX
  117 FORMAT(16F5.2)
      READ(J,17)CFY
   17 FORMAT(16F5.3)
      WRITE(K,60)
   60 FORMAT(1H1,////4X,'TIME IN HOURS',10X,'CUM.FREQ.',
     1//)
      DO 61 I=1,21
      WRITE(K,62) TX(I),CFY(I)
   62 FORMAT(4X,F9.2,14X,F10.4)
   61 CONTINUE
      READ(J,1)XKB
    1 FORMAT(16F5.2)
```

```
      XAU(J)=XA(I)
      J=J+1
      K2=K2+1
  406 CONTINUE
      L=K2
      WRITE(K,407) L
  407 FORMAT(////4X,'NUMBER OF NOT REJECTED OBSERVATIONS ='
     1,I4)
      DO 58 I=1,L
      CPX(I)=XK*XKTT*CAU(I)*XAU(I)
      ERX(I)=ABS(OBAD(I)-CPX(I))
   58 CONTINUE
      WRITE(K,408)
  408 FORMAT(1H1,///8X,'S.NO.',2X,'OBD',8X,'XA',8X,'CPD',
     18X,'ERR',//)
      DO 409 I=1,L
      WRITE(K,411) I,OBAD(I),XAU(I),CPX(I),ERX(I)
  411 FORMAT(8X,I3,4X,F5.2,6X,F5.2,6X,F5.2,6X,F5.2)
  409 CONTINUE
      SUMX=0.
      SUMSX=0.
      DO 56 I=1,L
      SUMX=SUMX+ERX(I)
       SUMSX=SUMSX+ERX(I)**2
   56 CONTINUE
      YA=FLOAT(L)
      STX=((YA*SUMSX-SUMX**2)/(YA*(YA-1.)))**.5
      XMX=SUMX/YA
      WRITE(K,57)XMX,STX
   57 FORMAT(///4X,'MEAN OF THE ERRORS = ',F10.4,//4X,
     1'STANDARD DEVIATION OF THE ERRORS = ',F10.4)
      KN=L
      XN=0.
      DO 100 I=1,144
      XN=XN+1.
      X=8.*XN-3.
      YY(I)=X
      CALL RAND(253.,32768.,X,899.,R)
C     INTERPOLATION FOR COMPUTING THE TIME CORRESPONDING TO
C     THE RANDOM NUMBER FROM THE SET OF RANDOM NUMHERS
C     NUMBER FROM THE SET OF RANDOM NUMBERS
C
      DO 253 JJ=1,KN
      DO 27 IJ=1,20
      XX(IJ)=R(JJ)-CFY(IJ)
      XX(IJ+1)=R(JJ)-CFY(IJ+1)
      IF(XX(IJ).EQ.0.) GO TO 40
      IF(XX(IJ).GT.0..AND.XX(IJ+1).LT.0.) GO TO 30
```

```
      READ(J,2)CFK
    2 FORMAT(10F8.4)
      WRITE(K,3)
    3 FORMAT(1H1,////4X,'FACTORS K ',10X,'CUM.FRQ.',//)
      DO 5 I=1,41
      WRITE(K,4) XKB(I),CFK(I)
    4 FORMAT(4X,F10.4,10X,F10.4)
    5 CONTINUE
      READ(J,1000) OBD
 1000 FORMAT(10F8.4)
      READ(J,1001) CU
 1001 FORMAT(16F5.2)
      READ(J,8)XA
    8 FORMAT(16F5.2)
      XKTT=24.
      XK=1.
      DO 9 I=1,253
      CPD(I)=XK*XKTT*CU(I)*XA(I)
      ERR(I)=ABS(CPD(I)-OBD(I))
    9 CONTINUE
      SUMS=0.
      SUM=0.
      DO 10 I=1,253
      SUM=SUM+ERR(I)
      SUMS=SUMS+ERR(I)**2
   10 CONTINUE
        YN=253.
      XMER=SUM/253.
      STDE=((YN*SUMS-SUM**2)/(YN*(YN-1.)))**.5
      WRITE(K,12)
   12 FORMAT(1H1,///8X,'S.NO.',2X,'OBD',8X,'XA',8X,'CPD',
     18X,'ERR',//)
      DO 15 I=1,253
      WRITE(K,14) I,OBD(I),XA(I),CPD(I),ERR(I)
   14 FORMAT(8X,I3,4X,F5.2,6X,F5.2,6X,F5.2,6X,F5.2)
   15 CONTINUE
      WRITE(K,11) XMER
   11 FORMAT(///4X,'MEAN OF THE ERRORS = ',F10.4)
      WRITE(K,16) STDE
   16 FORMAT(///4X,'STANDARD DEVIATION OF THE ERRORS = ',
     1F10.4)
      XMD=XMER+2.*STDE
      K2=0
      J=1
      DO 406 I=1,253
      IF(ERR(I)-XMD) 405,405,406
  405 OBAD(J)=OBD(I)
      CAU(J)=CU(I)
```

```
      GO TO 27
   30 DELTX=TX(IJ+1)-TX(IJ)
      DELCFY=CFY (IJ+1)-CFY(IJ)
      FRACT=(R(JJ)-CFY(IJ))/DELCFY
      T(JJ)=TX(IJ)+FRACT*DELTX
      GO TO 253
   40 T(JJ)=TX(IJ)
      GO TO 253
   27 CONTINUE
  253 CONTINUE
      T(126)=24.
      DO 400 L=1,KN
      CPX(L)=CAU(L)*T(L)*XAU(L)*XK
      ERX(L)=ABS(OBAD(L)-CPX(L))
  400 CONTINUE
      SUMT=0.
      SUM=0.
      SUMS=0.
      DO 430 L=1,KN
      SUMT=SUMT+T(L)
      SUM=SUM+ERX(L)
      SUMS=SUMS+ERX(L)**2
  430 CONTINUE
      YN=FLOAT(KN)
      XMT(I)=SUMT/YN
      XMERR(I)=SUM/YN
      STERR(I)=((SUMS*YN-SUM**2)/(YN*(YN-1.)))**.5
      XM(I)=XMERR(I)+2.*STERR(I)
      K1(I)=0
      DO 820 II=1,KN
      IF(ERX(II)-XM(I)) 640,640,820
  640 K1(I)=K1(I)+1
  820 CONTINUE
  100 CONTINUE
      WRITE(K,104)
  104 FORMAT(1H1,///4X,'SIM.NO.',4X,'MEAN ERR',4X,'STD.DEV'
     1,4X,'SEED NO.',4X,'NO.OBS.',4X,'MEAN T',//)
      DO 202 MI=1,144
      WRITE(K,106) MI,XMERR(MI),STERR(MI),YY(MI),K1(MI),
     1XMT(MI)
  106 FORMAT(6X,I3,6X,F6.2,6X,F5.2,6X,F8.2,4X,I4,6X,F5.2)
  202 CONTINUE
      Z=XMERR(1)
      MM=1
      DO 185 KK=2,144
      IF(Z.LT.XMERR(KK)) GO TO 185
      MM=KK
      CC=8.*FLOAT(MM)-3.
```

```
      Z=XMERR(KK)
  185 CONTINUE
      WRITE(K,189) MM,Z,CC
  189 FORMAT(1H1,////4X,'SIMULATION NUMBER = ',I6,//4X,
     1'  MINI,MEAN ERROR = ',F10.4,//4X,
     2'SEED NUMBER = ',F10.2)
      DO 1400 I=1,1
      X=725.
      CALL RAND(253.,32768.,X,899.,R)
      DO 354 JJ=1,237
      DO 131 IJ=1,20
      XX(IJ)=R(JJ)-CFY(IJ)
      XX(IJ+1)=R(JJ)-CFY(IJ+1)
      IF(XX(IJ).EQ.0.) GO TO 251
      IF(XX(IJ).GT.0..AND.XX(IJ+1).LT.0.) GO TO 250
      GO TO 131
  250 DELTX=TX(IJ+1)-TX(IJ)
      DELCFY=CFY (IJ+1)-CFY(IJ)
      FRACT=(R(JJ)-CFY(IJ))/DELCFY
      TB(JJ)=TX(IJ)+FRACT*DELTX
      GO TO 354
  251 TB(JJ)=TX(IJ)
      GO TO 354
  131 CONTINUE
  354 CONTINUE
 1400 CONTINUE
      XN=70.
      DO 800 I=1,144
      XN=XN+1.
      X=8.*XN-3.
      YYY(I)=X
      CALL RAND(253.,32768.,X,899.,R)
C     INTERPOLATION FOR COMPUTING THE TIME CORRESPONDING TO
C     THE RANDOM NUMBER FROM THE SET OF RANDOM NUMBERS
C
      DO 553 JJ=1,237
      DO 327 IJ=1,40
      ZX(IJ)=R(JJ)-CFK(IJ)
      ZX(IJ+1)=R(JJ)-CFK(IJ+1)
      IF(ZX(IJ).EQ.0.) GO TO 340
      IF(ZX(IJ).GT.0..AND.ZX(IJ+1).LT.0.) GO TO 330
      GO TO 327
  330 DELXK=XKB(IJ+1)-XKB(IJ)
      DELCFK=CFK (IJ+1)-CFK(IJ)
      FRACT=(R(JJ)-CFK(IJ))/DELCFK
      XKA(JJ)=XKB(IJ)+FRACT*DELXK
      GO TO 553
  340 XKA(JJ)=XKB(IJ)
```

```
      GO TO 553
  327 CONTINUE
  553 CONTINUE
      DO 650 L=1,237
      CPDA(L)=XKA(L)*CAU(L)*XAU(L)*TB(L)
      ERRA(L)=ABS(  OBAD(L)-CPDA(L))
  650 CONTINUE
      SUM=0.
      SUMK=0.
      SS=0.
      DO 660 L=1,237
      SUMK=SUMK+XKA(L)
      SUM=SUM+ERRA(L)
      SS=SS+ERRA(L)**2
  660 CONTINUE
      YN=237.
      XMERA(I)=SUM/YN
      XMK(I)=SUMK/YN
      AS(I)=((SS*YN-SUM**2)/(YN*(YN-1.)))**.5
  800 CONTINUE
      WRITE(K,300)
  300 FORMAT(1H1,///4X,'SIMULATION NUMBER',4X,'MEAN ERROR'
     1,9X,'STD.DEV.',6X,'SEED NO.',4X,'MEAN K',//)
      DO 301 I=1,144
      WRITE(K,302) I,XMERA(I),AS(I),YYY(I),XMK(I)
  302 FORMAT(40X,I4,10X,F10.4,10X,F8.4,4X,F9.2,4X,F8.4)
  301 CONTINUE
C     TO FIND THE MINIMUM MEAN ERROR
      W=XMERA(1)
      NN=1
      DO 180 KK=2,144
      IF(W.LT.XMERA(KK)) GO TO 180
      NN=KK
      AA=8.*(70.+FLOAT(NN))-3.
      W=XMERA(KK)
  180 CONTINUE
      WRITE(K,184) NN,W,AA
  184 FORMAT(1H1,////4X,'SIMULATION NUMBER = ',I6,//4X,
     1'  MINI.MEAN ERROR = ',F10.4,'SEED NUMBER = ',F10.2)
      DO 1500 IMM=1,1
      X=1501.
      CALL RAND(239.,32768.,X,899.,R)
      DO 780 JJ=1,237
      DO 781 IJ=1,40
      ZX(IJ)=R(JJ)-CFK(IJ)
      ZX(IJ+1)=R(JJ)-CFK(IJ+1)
      IF(ZX(IJ).EQ.0.) GO TO 782
      IF(ZX(IJ).GT.0..AND.ZX(IJ+1).LT.0.) GO TO 783
```

```
      GO TO 781
  783 DELXK=XKB(IJ+1)-XKB(IJ)
      DELCFK=CFK (IJ+1)-CFK(IJ)
      FRACT=(R(JJ)-CFK(IJ))/DELCFK
      XKAA(JJ)=XKB(IJ)+FRACT*DELXK
      GO TO 780
  782 XKAA(JJ)=XKB(IJ)
      GO TO 780
  781 CONTINUE
  780 CONTINUE
 1500 CONTINUE
      DO 503 I=1,237
      CPDAA(I)=XKAA(I)*CAU(I)*XAU(I)*TB(I)
      ERRAA(I)=ABS(CPDAA(I)-OBAD(I))
  503 CONTINUE
      WRITE(K,500)
  500 FORMAT(1H1,////3X,'OB.DIST',2X,'AV.FACT',2X,'FACT.K'
     1,2X,' TIME ',2X,'COMP.DIST',2X,'ERROR',//)
      DO 502 I=1,237
      WRITE(K,501) OBAD(I), XAU(I),XKAA(I),TB(I),CPDAA(I),
     1ERRAA(I)
  501 FORMAT(3X,F7.2,3X,F7.2,2X,F6.2,2X,F6.2,2X,F9.2,2X,
     1F5.2)
  502 CONTINUE
      STOP
      END
```

APPENDIX B1

Step 1 - Comparison of Computed and Observed Distances of 253 Observations (Duration of Successive Sightings = 24 Hours and K = 1)

```
      SUBROUTINE RAND(NUM,N,X,C,R)
C                  PSEUDORANDOM NUMBER GENERATOR
C
C     THIS PROGRAM GENERATES PSEUDORANDOM NUMBERS USING
C     THE POWER RESIDUE METHOD, ACCORDING TO WHICH EACH
C     NUMBER IS OBTAINED FROM THE PRECEDING ONE USING THE
C     FORMULA
C
C                   X = C*X (MOD N).
         REAL NUM,N,N1
         DIMENSION R(253)
C
C     NUM=NUMBER OF PAEUDORANDOM NUMBERS DESIRED
C     N=MODULUS
C     X=FIRST NUMBER IN THE SERIES
C     C=THE CONSTANT IN THE POWER RESIDUE FORMULA
C     GENERATES NUM RANDOM NUMBERS,6 AT A TIME
C
         N1=N-1.0
         M=N
         IX=X
         IC=C
      NUM1=NUM
C
C     GENERATE NUM RANDOM NUMBERS, 6 AT A TIME
C
C
         DO 30 J=1,NUM1
C
C     THE NEXT STATEMENT GIVES 10*IX (MOD N) ON COMPUTERS
C     FOR WHICH NUMBERS BIGGER THAN N ARE NOT PERMITTED
C
         IX=IABS(IC*IX)
         IF(IX-N1)20,20,10
C
   10    IX=IX-M*(IX/M)
   20    RAN=IX
C
C     THE NEXT STATEMENT GIVES 10*IX (MOD N) ON COMPUTERS
C     FOR WHICH NUMBERS BIGGER THAN N ARE PERMITTED
C
C
C     DIVIDE BY N-1, SO THAT RAN LIES BETWEEN ZERO AND ONE
C
         RAN=RAN/N1
         R(J)=RAN
   30 CONTINUE
      RETURN
```

S.NO.	OBD	XA	CPD	ERR
1	30.00	0.77	19.59	10.41
2	24.00	0.70	20.83	3.17
3	25.62	0.72	19.70	5.92
4	6.88	0.52	4.74	2.14
5	20.00	0.66	17.90	2.10
6	5.00	0.50	5.64	0.64
7	3.75	0.49	2.82	0.93
8	22.50	0.68	17.46	5.04
9	10.00	0.55	5.68	4.32
10	12.50	0.57	8.76	3.74
11	11.50	0.56	8.33	3.17
12	16.00	0.61	12.00	4.00
13	10.62	0.55	6.60	4.02
14	14.38	0.59	11.47	2.91
15	22.50	0.68	18.44	4.06
16	29.38	0.74	18.65	10.73
17	16.88	0.61	12.88	4.00
18	31.25	0.78	21.53	9.72
19	25.62	0.72	16.93	8.69
20	18.12	0.63	12.85	5.27
21	28.12	0.73	19.10	9.02
22	9.38	0.54	8.68	0.70
23	9.38	0.54	9.59	0.21
24	9.38	0.54	8.94	0.44
25	15.62	0.61	13.91	1.71
26	14.38	0.59	12.74	1.64
27	11.25	0.55	11.22	0.03
28	7.50	0.53	5.85	1.65
29	10.62	0.55	11.48	0.86
30	4.38	0.49	4.70	0.32
31	27.50	0.73	18.57	8.93
32	6.25	0.52	8.24	1.99
33	13.75	0.59	12.18	1.57
34	25.62	0.72	16.24	9.38
35	5.62	0.52	5.62	0.00
36	13.75	0.59	12.04	1.71
37	8.12	0.53	11.45	3.33
38	16.25	0.61	11.71	4.54
39	17.50	0.63	13.61	3.89
40	5.00	0.50	5.40	0.40
41	5.00	0.50	5.52	0.52
42	20.00	0.66	18.37	1.63
43	12.50	0.57	11.08	1.42
44	10.00	0.55	10.30	0.30
45	4.00	0.50	4.80	0.80
46	15.00	0.60	12.96	2.04
47	19.00	0.64	15.97	3.03
48	10.00	0.55	5.28	4.72
49	8.50	0.53	8.01	0.49

S.NO.	OBD	XA	CPD	ERR
50	12.00	0.57	9.44	2.56
51	9.50	0.54	8.42	1.08
52	11.50	0.56	10.75	0.75
53	5.80	0.52	4.99	0.81
54	5.00	0.50	4.80	0.20
55	5.50	0.51	5.51	0.01
56	18.00	0.63	13.61	4.39
57	6.50	0.52	4.37	2.13
58	6.50	0.52	5.62	0.88
59	8.00	0.53	6.36	1.64
60	6.00	0.52	6.24	0.24
61	16.50	0.61	13.18	3.32
62	4.00	0.49	5.88	1.88
63	20.00	0.66	17.42	2.58
64	6.50	0.52	4.37	2.13
65	7.50	0.53	4.45	3.05
66	3.00	0.48	4.61	1.61
67	10.00	0.55	10.03	0.03
68	11.50	0.56	10.62	0.88
69	11.00	0.56	9.95	1.05
70	14.00	0.59	12.74	1.26
71	11.50	0.56	10.48	1.02
72	27.00	0.73	18.92	8.08
73	9.00	0.54	8.29	0.71
74	10.00	0.55	6.47	3.53
75	10.00	0.55	5.28	4.72
76	17.50	0.62	15.33	2.17
77	3.50	0.49	5.88	2.38
78	28.00	0.74	18.83	9.17
79	20.00	0.66	15.05	4.95
80	11.00	0.56	10.75	0.25
81	11.00	0.56	10.35	0.65
82	25.50	0.72	19.01	6.49
83	3.00	0.48	2.30	0.70
84	4.50	0.50	5.40	0.90
85	12.50	0.57	6.16	6.34
86	4.50	0.50	5.40	0.90
87	3.50	0.49	5.29	1.79
88	15.00	0.60	13.54	1.46
89	7.50	0.53	10.81	3.31
90	19.00	0.64	16.90	2.10
91	10.00	0.55	6.60	3.40
92	7.50	0.53	5.34	2.16
93	18.00	0.63	18.60	0.60
94	21.00	0.68	15.50	5.50
95	4.50	0.50	3.48	1.02
96	23.50	0.69	15.90	7.60
97	21.50	0.67	13.67	7.83
98	27.00	0.73	18.22	8.78
99	19.00	0.64	13.06	5.94
100	15.00	0.60	13.82	1.18

S.NO.	OBD	XA	CPD	ERR
101	13,00	0,58	12,53	0,47
102	26,50	0,72	18,14	8,36
103	7,00	0,52	6,74	0,26
104	29,00	0,75	23,04	5,96
105	8,00	0,53	5,85	2,15
106	8,00	0,53	9,03	1,03
107	27,50	0,73	21,72	5,78
108	31,00	0,77	21,25	9,75
109	15,50	0,60	13,97	1,53
110	23,50	0,69	15,73	7,77
111	11,00	0,56	9,95	1,05
112	19,00	0,64	14,75	4,25
113	14,50	0,59	13,45	1,05
114	22,00	0,68	18,60	3,40
115	38,00	0,86	22,70	15,30
116	19,00	0,64	12,90	6,10
117	10,00	0,55	10,30	0,30
118	7,50	0,53	6,49	1,01
119	17,00	0,63	17,24	0,24
120	15,00	0,60	15,98	0,98
121	27,00	0,73	19,27	7,73
122	8,75	0,54	7,26	1,49
123	24,70	0,70	16,13	8,57
124	20,63	0,66	12,99	7,64
125	21,88	0,68	13,71	8,17
126	4,38	0,48	5,88	1,50
127	8,44	0,53	6,49	1,95
128	12,81	0,58	8,35	4,46
129	10,63	0,56	13,84	3,22
130	8,00	0,53	9,54	1,54
131	26,88	0,73	18,40	8,48
132	11,25	0,53	10,30	0,95
133	15,00	0,60	15,98	0,98
134	4,68	0,50	5,76	1,08
135	11,88	0,56	9,27	2,60
136	2,19	0,45	7,02	4,83
137	15,31	0,60	13,54	1,77
138	9,75	0,55	10,03	0,28
139	14,50	0,58	12,81	1,69
140	16,00	0,61	13,91	2,09
141	23,50	0,69	17,72	5,78
142	12,00	0,56	11,56	0,44
143	4,75	0,50	6,00	1,25
144	4,50	0,50	4,80	0,30
145	11,00	0,56	11,56	0,56
146	1,50	0,44	2,11	0,61
147	9,00	0,54	5,18	3,82
148	12,50	0,56	10,75	1,75
149	7,00	0,52	6,24	0,76
150	3,50	0,49	4,70	1,20

S.NO.	OBD	XA	CPD	ERR
151	10,00	0,55	6,60	3,40
152	10,00	0,55	5,28	4,72
153	14,50	0,59	13,03	1,47
154	13,75	0,59	13,88	0,13
155	18,50	0,63	13,61	4,89
156	13,00	0,58	11,41	1,59
157	8,00	0,53	6,36	1,64
158	18,00	0,61	16,10	1,90
159	5,75	0,52	10,48	4,73
160	1,00	0,44	1,27	0,27
161	15,00	0,58	11,83	3,17
162	7,50	0,53	8,78	1,28
163	21,00	0,66	14,26	6,74
164	17,00	0,63	12,55	4,45
165	5,00	0,50	2,40	2,60
166	13,00	0,58	11,14	1,86
167	14,25	0,59	13,59	0,66
168	11,25	0,56	8,47	2,78
169	8,50	0,54	8,04	0,46
170	13,75	0,59	13,88	0,13
171	14,50	0,59	12,60	1,90
172	18,50	0,63	15,27	3,23
173	4,50	0,50	4,80	0,30
174	12,00	0,57	12,72	0,72
175	20,00	0,66	13,46	6,54
176	8,00	0,53	5,09	2,91
177	18,00	0,63	14,06	3,94
178	11,75	0,57	10,81	0,94
179	16,25	0,60	13,39	2,86
180	6,00	0,50	5,40	0,60
181	14,75	0,60	11,38	3,37
182	6,50	0,52	9,98	3,48
183	9,50	0,55	7,92	1,58
184	25,42	0,70	20,16	5,26
185	8,33	0,53	7,50	0,83
186	7,08	0,52	5,62	1,47
187	13,96	0,59	12,32	1,64
188	9,02	0,55	8,84	0,17
189	3,13	0,48	3,92	0,79
190	8,75	0,59	4,81	3,94
191	8,54	0,59	5,66	2,88
192	2,71	0,48	4,61	1,90
193	8,33	0,53	5,72	2,61
194	13,33	0,58	14,06	0,73
195	10,00	0,55	6,20	3,80
196	20,50	0,66	14,26	6,24
197	7,67	0,53	3,82	3,85
198	14,00	0,59	12,32	1,68
199	2,33	0,45	4,32	1,99
200	5,83	0,52	4,99	0,84

S.NO.	OBD	XA	CPD	ERR
201	12.33	0.57	13.00	0.66
202	17.33	0.62	14.28	3.05
203	0.83	0.44	4.75	3.92
204	11.00	0.56	7.26	3.74
205	17.50	0.62	15.33	2.17
206	11.00	0.56	8.06	2.94
207	14.50	0.60	14.98	0.48
208	2.33	0.45	1.84	0.50
209	16.67	0.62	13.39	3.27
210	2.50	0.45	4.32	1.82
211	5.33	0.50	8.28	2.95
212	24.00	0.70	16.30	7.70
213	11.67	0.57	11.49	0.18
214	20.83	0.66	17.58	3.25
215	20.00	0.66	14.41	5.59
216	15.00	0.60	12.96	2.04
217	7.50	0.53	8.27	0.77
218	15.00	0.60	15.55	0.55
219	6.00	0.52	7.86	1.86
220	11.00	0.56	9.41	1.59
221	8.60	0.54	10.63	2.03
222	17.20	0.62	14.58	2.62
223	18.28	0.63	16.18	2.10
224	9.22	0.54	8.29	0.93
225	7.50	0.53	5.09	2.41
226	24.38	0.70	17.64	6.74
227	8.25	0.53	8.01	0.24
228	10.63	0.56	11.02	0.40
229	11.88	0.57	12.31	0.44
230	12.38	0.57	11.76	0.61
231	20.25	0.66	15.05	5.20
232	5.00	0.50	4.80	0.20
233	16.63	0.62	12.65	3.98
234	16.25	0.61	15.66	0.59
235	13.25	0.58	10.86	2.39
236	2.75	0.46	2.54	0.21
237	2.10	0.45	1.84	0.26
238	17.50	0.62	15.77	1.73
239	25.13	0.74	18.65	6.48
240	20.00	0.64	14.59	5.41
241	4.75	0.50	4.92	0.17
242	9.13	0.54	9.59	0.47
243	17.00	0.61	15.96	1.04
244	6.25	0.52	8.11	1.86
245	15.20	0.60	14.11	1.09
246	12.38	0.57	12.31	0.06
247	14.50	0.60	13.68	0.82
248	12.00	0.57	12.04	0.04
249	12.90	0.58	11.69	1.21

S.NO.	OBD	XA	CPD	ERR
250	2,90	0,46	2,76	0,14
251	6,80	0,53	8,90	2,10
252	5,40	0,50	5,04	0,36
253	2,00	0,45	2,48	0,48

MEAN OF THE ERRORS = 2,7281

STANDARD DEVIATION OF THE ERRORS = 2,5926

NUMBER OF NOT REJECTED OBSERVATIONS = 237

APPENDIX B1.A

Step 1 - List of 237 Observation Selected

S.NO.	OBD	XA	CPD	ERR
1	24,00	0,70	20,83	3,17
2	25,62	0,72	19,70	5,92
3	6,88	0,52	4,74	2,14
4	20,00	0,66	17,90	2,10
5	5,00	0,50	5,64	0,64
6	3,75	0,49	2,82	0,93
7	22,50	0,68	17,46	5,04
8	10,00	0,55	5,68	4,32
9	12,50	0,57	8,76	3,74
10	11,50	0,56	8,33	3,17
11	16,00	0,61	12,00	4,00
12	10,62	0,55	6,60	4,02
13	14,38	0,59	11,47	2,91
14	22,50	0,68	18,44	4,06
15	16,88	0,61	12,88	4,00
16	18,12	0,63	12,85	5,27
17	9,38	0,54	8,68	0,70
18	9,38	0,54	9,59	0,21
19	9,38	0,54	8,94	0,44
20	15,62	0,61	13,91	1,71
21	14,38	0,59	12,74	1,64
22	11,25	0,55	11,22	0,03
23	7,50	0,53	5,85	1,65
24	10,62	0,55	11,48	0,86
25	4,38	0,49	4,70	0,32
26	6,25	0,52	8,24	1,99
27	13,75	0,59	12,18	1,57
28	5,62	0,52	5,62	0,00
29	13,75	0,59	12,04	1,71
30	8,12	0,53	11,45	3,33
31	16,25	0,61	11,71	4,54
32	17,50	0,63	13,61	3,89
33	5,00	0,50	5,40	0,40
34	5,00	0,50	5,52	0,52
35	20,00	0,66	18,37	1,63
36	12,50	0,57	11,08	1,42
37	10,00	0,55	10,30	0,30
38	4,00	0,50	4,80	0,80
39	15,00	0,60	12,96	2,04
40	19,00	0,64	15,97	3,03
41	10,00	0,55	5,28	4,72
42	8,50	0,53	8,01	0,49
43	12,00	0,57	9,44	2,56
44	9,50	0,54	8,42	1,08
45	11,50	0,56	10,75	0,75
46	5,80	0,52	4,99	0,81
47	5,00	0,50	4,80	0,20
48	5,50	0,51	5,51	0,01
49	18,00	0,63	13,61	4,39
50	6,50	0,52	4,37	2,13

S.NO.	OBD	XA	CPD	ERR
51	6.50	0.52	5.62	0.88
52	8.00	0.53	6.36	1.64
53	6.00	0.52	6.24	0.24
54	16.50	0.61	13.18	3.32
55	4.00	0.49	5.88	1.88
56	20.00	0.66	17.42	2.58
57	6.50	0.52	4.37	2.13
58	7.50	0.53	4.45	3.05
59	3.00	0.48	4.61	1.61
60	10.00	0.55	10.03	0.03
61	11.50	0.56	10.62	0.88
62	11.00	0.56	9.95	1.05
63	14.00	0.59	12.74	1.26
64	11.50	0.56	10.48	1.02
65	9.00	0.54	8.29	0.71
66	10.00	0.55	6.47	3.53
67	10.00	0.55	5.28	4.72
68	17.50	0.62	15.33	2.17
69	3.50	0.49	5.88	2.38
70	20.00	0.66	15.05	4.95
71	11.00	0.56	10.75	0.25
72	11.00	0.56	10.35	0.65
73	25.50	0.72	19.01	6.49
74	3.00	0.48	2.30	0.70
75	4.50	0.50	5.40	0.90
76	12.50	0.57	6.16	6.34
77	4.50	0.50	5.40	0.90
78	3.50	0.49	5.29	1.79
79	15.00	0.60	13.54	1.46
80	7.50	0.53	10.81	3.31
81	19.00	0.64	16.90	2.10
82	10.00	0.55	6.60	3.40
83	7.50	0.53	5.34	2.16
84	18.00	0.63	18.60	0.60
85	21.00	0.68	15.50	5.50
86	4.50	0.50	3.48	1.02
87	23.50	0.69	15.90	7.60
88	21.50	0.67	13.67	7.83
89	19.00	0.64	13.06	5.94
90	15.00	0.60	13.82	1.18
91	13.00	0.58	12.53	0.47
92	7.00	0.52	6.74	0.26
93	29.00	0.75	23.04	5.96
94	8.00	0.53	5.85	2.15
95	8.00	0.53	9.03	1.03
96	27.50	0.73	21.72	5.78
97	15.50	0.60	13.97	1.53
98	23.50	0.69	15.73	7.77
99	11.00	0.56	9.95	1.05
100	19.00	0.64	14.75	4.25

S.NO.	OBD	XA	CPD	ERR
101	14,50	0,59	13,45	1,05
102	22,00	0,68	18,60	3,40
103	19,00	0,64	12,90	6,10
104	10,00	0,55	10,30	0,30
105	7,50	0,53	6,49	1,01
106	17,00	0,63	17,24	0,24
107	15,00	0,60	15,98	0,98
108	27,00	0,73	19,27	7,73
109	8,75	0,54	7,26	1,49
110	20,63	0,66	12,99	7,64
111	4,38	0,48	5,88	1,50
112	8,44	0,53	6,49	1,95
113	12,81	0,58	8,35	4,46
114	10,63	0,56	13,84	3,22
115	8,00	0,53	9,54	1,54
116	11.25	0,53	10,30	0,95
117	15,00	0,60	15,98	0,98
118	4,68	0,50	5,76	1,08
119	11,88	0,56	9,27	2,60
120	2,19	0,45	7,02	4,83
121	15,31	0,60	13,54	1,77
122	9,75	0,55	10,03	0,28
123	14,50	0,58	12,81	1,69
124	16,00	0,61	13,91	2,09
125	23,50	0,69	17,72	5,78
126	12,00	0,56	11,56	0,44
127	4,75	0,50	6,00	1,25
128	4,50	0,50	4,80	0,30
129	11,00	0,56	11,56	0,56
130	1,50	0,44	2,11	0,61
131	9,00	0,54	5,18	3,82
132	12,50	0,56	10,75	1,75
133	7,00	0,52	6,24	0,76
134	3,50	0,49	4,70	1,20
135	10,00	0,55	6,60	3,40
136	10,00	0,55	5,28	4,72
137	14,50	0,59	13,03	1,47
138	13,75	0,59	13,88	0,13
139	18,50	0,63	13,61	4,89
140	13,00	0,58	11,41	1,59
141	8,00	0,53	6,36	1,64
142	18,00	0,61	16,10	1,90
143	5,75	0,52	10,48	4,73
144	1,00	0,44	1,27	0,27
145	15,00	0,58	11,83	3,17
146	7,50	0,53	8,78	1,28
147	21,00	0,66	14,26	6,74
148	17,00	0,63	12,55	4,45
149	5,00	0,50	2,40	2,60
150	13,00	0,58	11,14	1,86

S.NO.	OBD	XA.	CPD	ERR
151	14,25	0,59	13,59	0,66
152	11,25	0,56	8,47	2,78
153	8,50	0,54	8,04	0,46
154	13,75	0,58	13,88	0,13
155	14,50	0,59	12,60	1,90
156	18,50	0,63	15,27	3,23
157	4,50	0,50	4,80	0,30
158	12,00	0,57	12,72	0,72
159	20,00	0,66	13,46	6,54
160	8,00	0,53	5,09	2,91
161	18,00	0,63	14,06	3,94
162	11,75	0,57	10,81	0,94
163	16,25	0,60	13,39	2,86
164	6,00	0,50	5,40	0,60
165	14,75	0,60	11,38	3,37
166	6,50	0,52	9,98	3,48
167	9,50	0,55	7,92	1,58
168	25,42	0,70	20,16	5,26
169	8,33	0,53	7,50	0,83
170	7,08	0,52	5,62	1,47
171	13,96	0,59	12,32	1,64
172	9,02	0,55	8,84	0,17
173	3,13	0,48	3,92	0,79
174	8,75	0,59	4,81	3,94
175	8,54	0,59	5,66	2,88
176	2,71	0,48	4,61	1,90
177	8,33	0,53	5,72	2,61
178	13,33	0,58	14,06	0,73
179	10,00	0,55	6,20	3,80
180	20,50	0,66	14,26	6,24
181	7,67	0,53	3,82	3,85
182	14,00	0,59	12,32	1,68
183	2,33	0,45	4,32	1,99
184	6,83	0,52	4,99	0,84
185	12,33	0,57	13,00	0,66
186	17,33	0,62	14,28	3,05
187	0,83	0,44	4,75	3,92
188	11,00	0,56	7,26	3,74
189	17,50	0,62	15,33	2,17
190	11,00	0,56	8,06	2,94
191	14,50	0,60	14,98	0,48
192	2,33	0,45	1,84	0,50
193	16,67	0,62	13,39	3,27
194	2,50	0,45	4,32	1,82
195	5,33	0,50	8,28	2,95
196	24,00	0,70	16,30	7,70
197	11,67	0,57	11,49	0,18
198	20,83	0,66	17,58	3,25
199	20,00	0,66	14,41	5,59
200	15,00	0,60	12,96	2,04

S.NO.	OBD	XA	CPD	ERR
201	7,50	0,53	8,27	0,77
202	15,00	0,60	15,55	0,55
203	6,00	0,52	7,86	1,86
204	11,00	0,56	9,41	1,59
205	8,60	0,54	10,63	2,03
206	17,20	0,62	14,58	2,62
207	18,28	0,63	16,18	2,10
208	9,22	0,54	8,29	0,93
209	7,50	0,53	5,09	2,41
210	24,38	0,70	17,64	6,74
211	8,25	0,53	8,01	0,24
212	10,63	0,56	11,02	0,40
213	11,88	0,57	12,31	0,44
214	12,38	0,57	11,76	0,61
215	20,25	0,66	15,05	5,20
216	5,00	0,50	4,80	0,20
217	16,63	0,62	12,65	3,98
218	16,25	0,61	15,66	0,59
219	13,25	0,58	10,86	2,39
220	2,75	0,46	2,54	0,21
221	2,10	0,45	1,84	0,26
222	17,50	0,62	15,77	1,73
223	25,13	0,74	18,65	6,48
224	20,00	0,64	14,59	5,41
225	4,75	0,50	4,92	0,17
226	9,13	0,54	9,59	0,47
227	17,00	0,61	15,96	1,04
228	6,25	0,52	8,11	1,86
229	15,20	0,60	14,11	1,09
230	12,38	0,57	12,31	0,06
231	14,50	0,60	13,68	0,82
232	12,00	0,57	12,04	0,04
233	12,90	0,58	11,69	1,21
234	2,90	0,46	2,76	0,14
235	6,80	0,53	8,90	2,10
236	5,40	0,50	5,04	0,36
237	2,00	0,45	2,48	0,48

MEAN OF THE ERRORS = 2,2730

STANDARD DEVIATION OF THE ERRORS = 1,9228

APPENDIX B2

Step 2 - Comparison of the Computed and Observed Distances of Icebergs (Simulating Time T)

SIM.NO.	MEAN ERR	STD.DEV.	SEED NO.	NO.OBS.	MEAN T
1	2.58	2.18	5.00	226	23.44
2	2.48	2.10	13.00	224	23.64
3	2.59	2.28	21.00	220	23.44
4	2.67	2.17	29.00	224	23.27
5	2.56	2.34	37.00	224	23.07
6	2.58	2.17	45.00	225	23.53
7	2.77	2.44	53.00	222	23.36
8	2.53	2.16	61.00	223	23.55
9	2.65	2.25	69.00	222	23.35
10	2.79	2.31	77.00	223	23.40
11	2.67	2.19	85.00	229	23.60
12	2.70	2.28	93.00	226	23.39
13	2.76	2.19	101.00	225	23.39
14	2.55	2.09	109.00	223	23.63
15	2.58	2.24	117.00	225	23.42
16	2.50	2.28	125.00	225	23.63
17	2.71	2.31	133.00	225	23.12
18	2.51	2.16	141.00	226	23.58
19	2.60	2.23	149.00	226	23.59
20	2.52	2.07	157.00	224	23.59
21	2.51	2.12	165.00	227	23.43
22	2.71	2.35	173.00	221	23.41
23	2.80	2.27	181.00	220	23.32
24	2.65	2.25	189.00	225	23.35
25	2.66	2.26	197.00	226	23.51
26	2.71	2.23	205.00	224	23.37
27	2.62	2.17	213.00	227	23.43
28	2.63	2.27	221.00	224	23.36
29	2.56	2.14	229.00	225	23.51
30	2.66	2.22	237.00	224	23.28
31	2.57	2.16	245.00	225	23.49
32	2.60	2.21	253.00	223	23.81
33	2.59	2.32	261.00	223	23.50
34	2.68	2.16	269.00	227	23.53
35	2.64	2.23	277.00	226	23.54
36	2.68	2.14	285.00	228	23.06
37	2.56	2.31	293.00	224	23.54
38	2.59	2.24	301.00	226	23.43
39	2.63	2.27	309.00	225	23.37
40	2.42	2.20	317.00	226	23.81
41	2.69	2.18	325.00	225	23.26
42	2.61	2.17	333.00	224	23.77
43	2.64	2.36	341.00	228	23.61
44	2.47	2.16	349.00	226	23.54
45	2.58	2.25	357.00	225	23.46
46	2.70	2.36	365.00	225	23.57
47	2.70	2.34	373.00	222	23.40
48	2.52	2.13	381.00	225	23.77
49	2.61	2.20	389.00	223	23.49
50	2.67	2.42	397.00	221	23.36

SIM.NO.	MEAN ERR	STD.DEV.	SEED NO.	NO.CBS.	MEAN T
51	2.67	2.30	405.00	221	23.58
52	2.60	2.12	413.00	226	23.37
53	2.44	2.06	421.00	224	23.84
54	2.65	2.21	429.00	225	23.44
55	2.69	2.36	437.00	224	23.53
56	2.75	2.36	445.00	225	23.37
57	2.56	2.21	453.00	226	23.54
58	2.54	2.13	461.00	226	23.49
59	2.71	2.25	469.00	223	23.27
60	2.64	2.25	477.00	224	23.65
61	2.44	2.25	485.00	222	23.72
62	2.60	2.28	493.00	226	23.55
63	2.56	2.10	501.00	223	23.53
64	2.59	2.24	509.00	225	23.22
65	2.63	2.13	517.00	227	23.69
66	2.56	2.24	525.00	226	23.34
67	2.53	2.08	533.00	227	23.52
68	2.67	2.20	541.00	221	23.33
69	2.71	2.35	549.00	226	23.63
70	2.66	2.45	557.00	224	23.48
71	2.70	2.20	565.00	226	23.20
72	2.58	2.19	573.00	225	23.57
73	2.53	2.16	581.00	223	23.49
74	2.50	2.26	589.00	222	23.76
75	2.62	2.29	597.00	225	23.27
76	2.59	2.10	605.00	226	23.42
77	2.46	2.25	613.00	222	23.87
78	2.59	2.12	621.00	224	23.75
79	2.66	2.26	629.00	223	22.99
80	2.58	2.31	637.00	226	23.48
81	2.59	2.22	645.00	227	23.47
82	2.55	2.19	653.00	226	23.60
83	2.65	2.21	661.00	228	23.35
84	2.60	2.09	669.00	227	23.70
85	2.62	2.18	677.00	223	23.99
86	2.64	2.24	685.00	223	23.58
87	2.73	2.39	693.00	224	23.35
88	2.49	2.18	701.00	227	23.54
89	2.68	2.24	709.00	226	23.48
90	2.45	2.22	717.00	226	23.92
91	2.34	1.96	725.00	226	23.67
92	2.66	2.36	733.00	229	23.50
93	2.68	2.49	741.00	224	23.43
94	2.70	2.26	749.00	224	23.26
95	2.60	2.17	757.00	224	23.25
96	2.72	2.38	765.00	222	23.45
97	2.47	2.23	773.00	222	23.77
98	2.69	2.26	781.00	222	23.39
99	2.59	2.17	789.00	225	23.27
100	2.65	2.29	797.00	228	23.42

SIM.NO.	MEAN ERR	STD.DEV.	SEED NO.	NO.OBS.	MEAN T
101	2.58	2.23	805.00	222	23.56
102	2.57	2.24	813.00	222	23.59
103	2.64	2.24	821.00	222	23.64
104	2.56	2.30	829.00	224	23.84
105	2.56	2.24	837.00	228	23.45
106	2.61	2.27	845.00	226	23.61
107	2.66	2.18	853.00	228	23.57
108	2.61	2.23	861.00	224	23.77
109	2.57	2.16	869.00	225	23.68
110	2.56	2.20	877.00	221	23.41
111	2.68	2.28	885.00	223	23.31
112	2.67	2.37	893.00	226	23.88
113	2.44	2.13	901.00	226	23.68
114	2.54	2.05	909.00	223	23.62
115	2.55	2.11	917.00	227	23.61
116	2.67	2.47	925.00	226	23.54
117	2.55	2.23	933.00	222	23.48
118	2.61	2.27	941.00	222	23.65
119	2.65	2.34	949.00	224	23.72
120	2.61	2.09	957.00	225	23.37
121	2.47	2.28	965.00	226	23.73
122	2.56	2.14	973.00	223	23.59
123	2.59	2.17	981.00	227	23.56
124	2.68	2.18	989.00	226	23.65
125	2.68	2.42	997.00	224	23.47
126	2.53	2.11	1005.00	225	23.21
127	2.64	2.19	1013.00	223	23.47
128	2.50	2.22	1021.00	222	23.48
129	2.67	2.27	1029.00	226	23.48
130	2.62	2.22	1037.00	226	23.47
131	2.54	2.16	1045.00	225	23.52
132	2.60	2.17	1053.00	225	23.43
133	2.61	2.18	1061.00	223	23.46
134	2.65	2.18	1069.00	225	23.18
135	2.67	2.25	1077.00	226	23.18
136	2.51	2.12	1085.00	222	23.80
137	2.59	2.18	1093.00	225	23.83
138	2.60	2.03	1101.00	227	23.71
139	2.65	2.31	1109.00	224	23.52
140	2.64	2.32	1117.00	225	23.33
141	2.54	2.07	1125.00	222	23.58
142	2.58	2.25	1133.00	226	23.64
143	2.72	2.43	1141.00	224	23.02
144	2.72	2.42	1149.00	223	23.38

SIMULATION NUMBER = 91

MINI.MEAN ERROR = 2.3402

SEED NUMBER = 725.00

APPENDIX B3

Step 3 - Comparison of the Computed and Observed Distances of Icebergs (Simulating K)

C/1

SIM. NO	MEAN ERROR	STD.DEV.	SEED NO.	MEAN K
1	2,1183	1,6533	565,00	1,0891
2	2,1040	1,6629	573,00	1,0973
3	2,0532	1,7142	581,00	1,0956
4	2,0640	1,7439	589,00	1,1020
5	2,0781	1,7370	597,00	1,0912
6	2,0673	1,5943	605,00	1,0938
7	2,0760	1,6994	613,00	1,1042
8	2,0741	1,6152	621,00	1,1015
9	2,0260	1,6956	629,00	1,0850
10	2,0798	1,7475	637,00	1,0959
11	2,0742	1,7288	645,00	1,0949
12	2,0614	1,6571	653,00	1,0972
13	2,0737	1,6344	661,00	1,0926
14	2,0840	1,6238	669,00	1,1006
15	2,1715	1,6005	677,00	1,1073
16	2,0826	1,6996	685,00	1,0973
17	2,1114	1,7075	693,00	1,0926
18	2,0525	1,6458	701,00	1,0962
19	2,0815	1,7521	709,00	1,0951
20	2,0426	1,6766	717,00	1,1056
21	2,2224	1,7535	725,00	1,0993
22	2,1450	1,7329	733,00	1,0961
23	2,0734	1,7806	741,00	1,0945
24	2,0974	1,6694	749,00	1,0910
25	2,0779	1,6940	757,00	1,0911
26	2,1182	1,7398	765,00	1,0945
27	2,0038	1,5863	773,00	1,1020
28	2,0657	1,7265	781,00	1,0935
29	1,9895	1,6694	789,00	1,0911
30	2,1179	1,6587	797,00	1,0947
31	2,0337	1,6185	805,00	1,0971
32	2,1001	1,6902	813,00	1,0972
33	2,0791	1,7183	821,00	1,0992
34	2,0662	1,6708	829,00	1,1037
35	2,1089	1,6401	837,00	1,0954
36	2,1032	1,6354	845,00	1,0984
37	2,0945	1,6574	853,00	1,0974
38	2,0465	1,6839	861,00	1,1020
39	2,0602	1,6632	869,00	1,1004
40	1,9899	1,6728	877,00	1,0944
41	2,1354	1,6804	885,00	1,0917
42	2,1419	1,7138	893,00	1,1043
43	2,0100	1,6529	901,00	1,1001
44	2,0797	1,6196	909,00	1,0988
45	2,0626	1,6338	917,00	1,0989
46	2,1500	1,7314	925,00	1,0966
47	2,0126	1,6235	933,00	1,0955
48	2,1188	1,6518	941,00	1,0986
49	2,0869	1,6876	949,00	1,1013
50	2,0285	1,6230	957,00	1,0936

SIM. NO	MEAN ERROR	STD.DEV.	SEED NO.	MEAN K
51	1,9930	1,6593	965,00	1,1008
52	2,1032	1,5672	973,00	1,0978
53	2,0847	1,6804	981,00	1,0964
54	2,0503	1,7136	989,00	1,0994
55	2,0783	1,7562	997,00	1,0958
56	2,0353	1,5710	1005,00	1,0894
57	2,1019	1,6116	1013,00	1,0953
58	2,0859	1,6389	1021,00	1,0954
59	2,0963	1,7111	1029,00	1,0958
60	2,0786	1,6553	1037,00	1,0959
61	2,0324	1,6607	1045,00	1,0962
62	2,0496	1,6360	1053,00	1,0943
63	2,0492	1,6199	1061,00	1,0947
64	2,0680	1,7150	1069,00	1,0890
65	2,0572	1,6691	1077,00	1,0895
66	2,0463	1,6047	1085,00	1,1026
67	2,1343	1,6886	1093,00	1,1033
68	2,1018	1,5884	1101,00	1,1008
69	2,1005	1,6882	1109,00	1,0959
70	2,0754	1,7422	1117,00	1,0930
71	2,0218	1,5928	1125,00	1,0977
72	2,0610	1,6852	1133,00	1,0988
73	2,1225	1,7286	1141,00	1,0855
74	2,1205	1,7096	1149,00	1,0936
75	2,1182	1,7590	1157,00	1,0984
76	2,1001	1,7185	1165,00	1,0978
77	2,0472	1,6601	1173,00	1,0965
78	2,0407	1,6694	1181,00	1,1009
79	2,0854	1,7090	1189,00	1,0925
80	2,0646	1,7063	1197,00	1,0897
81	2,1090	1,6404	1205,00	1,0901
82	2,0399	1,6746	1213,00	1,0928
83	2,0624	1,6837	1221,00	1,0961
84	2,1816	1,7128	1229,00	1,0980
85	2,0757	1,6854	1237,00	1,0949
86	2,0828	1,6792	1245,00	1,0936
87	2,0756	1,7076	1253,00	1,0979
88	2,0732	1,7534	1261,00	1,1019
89	2,1460	1,7334	1269,00	1,0972
90	2,1422	1,7054	1277,00	1,0948
91	2,0379	1,7090	1285,00	1,0925
92	1,9878	1,6864	1293,00	1,1062
93	2,1079	1,7046	1301,00	1,0965
94	1,9926	1,5520	1309,00	1,0960
95	2,0343	1,6600	1317,00	1,0965
96	2,0818	1,7128	1325,00	1,0847
97	2,0758	1,7372	1333,00	1,0977
98	2,0356	1,6457	1341,00	1,0938
99	2,1199	1,7286	1349,00	1,0866
100	2,0627	1,5731	1357,00	1,0941

SIM. NO.	MEAN ERROR	STD.DEV.	SEED NO.	MEAN K
101	2,1155	1,6680	1365,00	1,0939
102	2,0552	1,6860	1373,00	1,0981
103	2,0911	1,6062	1381,00	1,0993
104	2,0257	1,7489	1389,00	1,0963
105	2,1081	1,7838	1397,00	1,0847
106	2,1241	1,6670	1405,00	1,0965
107	2,1413	1,7341	1413,00	1,0941
108	2,0986	1,6865	1421,00	1,0907
109	2,0704	1,6801	1429,00	1,1007
110	2,0805	1,6918	1437,00	1,0973
111	2,0428	1,6519	1445,00	1,1031
112	2,1233	1,6298	1453,00	1,0878
113	2,1009	1,7658	1461,00	1,0972
114	1,9961	1,6792	1469,00	1,0960
115	2,0333	1,7255	1477,00	1,0909
116	2,0948	1,6693	1485,00	1,0939
117	2,0804	1,7665	1493,00	1,0890
118	1,9784	1,5936	1501,00	1,1008
119	2,1034	1,7569	1509,00	1,1018
120	2,0882	1,6817	1517,00	1,0943
121	2,0156	1,6733	1525,00	1,0969
122	2,0721	1,7067	1533,00	1,0931
123	2,0605	1,6798	1541,00	1,0939
124	2,0991	1,7554	1549,00	1,0873
125	2,1037	1,6002	1557,00	1,0966
126	2,0633	1,6684	1565,00	1,0940
127	2,0982	1,6670	1573,00	1,0936
128	2,1174	1,6910	1581,00	1,0941
129	2,0146	1,6424	1589,00	1,0910
130	2,1288	1,7486	1597,00	1,1028
131	2,0530	1,6293	1605,00	1,0968
132	2,0746	1,6014	1613,00	1,0945
133	2,1257	1,6722	1621,00	1,0952
134	2,0475	1,7358	1629,00	1,0972
135	2,0582	1,7150	1637,00	1,0885
136	2,0114	1,6855	1645,00	1,0952
137	2,0480	1,6513	1653,00	1,0871
138	2,1367	1,7586	1661,00	1,0925
139	2,0674	1,6675	1669,00	1,0978
140	2,0406	1,6775	1677,00	1,0930
141	2,0695	1,6656	1685,00	1,0951
142	2,0451	1,6078	1693,00	1,0920
143	1,9938	1,6853	1701,00	1,0980
144	2,1048	1,6321	1709,00	1,0908

SIMULATION NUMBER = 118

MINI,MEAN ERROR = 1,9784

SEED NUMBER = 1501,00

APPENDIX B4

Comparison of Computed and Observed Distances of Icebergs - Summarizing Steps 1, 2, and 3

OB.DIST	AV.FACT	FACT.K	TIME	COMP.DIST	ERROR
24,00	0,70	1,03	27,20	24,41	0,41
25,62	0,72	1,03	24,62	20,84	4,78
6,88	0,52	1,18	22,33	5,21	1,67
20,00	0,66	1,07	26,13	20,84	0,84
5,00	0,50	1,10	20,76	5,37	0,37
3,75	0,49	1,10	22,24	2,88	0,87
22,50	0,68	1,21	26,95	23,66	1,16
10,00	0,55	1,06	25,03	6,30	3,70
12,50	0,57	1,17	25,88	11,09	1,41
11,50	0,56	1,18	28,50	11,66	0,16
16,00	0,61	1,20	20,25	12,11	3,89
10,62	0,55	1,00	26,14	7,20	3,42
14,38	0,59	1,11	18,82	9,99	4,39
22,50	0,68	1,07	24,25	19,89	2,61
16,88	0,61	1,04	23,70	13,27	3,61
18,12	0,63	1,14	21,66	13,23	4,89
9,38	0,54	0,98	22,70	8,07	1,31
9,38	0,54	0,95	22,82	8,69	0,69
9,38	0,54	1,03	22,76	8,78	0,60
15,62	0,61	1,09	21,10	13,31	2,31
14,38	0,59	1,12	20,45	12,11	2,27
11,25	0,55	0,98	23,60	10,83	0,42
7,50	0,53	1,04	20,30	5,15	2,35
10,62	0,55	1,07	25,64	13,09	2,47
4,38	0,49	1,13	25,34	5,60	1,22
6,25	0,52	1,10	17,69	6,70	0,45
13,75	0,59	1,12	20,13	11,46	2,29
5,62	0,52	1,10	17,66	4,53	1,09
13,75	0,59	1,11	23,31	13,03	0,72
8,12	0,53	1,12	19,30	10,33	2,21
16,25	0,61	1,19	25,42	14,72	1,53
17,50	0,63	1,00	20,34	11,56	5,94
5,00	0,50	1,15	25,81	6,67	1,67
5,00	0,50	1,09	26,09	6,56	1,56
20,00	0,66	1,07	22,18	18,14	1,86
12,50	0,57	1,04	21,42	10,27	2,23
10,00	0,55	1,11	16,30	7,75	2,25
4,00	0,50	1,03	22,02	4,54	0,54
15,00	0,60	1,07	21,85	12,59	2,41
19,00	0,64	1,24	23,11	19,04	0,04
10,00	0,55	1,07	23,83	5,62	4,38
8,50	0,53	1,16	25,41	9,84	1,34
12,00	0,57	1,05	32,78	13,55	1,55
9,50	0,54	1,10	26,94	10,44	0,94
11,50	0,56	1,10	25,67	12,61	1,11
5,80	0,52	1,11	20,90	4,83	0,97
5,00	0,50	1,09	26,28	5,74	0,74
5,50	0,51	0,98	24,69	5,53	0,03
18,00	0,63	1,08	17,85	10,91	7,09

OB.DIST	AV.FACT	FACT.K	TIME	COMP.DIST	ERROR
6,50	0,52	1,11	26,30	5,31	1,19
6,50	0,52	1,08	20,14	5,07	1,43
8,00	0,53	1,11	27,52	8,06	0,06
6,00	0,52	1,08	25,40	7,13	1,13
16,50	0,61	1,19	25,43	16,63	0,13
4,00	0,49	1,07	22,05	5,77	1,77
20,00	0,66	1,05	25,68	19,57	0,43
6,50	0,52	1,19	21,33	4,61	1,89
7,50	0,53	1,14	18,89	3,99	3,51
3,00	0,48	1,14	25,45	5,55	2,55
10,00	0,55	1,04	22,29	9,73	0,27
11,50	0,56	1,06	27,84	13,01	1,51
11,00	0,56	1,03	23,00	11,93	0,93
14,00	0,59	1,19	25,83	16,35	2,35
11,50	0,56	1,12	25,84	12,59	1,09
9,00	0,54	1,18	20,50	8,35	0,65
10,00	0,55	1,06	23,23	6,64	3,36
10,00	0,55	1,06	26,18	6,10	3,90
17,50	0,62	1,10	20,82	14,67	2,83
3,50	0,49	1,02	22,19	5,53	2,03
20,00	0,66	1,06	25,89	17,21	2,79
11,00	0,56	1,04	21,07	9,85	1,15
11,00	0,56	1,02	25,10	11,07	0,07
25,50	0,72	1,07	26,13	22,09	3,41
3,00	0,48	1,05	17,18	1,74	1,26
4,50	0,50	1,00	22,36	5,04	0,54
12,50	0,57	1,10	23,06	6,50	6,00
4,50	0,50	1,19	28,84	7,75	3,25
3,50	0,49	1,07	21,85	5,15	1,65
15,00	0,60	1,05	24,37	14,40	0,60
7,50	0,53	1,16	23,73	12,37	4,87
19,00	0,64	1,05	20,57	15,23	3,77
10,00	0,55	1,12	25,38	7,83	2,17
7,50	0,53	1,00	22,44	5,01	2,49
18,00	0,63	1,03	19,55	15,57	2,43
21,00	0,68	1,13	26,13	19,10	1,90
4,50	0,50	1,06	23,19	3,57	0,93
23,50	0,69	1,24	29,92	24,48	0,98
21,50	0,67	1,12	21,59	13,81	7,69
19,00	0,64	1,12	21,44	13,06	5,94
15,00	0,60	1,08	24,26	15,14	0,14
13,00	0,58	1,06	26,57	14,71	1,71
7,00	0,52	1,09	20,48	6,25	0,75
29,00	0,75	1,09	26,92	28,08	0,92
8,00	0,53	1,03	21,72	5,45	2,55
8,00	0,53	1,08	22,10	9,02	1,02
27,50	0,73	1,12	27,54	27,97	0,47
15,50	0,60	1,09	18,45	11,75	3,75
23,50	0,69	1,12	24,46	17,89	5,61

OB.DIST	AV.FACT	FACT.K	TIME	COMP.DIST	ERROR
11.00	0.56	1.14	25.96	12.26	1.26
19.00	0.64	1.08	24.52	16.22	2.78
14.50	0.59	1.03	20.42	11.78	2.72
22.00	0.68	1.19	25.63	23.73	1.73
19.00	0.64	1.11	24.50	14.68	4.32
10.00	0.55	1.15	23.17	11.45	1.45
7.50	0.53	1.16	24.01	7.51	0.01
17.00	0.63	1.04	26.10	19.54	2.54
15.00	0.60	1.08	21.04	15.12	0.12
27.00	0.73	1.28	23.55	24.20	2.80
8.75	0.54	1.16	24.75	8.71	0.04
20.63	0.66	1.11	27.23	16.40	4.23
4.38	0.48	1.10	27.50	7.38	3.00
8.44	0.53	1.01	27.58	7.54	0.90
12.81	0.58	1.11	26.12	10.13	2.68
10.63	0.56	1.04	20.24	12.17	1.54
8.00	0.53	1.06	19.49	8.18	0.18
11.25	0.53	1.05	25.94	11.70	0.45
15.00	0.60	1.09	22.58	16.46	1.46
4.68	0.50	1.03	24.92	6.18	1.50
11.88	0.56	1.01	20.35	7.98	3.89
2.19	0.45	1.11	21.63	7.00	4.81
15.31	0.60	1.17	25.67	16.97	1.66
9.75	0.55	1.12	24.55	11.46	1.71
14.50	0.58	1.07	23.12	13.25	1.25
16.00	0.61	1.03	23.33	13.95	2.05
23.50	0.69	1.02	22.10	16.57	6.93
12.00	0.56	1.12	20.07	10.86	1.14
4.75	0.50	1.09	22.45	6.09	1.34
4.50	0.50	1.04	23.77	4.92	0.42
11.00	0.56	1.11	23.03	12.34	1.34
1.50	0.44	1.08	21.76	2.08	0.58
9.00	0.54	1.13	21.65	5.28	3.72
12.50	0.56	1.14	24.04	12.27	0.23
7.00	0.52	1.13	23.36	6.87	0.13
3.50	0.49	0.99	21.25	4.12	0.62
10.00	0.55	1.09	23.85	7.18	2.82
10.00	0.55	1.22	25.18	6.73	3.27
14.50	0.59	1.15	26.41	16.52	2.02
13.75	0.59	1.12	19.40	12.59	1.16
18.50	0.63	1.05	23.98	14.21	4.29
13.00	0.58	1.22	19.10	11.11	1.89
8.00	0.53	1.05	26.76	7.46	0.54
18.00	0.61	1.07	30.52	21.92	3.92
5.75	0.52	1.05	25.07	11.53	5.78
1.00	0.44	1.18	25.93	1.61	0.61
15.00	0.58	1.09	28.30	15.20	0.20
7.50	0.53	1.06	18.50	7.15	0.35
21.00	0.66	1.24	22.13	16.28	4.72
17.00	0.63	1.17	29.81	18.18	1.18

OB.DIST	AV.FACT	FACT.K	TIME	COMP.DIST	ERROR
5,00	0,50	1,15	23,17	2,66	2,34
13,00	0,58	1,11	22,76	11,68	1,32
14,25	0,59	1,14	26,27	16,98	2,73
11,25	0,56	1,24	25,79	11,24	0,01
8,50	0,54	1,11	25,78	9,61	1,11
13,75	0,59	1,06	20,58	12,65	1,10
14,50	0,59	1,21	23,91	15,17	0,67
18,50	0,63	1,08	21,86	14,98	3,52
4,50	0,50	1,06	21,64	4,57	0,07
12,00	0,57	1,13	23,31	13,90	1,90
20,00	0,66	1,21	27,34	18,74	1,26
8,00	0,53	1,04	24,80	5,49	2,51
18,00	0,63	1,04	22,11	13,48	4,52
11,75	0,57	1,14	23,08	11,86	0,11
16,25	0,60	1,02	21,46	12,26	3,99
6,00	0,50	1,11	16,80	4,20	1,80
14,75	0,60	1,14	21,96	11,87	2,88
6,50	0,52	1,13	20,98	9,85	3,35
9,50	0,55	1,18	28,97	11,24	1,74
25,42	0,70	1,12	23,23	21,78	3,64
8,33	0,53	1,06	24,20	7,99	0,34
7,08	0,52	1,11	26,95	7,01	0,07
13,96	0,59	1,10	22,89	12,98	0,98
9,02	0,55	1,09	20,22	8,08	0,93
3,13	0,48	1,03	23,93	4,04	0,91
8,75	0,59	1,11	24,16	5,40	3,35
8,54	0,59	1,10	30,83	8,00	0,54
2,71	0,48	1,03	20,56	4,08	1,37
8,33	0,53	1,16	24,10	6,65	1,68
13,33	0,58	1,16	23,22	15,84	2,51
10,00	0,55	1,03	18,62	4,98	5,02
20,50	0,66	1,21	24,85	17,82	2,68
7,67	0,53	1,11	17,72	3,13	4,54
14,00	0,59	1,08	24,48	13,63	0,37
2,33	0,45	1,18	30,28	6,42	4,09
5,83	0,52	1,18	25,83	6,33	0,49
12,33	0,57	1,16	21,77	13,68	1,35
17,33	0,62	1,10	21,01	13,71	3,62
0,83	0,44	0,97	20,46	3,92	3,08
11,00	0,56	1,02	24,35	7,47	3,53
17,50	0,62	1,21	25,28	19,51	2,01
11,00	0,56	1,03	22,11	7,67	3,33
14,50	0,60	1,22	28,54	21,80	7,30
2,33	0,45	1,14	21,86	1,91	0,42
16,67	0,62	1,06	25,18	14,93	1,74
2,50	0,45	1,11	19,67	3,92	1,42
5,33	0,50	1,01	25,40	8,82	3,49
24,00	0,70	1,20	28,68	23,35	0,65
11,67	0,57	1,06	24,50	12,42	0,75

OB.DIST	AV.FACT	FACT.K	TIME	COMP.DIST	ERROR
20,83	0,66	1,16	24,87	21,06	0,23
20,00	0,66	1,15	27,08	18,62	1,38
15,00	0,60	1,15	25,25	15,65	0,65
7,50	0,53	1,05	26,69	9,68	2,18
15,00	0,60	0,98	20,46	12,96	2,04
6,00	0,52	1,07	25,80	9,08	3,08
11,00	0,56	1,08	25,14	10,65	0,35
8,60	0,54	1,11	25,63	12,63	4,03
17,20	0,62	1,07	24,94	16,24	0,96
18,28	0,63	1,06	25,89	18,46	0,18
9,22	0,54	1,22	18,35	7,71	1,51
7,50	0,53	1,13	25,24	6,03	1,47
24,38	0,70	1,19	22,51	19,65	4,72
8,25	0,53	1,17	21,78	8,54	0,29
10,63	0,56	1,10	26,81	13,59	2,96
11,88	0,57	1,17	19,67	11,84	0,04
12,38	0,57	1,16	22,32	12,65	0,28
20,25	0,66	1,10	24,71	17,04	3,21
5,00	0,50	1,06	21,74	4,61	0,39
16,63	0,62	1,11	21,88	12,76	3,86
16,25	0,61	1,04	25,47	17,25	1,00
13,25	0,58	1,11	21,58	10,87	2,38
2,75	0,46	1,07	22,95	2,59	0,16
2,10	0,45	1,02	24,83	1,93	0,17
17,50	0,62	1,03	24,83	16,86	0,64
25,13	0,74	1,09	23,45	19,90	5,23
20,00	0,64	1,15	22,92	16,03	3,97
4,75	0,50	1,19	24,24	5,91	1,16
9,13	0,54	1,18	21,58	10,14	1,02
17,00	0,61	1,10	25,22	18,49	1,49
6,25	0,52	1,15	22,71	8,81	2,56
15,20	0,60	1,07	23,15	14,52	0,68
12,38	0,57	1,09	24,65	13,73	1,35
14,50	0,60	1,03	21,92	12,84	1,66
12,00	0,57	1,09	23,29	12,67	0,67
12,90	0,58	1,14	24,39	13,54	0,64
2,90	0,46	1,24	28,39	4,04	1,14
6,80	0,53	1,13	24,51	10,28	3,48
5,40	0,50	1,18	25,78	6,37	0,97
2,00	0,45	1,10	23,18	2,63	0,63

BIBLIOGRAPHY

1. Atlas of Canada, Department of Mines and Technical Surveys, Geographical Branch, Ottawa, Canada, 1951.

2. Bruneau, A. A. and Dempster, R.T., "Engineering and Economic Implications of Icebergs in the North Atlantic", Conference Papers, Oceanology International, Brighton, March 1972, pp. 176-180.

3. Chari, T. R., "Some Geotechnical Aspects of Iceberg Grounding", Thesis for the Degree of Doctor of Philosophy, Memorial University of Newfoundland, St. John's, Newfoundland, 1975.

4. Cochkanoff, O., Graham, J. W. and Warner, J. L., "Simulation Techniques in the Prediction of Iceberg Motion", Proceedings of the Canadian Seminar on Icebergs, Halifax, December 1971, pp. 135-152.

5. Defant, A., Physical Oceanography, Vol. I, The Pergannon Press, 1961.

6. Dempster, R.T., "The Measurement and Modelling of Iceberg Drift", Proceedings, IEEE Conference Ocean '74, Halifax, Aug. 1974, Vol. I, pp. 125-129.

7. Dinnsmore, R. P., "Ice and its Drift into the North Atlantic Ocean", Special Publication No. 8, Symposium on Environment Conditions in the Northwest Atlantic, 1960-1969, pp. 89-127.

8. Ekman, V. W., "Om jordrotationens iverkan pa vindstrommar i hafvet", Nyt. Mag. f. Naturvid., Vol. 20, Kristiania.

9. Kollmeyer, R. C., O'Hagan, R.M., and Morse, R. M., U. S. Coast Guard Report No. 10, 1969.

MARKS ON ORIGINAL

10. Mecking, L., "Die Eistrift aus dem Bereichder Baffinbai beherrscht von strom und Wetter", Ver of. Inst. Meeresk., University of Berlin, Heft 7, Berlin.

11. Murray, J. E., "The Drift, Deterioration and Distribution of Icebergs in the North Atlantic Ocean", Ice Seminar, Canadian Institute of Mining and Metallurgy, Special Vol. 10, 1969, pp. 3-18.

12. Neumann, G., and Pierson, W. J. Jr., Principles of Physical Oceahigraphy, Prentice-Hall, Inc. 1966.

13. Post, L. A., "The Role of the Gulf Stream in the Prediction of Iceberg Distribution in the North Atlantic", Tellus, 1956, Vol. 8, No. I, pp. 102-111.

14. Robe, R. Q., "Height to Draft Ratios of Icebergs", Third International Conference on Port and Ocean Engineering under Arctic Conditions, University of Alaska, 1975.

15. Rossby, C. G., and Montogomery, R. B., "The Layer of Frictional Influence in Wind and Ocean Currents", Physical Oceanogr. and Meterol., 1935, Vol. 3, No. 3, pp. 101.

16. Russell, W. E., "Current Studies in the Labrador Current with respect to the Motion of Icebergs", Master of Engineering Thesis, Memorial University of Newfoundland, St. John's, Newfoundland, 1973.

17. Sailing Directions for Newfoundland published by the U.S. Naval Oceanographic Office, H. O. Pub. 14, 1969.

18. Schell, I., "On the Iceberg Severity off Newfoundland and its Prediction", Journal of Glaciology, 1962, Vol. 4, No. 32, pp. 161-172.

19. Smith, E. H., "The Marion Expedition to Davis Strait and Baffin Bay", U. S. Coast Guard Bulletin, No. 19, Part 3, Scientific Results, 1931, pp. 60-216.

20. Sodhi, D.S. and Dempster, R. T., "Motion of Icebergs due to Changes in Water Currents", IEEE Ocean '75, pp. 348-350.

21. Sverdrup, H. U., Johnson, M. W., and Fleming, R. H., The Oceans, Their Physics, Chemistry, and General Biology, Prentice-Hall, Inc. 1946.

22. U. S. Treasury Dept. (Coast Guard), 1950-1956, Bulletin No. 36-42. International Ice Observation and Ice Patrol Service in the North Atlantic Ocean.

MARKS ON ORIGINAL