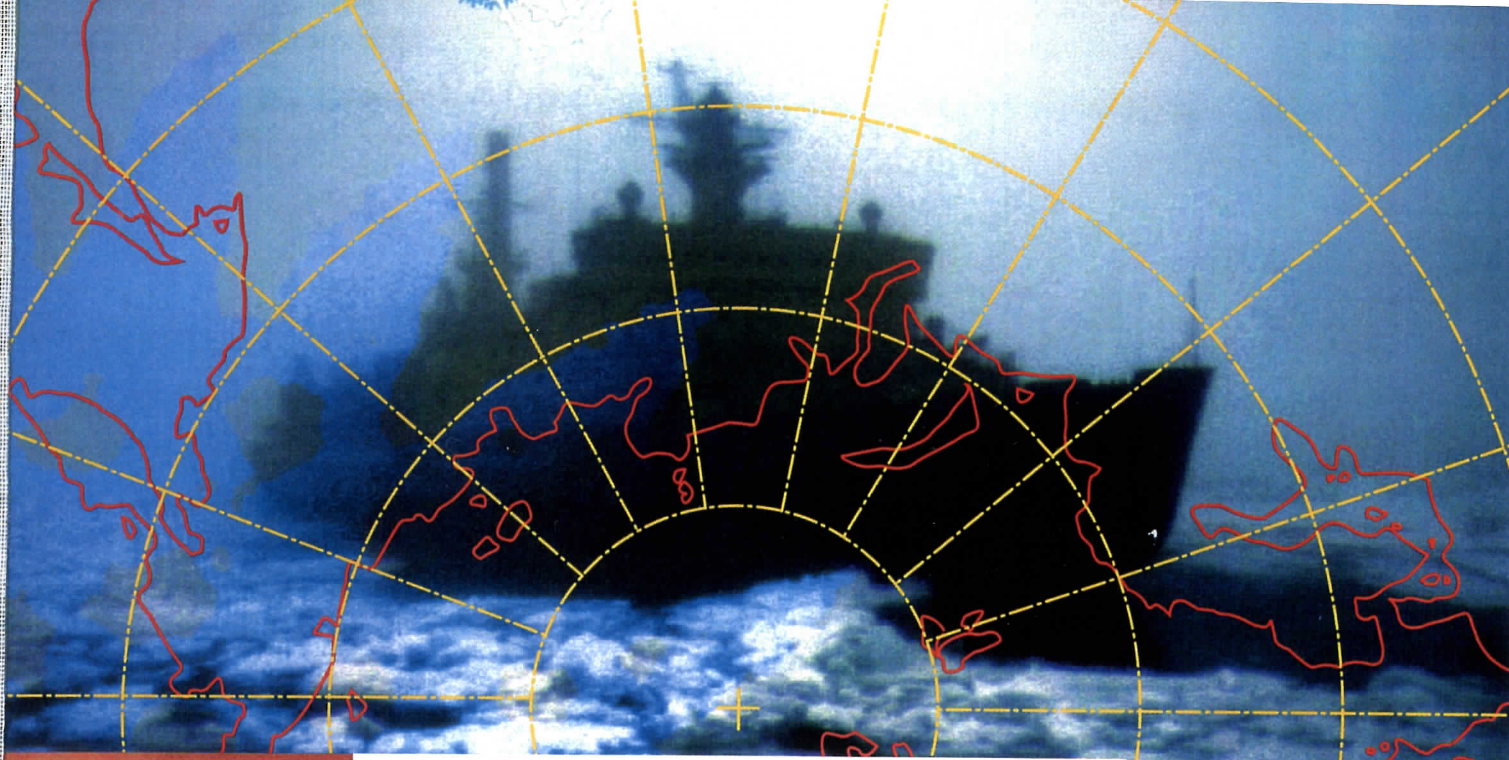
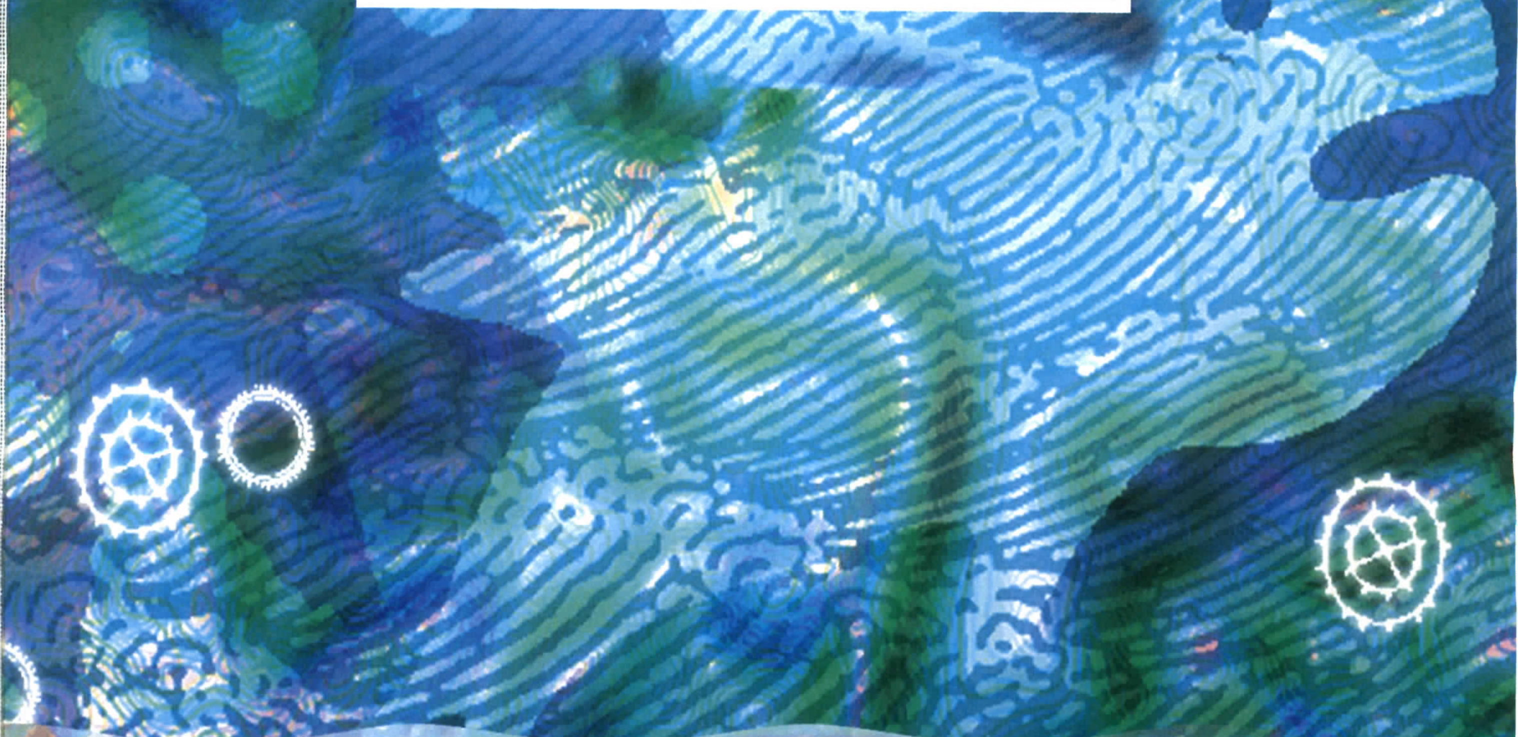


INSROP WORKING PAPER
NO. 42-1996, I.4.1

Content of Database
Volume 2 -1994 project work

Loly Tsoy, Alexander Baskin
and Sergey Brestkin et al.



INSROP International Northern Sea Route Programme

Central Marine Research & Design Institute, Russia

The Fridtjof Nansen Institute, Norway

Ship and Ocean Foundation, Japan

International Northern Sea Route Programme (INSROP)

Central Marine Research & Design Institute, Russia

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INSROP WORKING PAPER NO. 42-1996

Sub-programme I: Natural Conditions and Ice Navigation

Project I.4.1: Content of Database.
Volume 2 - 1994 project work.

By: A. Baskin*, V. Vasilyev*, L. Tsoy*, Yu. Glebko*, L. Timofeeva*, Ye. Aksenov**, S. Brestkin**, A. Buzuyev**, Yu. Gorbunov**, G. Kuznetsova **, S. Losev**, S. Nikolayev**, V. Porubayev**, K. Teitel'baum** and S. Frolov**.

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Date: 25 March 1996.

Reviewed by: Dr. Robert Frederking, National Research Council of Canada, Canada.

What is an INSROP Working Paper and how to handle it:

This publication forms part of a Working Paper series from the **International Northern Sea Route Programme - INSROP**. This Working Paper has been evaluated by a reviewer and can be circulated for comments both within and outside the INSROP team, as well as be published in parallel by the researching institution. A Working Paper will in some cases be the final documentation of a technical part of a project, and it can also sometimes be published as part of a more comprehensive INSROP Report. For any comments, please contact the authors of this Working Paper.

PART I

DATABASE ON TECHNICAL, OPERATIONAL AND COST CHARACTERISTICS AND ICE PERFORMANCE OF EXISTING ICEBREAKERS OF THE RUSSIAN ARCTIC FLEET

I.4.1.1 Database on technical, operational and cost characteristics and ice performance of existing icebreakers of the Russian Arctic Fleet

KEY PERSONNEL

Dr. Loly G.Tsoy, head of laboratory, CNIIMF
Dipl.eng. Yuri V.Glebko, scientist, CNIIMF
Dipl.eng. Ludmila A.Timofeeva, scientist, CNIIMF

SUMMARY

Structure of the information database on technical, operational and cost characteristics and ice performance of Russian icebreakers was developed. This structure is convenient for use in personal computers as a part of mathematical models to solve practical problems of icebreaker support of transport ships navigating along the NSR.

Basis data were prepared on 33 operating domestic icebreakers for the subsequent loading into the database to be developed within GIS (ARCInfo). The information presented is similar to that developed in 1993-1994 for Russian transport ships of arctic navigation (INSROP Working Paper No.26 - 1995, I.4.1, Part I).

Both bases are arranged in files of the DBASE III PLUS structure.

<u>Minimum required hardware and software to run the database:</u>

- IBM PC type personal computer with a base memory size of at least 640 KB,
- MS-DOS operating system, version 3.3 and over,
- availability of 4 MB free space on a hard disk.

<u>Information about ships is collected in the following information blocks:</u>

- SH01.dbf - general data on ship (principal dimensions, displacement, power of the propulsion plant etc.),
- SH02.dbf - structural data on hull,
- SH02l.dbf - information on ice properties,
- SH03.dbf - technical characteristics of the propulsion plant,
- SH04.dbf - technical and operational data,
- SH07.dbf - other information.

Data base parameters

IDEN - TIFIER	FORMAT N - num., C - sys., D - date	PARAMETER NAME	GLOSSARY FILE NAME	FILE NAMES
mns	N 6	1.1. Identification number of vessel		SH01
lsu	C 24	1.5. Name of vessel		SH01
ost	N 5	Basic type	SL2	SH01
por	C 20	1.12. Port of registry		SH01
dps	D	1.16. Building data		SH01
slk	C 3	Ice category		SH01
snp	C 1	Subdivision marks		SH01
rgw	C 6	1.20. Gross tonnage, r.t		SH01
rgn	C 6	1.21. Net tonnage, r.t		SH01
nrtp	C 6	1.22. Net Panama Canal tonnage		SH01
nrts	C 6	1.23. Net Suez Canal tonnage		SH01
dpz	C 6	1.24.Deadweight, t		SH01
lmx	C 6	2.1. Overall length, m		SH02
lpe	C 6	2.2. Designed length, m		SH02
bmx	C 5	2.3. Extreme breadth, m		SH02
hbo	C 5	2.4. Depth, m		SH02
hsu	C 6	2.5. Air draft, m		SH02
olm	C 5	2.6. Summer draft, m		SH02
gfu	C 6	2.14. Displacement at summer draft,		SH02
gpo	C 6	2.15. Light displacement, t		SH02
g1s	C 4	2.16. Displacement per 1 cm of draft		SH02
lkwl	C 6	2l.1 Length on DLW, m		SH02L
bkwl	C 5	2l.2 Breadth on DLW, m		SH02L
oar	C 5	2l.3 Draft, arctic water, m		SH02L
gar	C 6	2l.4 Displacement at arctic draft, t		SH02L
dar	C 6	2l.5 DWT at arctic draft, t		SH02L
nar	C 6	2l.6 Load carrying cap. at arctic draft		SH02L
pwo	C 5	2l.7 Shaft power, total, kW		SH02L
rpw	C 7	Power distribution on shafts		SH02L
tgws	C 4	2l.8 Propeller thrust, center		SH02L
tgwb	C 4	2l.8 Propeller thrust, side		SH02L
tgwo	C 4	2l.8 Propeller thrust, total		SH02L
dgwo	C 4	2l.9 Propeller diameter, m		SH02L
unf	C 3	2l.10 Bow rake, deg		SH02L
uns	C 3	2l.11 Entrance angle of DLW, deg		SH02L
ur0	C 3	2l.12 Flare angle of frame No.0, deg.		SH02L
nbm	C 3	2l.13 Side slope at midships, deg.		SH02L
kop	C 3	2l.14 Block coefficient		SH02L
urnp	C 3	2l.15 Section flare angle at F.P, deg		SH02L
ur2t	C 3	Section flare angle at sec. No.2		SH02L
urms	C 3	Section flare angle at midships		SH02L
eps	C 3	2l.16 Service period, days		SH02L
rtl	C 4	2l.17 Fuel consumption, kg/kw.hr		SH02L
wtl	C 12	2l.18 Kind of fuel		SH02L
tsu	N 1	3.1. Type of propulsion plant	SL9	SH03
kis	C 1	3.2. Number of M.E.1		SH03
pdk	C 5	Power of M.E.1, kW		SH03
kis1	C 1	Number of M.E.2		SH03
pdk1	C 5	Power of M.E.2, kW		SH03
kgd1	C 1	3.10. Number of propulsion motors 1		SH03
mgd1	C 5	Power of propulsion motors 2, kW		SH03
kgd2	C 1	Number of propulsion motors 2		SH03
mgd2	C 5	Power of propulsion motors 2, kW		SH03
tdg	C 36	3.15. Propeller type		SH03
kgw	C 1	3.16. Number of propeller		SH03
klp	C 1	Number of blades on a propeller		SH03
fws	C 3	3.17. Propeller RPM center		SH03
fwb	C 3	Propeller RPM side		SH03

IDEN - TIFIER	FORMAT N - num., C - sys., D - date	PARAMETER NAME	GLOSSARY FILE NAME	FILE NAMES
net	C 6	4.1. Net capacity, t		SH04
gls	C 6	4.2. Timber capacity, t		SH04
ogs	C 5	4.3. Load draft, m		SH04
oss	C 5	4.4. Specification draft, m		SH04
gsp	C 6	4.5. Net capacity specification, t		SH04
kom	C 3	4.8. Crew size		SH04
vgr	C 4	4.10. Speed loaded		SH04
vbl	C 4	Speed in ballast		SH04
dals	C 5	4.25. Operating range, n.mil,		SH04
dalm	C 5	Operating range, n.mil, maximum		SH04
spo	C 8	7.7. Building cost, m.rbls.		SH07
spbr	C 8	Book cost, m.rbls		SH07
dsbr	D	Date of entry of book cost		SH07
spbd	C 8	Book cost, m.rbls		SH07
nss	C 2	7.8. Set service life		SH07

PART II:

DEVELOPMENT OF THE BASE OF CARTOGRAPHY DATA IN THE FORM OF ELECTRONIC CATALOGUE OF CHARTS

I.4.1.2 DEVELOPMENT OF THE BASE OF CARTOGRAPHY DATA IN THE FORM OF ELECTRONIC CATALOGUE OF CHARTS

KEY PERSONNEL

Dr.V.Vasilyev, researcher, CNIIMF
Dipl.eng. V.Isakov, hydrographer, CNIIMF

SUMMARY

The structure of the catalogue was described in the 1993 report

Up to the end of 1995, Russian Navy issued 248 charts of different scales for the NSR the data on them was already entered in the catalogue.

The charts coverage totally provides sailing along traditional and high latitude routes.

All the data is instantly updated in the frameworks of I.4.1 Project.

In February 1995 we have sent to FNI 172 NSR paper charts according the Catalogue data.

PART III:
DATABASE ON ICE AND HYDRO-METEOROLOGICAL CONDITIONS

LIST OF SCIENTISTS RESPONSIBLE FOR DIFFERENT SECTIONS OF PROJECT (AARI)

1. Mr. Aksenov Ye.O. - scientist - section 5
2. Mr. Brestkin S.V. - introduction, section 1, 4, 6
3. Dr. Buzuyev A.Ya. - leading scientist
4. Dr. Gorbunov Yu.A. - leading scientist - section 4
5. Dr. Kuznetsova G.S. - drafting
6. Mr. Losev S.M. - senior scientist - section 6
7. Mr. Nikolayev S.Yu. -junior scientist - section 5
8. Mr. Porubayev V.S. - section 2
9. Mrs Teitel'baum K.A. - section 2
10. Mr. Frolov S.V. - scientist - section 5

ABSTRACT

The project aims to create databases on navigation conditions along different segments of the NSR which are necessary for the justification of possibilities and perspectives for international shipping along the NSR, a restrospective analysis of effectiveness and safety of shipping in different seasons, modelling of motion of ships in ice. The Report contains a description of the results of Stage II (April 1994 - March 1995). A great deal of attention has been given to choosing priorities in the preparation of different databases to be used in the interests of INSROP. It is shown that main efforts should be focused on supplementing and adapting (in view of specific goals of INSROP) the databases available at the AARI:

- shipborne ice observations on the ship's motion route;
- ice thickness measurements and associated characteristics;
- discontinuities in ice cover;
- atmospheric pressure (for estimating probabilities of ice pressures of varying intensity).

The Report presents a concept for using the AARI's data for estimating conditions of transit navigation along the NSR and a preliminary classification of these data by their availability and readiness for transfer to investigators under INSROP projects. The Report also justifies the technology for using climatic (review) databases, the database of ice thickness measurements and associated characteristics, the database of shipborne ice observations and the database on discontinuities in ice cover for estimating navigation conditions.

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A N N E X 34

INTRODUCTION

The main aim of the Subproject is to form databases on ice, meteorological and hydrological conditions for different segments of transit navigation along the NSR. They are necessary for substantiating possibilities and perspectives for international shipping along the NSR, retrospective analysis of effectiveness and safety of shipping in different seasons, modelling of the transit of ships in ice.

At the first stage the content of the databases that can be used in the interests of the program was preliminarily defined, a brief description of the data available at the AARI was prepared and their volume, quality and organization level were estimated. These data allow a conclusion that the AARI has available meteorological information that in principle meets the requirements of the program goals, but much of this information is contained on paper media. The work for creating all necessary databases is beyond the scope of this subproject both with regard to time frames and financing.

In this connection a correct choice of priorities is of special importance. Our view point is that for estimating the conditions of transit navigation using different scenarios, the databases that are created at the AARI in the interests of other national and international programs should be used to a maximum. It is desirable that the main efforts of investigators under this subproject be aimed at supplementing and adapting the databases that are most important for addressing the INSROP goals taking into account their specific features. First of all, it is necessary to pay attention to those databases that will provide an assessment of the probability of some conditions or other on different NSR segments at minimum labour and time consumption for their preparation. Further, provided there is sufficient funding, other bases that are of interest for the INSROP participants can also be prepared.

The main directions of the activities under the subproject were selected on the basis of existing understanding of the influence of different environmental characteristics on navigation conditions along the NSR and by analysing the state of the information base of the AARI.

1 ORGANIZATION PRINCIPLES FOR USING THE DATA ON ICE AND HYDRO-METEOROLOGICAL CONDITIONS IN THE REGION OF THE NORTHERN SEA ROUTE

The main data archive of ice, meteorological and hydrological observations in the Arctic Seas is centered at the State Scientific Center the "Arctic and Antarctic Research Institute" (AARI). Recently, the issues of making these data available for some Norwegian and Japanese INSROP projects have become of particular importance.

The position of the AARI on this problem is presented below.

The hydrometeorological data is the property of the State, millions of US dollars have been spent on their collection and processing and their general amount cannot be just passed to anyone. The transfer is possible only in restricted amounts within the framework of joint projects in accordance with the requirements of these projects within the limits permitted by law and the instructions of the respective Agencies. In all cases it is preferable to provide the results of statistical processing of the data available at the AARI to foreign partners. The transfer of primary hydrometeorological information does not meet the interests of the Russian Side. Moreover this is not desirable since the interpretation and processing of the observation data, the largest portion of which is quite specific, can be performed most correctly by the AARI specialists.

In order to define the mechanism of access to the information base of the AARI for the INSROP participants it is necessary to take into account its state and perspectives of development. The Report of stage I under Project I.4.1 contains the characteristics of primary data, data sets on computer media and databases, estimates of their volume, quality and organization level available at the AARI. An analysis of this description shows that the data formalization is in most cases laborious and cannot be fulfilled within the budget of Subproject I.4.1.3 that is only NOK 150 000 . It is necessary to redistribute the funds or transfer to the Russian Side (the AARI) part of the finances of the projects that are interested in data submitting (in the framework of umbrella contracts). The lists of required data, time frames, financing volumes, averaging scales of characteristics, boundaries of regions and other details should be agreed upon in the course of direct contacts with the investigators under project.

In some cases the information transfer will be impossible due to legal restrictions and restrictions of the Agencies or it will be not desirable from the viewpoint of the long-term interests of the Russian Side. The following principles should be observed for a successful solution to the main objectives of the Program that require the use of the AARI data:

- in all cases, when possible, we should speak about the transfer of the results of statistical processing of primary information, rather than about the transfer of primary information (time series with high spatial resolution, charts, etc.);
- time series that are not planned for transfer or are not ready for transfer can be replaced by reconstructed series using known means, dispersions and physical variability limits of characteristics;
- it is desirable to request the AARI to resolve the problems that obviously require the primary data that are not to be transferred. The AARI has all necessary primary information, as well as unique experience of processing and analysing this information and of its assessment on the basis of navigation conditions along the NSR and practical support to marine operations.

The Report of stage I noted that the databases on natural conditions should be included in the INSROP Information System on a shared basis. This means that the databases containing primary information will remain in those institutions where they are created. The staff of these institutions will maintain, supplement, and develop software and use the databases for meeting the requests (including the requests of INSROP participants), preparation of information letters and recommendations. And to meet the requirements of the INSROP projects, generalized specialized information and evidence on the contents of initial databases will be mainly provided.

Such an approach renders the development of separate databases and of the information system of the AARI as a whole to be of particular importance.

- fast ice boundaries, 1933-1990; mean monthly data (10-day period data for some years);
- data obtained at hydrological stations along the NSR (tidal currents, 1930-1989).

The fourth type includes non-formalized data (on paper media) that are allowed for open publishing and transfer to foreign partners:

- dimensions of drifting floes 1963-1976 (data of special surveys);
- ice drift (coordinates of automated buoys in the northern regions of the Chukchi and East-Siberian Seas for the period 1979-1990 at 24 h intervals, coordinates of radio markers in the East-Siberian Sea for the period 1953-1975 at 5-10 day intervals, coordinates of 9 drifting stations "North Pole" are available for the northern regions of the East-Siberian Sea for the period 1957-1981 at 1-7 day intervals);
- sea surface temperature (mean seasonal - summer, winter);
- surface water salinity (mean seasonal - summer, winter);
- surface air temperature (mean monthly);
- surface atmospheric pressure (mean monthly);
- precipitation (mean by seasons);
- wind direction and speed (for 4 observation times).

The last three items of this section refer to 33 stations of the WMO system.

The fifth type includes non-formalized data (on paper media) that are not permitted for open publishing and transfer to foreign partners:

- ice thickness in the Arctic, 1937 -1991;
- pressures, 1960 - 1988 during the period of airborne ice reconnaissance and from shipborne data;
- cracks, leads and fractures (there are more than 2000 films of radar ice surveys from aircraft in all Arctic seas for the period from 1968 to 1992);
- wave height, 1950-1991;
- temperature and salinity of water surface, 1950-1994;

- level height, 1956-1990;
- surface atmospheric pressure (mean monthly);
- precipitation (mean by seasons);
- wind speed and direction (by 4 observation times).

The last three items refer to the stations along the NSR that are not included in the WMO system.

As is evident from the above list, a significant portion of the information necessary for the implementation of INSROP projects (first of all for GIS creation) cannot be submitted to a foreign partner in the near future. In order to test the mechanisms for manipulating geographically linked data by means of Arc/Info GIS the AARI used files containing gridded characteristics averaged by seasons or months. The examples of such data are given in Annexes. Annex 1 contains coordinates of regular grid points with a spacing of 2.5^0 by latitude and 5^0 by longitude. Annex 2 contains mean water surface temperatures and salinities for summer and winter in geographical grid points. Annex 3 presents mean monthly air temperatures in geographical grid points.

3 DEVELOPMENT OF TECHNOLOGIES FOR USING CLIMATIC (GENERAL) DATABASES FOR ESTIMATING NAVIGATION CONDITIONS

The technologies for using climatic (general) databases including Global Sea Ice Data Bank (GSIDB) are being developed within the framework of INSROP according to the following directions:

- development of software for sampling ice characteristics along the prescribed section within the prescribed band;
- estimate of errors in the use of the information selected from climatic databases for estimating ice conditions by routes;
- further testing of the mechanism for an indirect assessment of physical characteristics of ice cover that are of navigational importance;

The software for sampling of ice characteristics was developed taking into account:

- specific features of archiving and methods for access to climatic data;
- a possibility for using different variants for prescribing sampling location;
- the need for subsequent interfacing with INSROP GIS.

The developed software represents an additional modulus to the already existing program of visualization and viewing of climatic databases.

The software for sampling of ice characteristics along the prescribed section or within the prescribed band fulfils the following functions:

- prescription of spatial position of the section or band is made:
- interactively by output of the chart of the region to the monitor screen and by plotting of the section or band on it;
- by entry of the parameters of rectangular or geographical coordinates of the turning points of the section (band limits) into a special file;
- automatically when processing enquiries (including GIS enquiries) where the sampling band of a width equal to spatial resolution of the databases is identified by an axis line;
- prescription of the time period, sampling interval in time and space that can be larger or smaller than spatial and temporal resolution of climatic databases;

- sampling and accumulation of data referring to one or several charts (matrices) by nodes (can be made by a 4-point interpolation or by choosing a value of the characteristics from the nearest matrix node);
- processing and output of the result to external file in the form:
- values of ice characteristics by nodes;
- values of the characteristics averaged by uniform (prescribed) segments of the section or band and length (areas) of these segments.

When using climatic (general) databases for navigation purposes it is necessary to take into account that actual (or current) ice characteristics on a specific route can significantly differ from the values of the characteristics averaged by 10-day periods and grid squares that are entered into the general databases. Obtaining of corresponding transition functions should be based on a joint analysis of general databases and databases of observations on an opportunity basis, as well as on knowledge of spatial distribution of data errors.

The Global Sea Ice Data Bank combines information from two sources: the National Data Center for Snow and Ice (NDCSI) of the USA and the Center for Ice and Hydrometeorological Information (CIHMI) of the AARI.

The NDCSI data obtained by processing multichannel microwave satellite observations have an error of ice characteristics uniformly distributed in space. However, only data for the period from the end of the 70s have absolute errors that can be considered to be acceptable.

The CIHMI data are obtained mainly by interpolation in time and space of the data of visual and instrumental airborne-, shipborne and coastal observations. Their error corresponds to the observation accuracy only within the limits of the band of airborne surveys. However, the indicated data differ by a much longer series, as compared with the NDCSI data.

In order to assess errors of estimating total ice cover concentration by data of general databases and compare them with observation data of ships of opportunity special technology was developed and applied. It includes the following main elements:

- sampling of the data of CIHMI and NDCSI from climatic database within a 50-km survey band along standard routes of airborne reconnaissance, as well as beyond this band (grid of standard routes of airborne reconnaissance flights is given in Fig. 1);
- a comparative analysis of the data of the CIHMI and NDCSI and identification of a spatial distribution of a relative error of the CIHMI data as a result of the effects of data interpolation and extrapolation;

- selection of data of measurements by ships of opportunity that are within the airborne reconnaissance band and between the bands;
- a comparative analysis of data and determination of transition functions from the data of general databases to the conditions along the navigation route (separately for data belonging to the airbone reconnaissance band and beyond it).

At present series of characteristics that have evident navigational significance but are very difficult to be physically interpreted are centered in climatic databases. Of obvious interest appears to be a possibility for an indirect estimate of physical ice cover characteristics that are difficult to be measured in mass from the data of general databases. Thus, for example, general databases on concentration of ice of different age gradations, degree of destruction, amount of hummocking and amount of snow on ice cover (taking into account data on marine meteorology) can be used for assessing:

- mean weighted and effective thickness of ice cover;
- strength characteristics of ice cover (Young's modulus);
- interaction characteristics of snow and ice cover with the ship's hull.

As transfer functions, empirical relations that are contained in published materials on methods can be used. One of the most important problems is to specify these relations. As has already been mentioned, most effective for this is to systematize data of direct measurements of physical characteristics in the form of a database.

Fig. 2 presents the result of processing information that is contained in the secondary database of mean weighted ice cover thickness in the form of a multiyear estimate of ice cover thickness of a 25% probability. The secondary database is formed on the basis of the GSIDB using partial concentrations of sea ice of different age gradations.

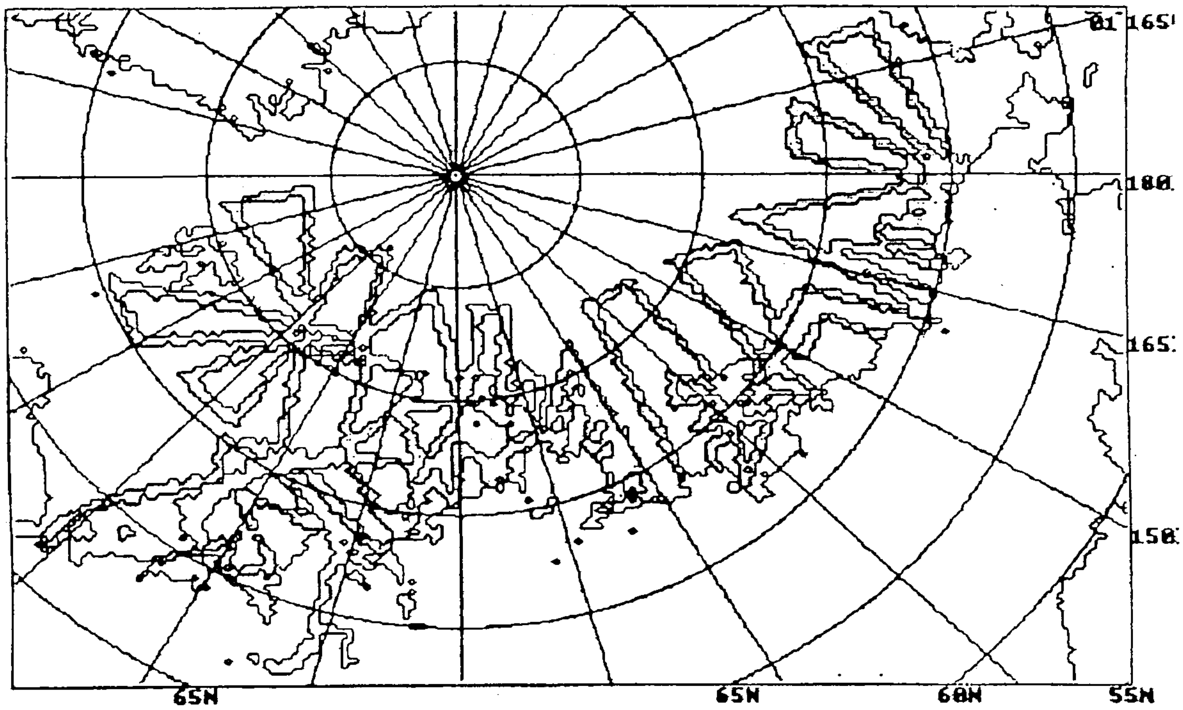

Fig. 1. The NSR coverage by data of standard airborne observations under condition of a 50 km survey width

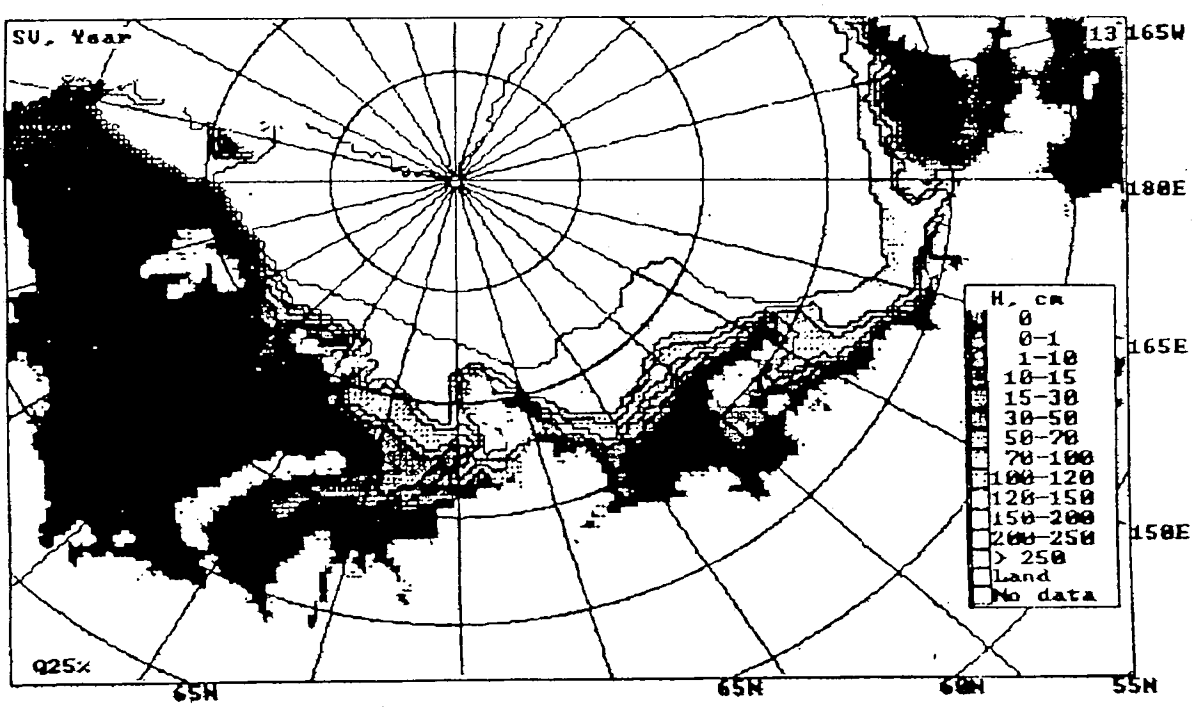

Fig. 2. Multiyear estimate of mean weighted ice cover thickness of a 25% probability

4 FORMATION OF THE DATABASE ON ICE THICKNESS MEASUREMENTS AND RELATED CHARACTERISTICS

There are wide possibilities in Russia for creating the indicated database. In addition to observation data from submarines, a vast amount of the results of direct measurements of ice thickness and related characteristics (draft, ice elevation above sea level, snow height on the ice, etc.) in the Arctic Ocean for a long observation period can be used.The formation of the database is financed mainly by national programs. Activities in the framework of INSROP include entry of information for the regions of transit navigation, development of software for obtaining transitions functions from ice age to its thickness (for any prescribed period and region) and adaptation of the database to the Data Base Management System (DBMS) ORACLE that is compatible with the geographical information system (GIS) Arc/Info.

At the initial stage a catalogue of the data available at the AARI has been prepared. It indicates that data differ by a large non-uniformity in a set of observations, accuracy, spatial-temporal interval, scale of the geographical region covered, etc. For example, spatial spacing of data can vary from a meter (the nuclear submarine data) to several hundred kilometers (data of the "Sever" expeditions). Time coverage can vary from a 10-day period to several decades, spatial scales of the observation region - from dimensions of one ice floe to several thousand kilometers.

An important feature of initial data that is necessary to take into account both for forming the database and for its use is that accuracy, spatial-temporal interval and averaging scales vary on a wide range in thickness determinations. Also, thickness observations are carried out mostly on an opportunity basis or as additional. The data obtained do not form independent samplings. For example, shipborne data on an opportunity basis refer mainly to ice zones of decreased thickness (since ship usually moves selectively) and do not always characterize natural variability of these characteristics in the given region.

Experience of processing and analysing observation data on ice thickness and related characteristics allows formulating the main requirements to the database that is being created:

- a possibility for combining information on different characteristics estimated by different methods for a large time period in different regions of the Arctic Ocean, as well as information on data collection methods and their accuracy;

INTRODUCTION

The main aim of the Subproject is to form databases on ice, meteorological and hydrological conditions for different segments of transit navigation along the NSR. They are necessary for substantiating possibilities and perspectives for international shipping along the NSR, retrospective analysis of effectiveness and safety of shipping in different seasons, modelling of the transit of ships in ice.

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In this connection a correct choice of priorities is of special importance. Our view point is that for estimating the conditions of transit navigation using different scenarios, the databases that are created at the AARI in the interests of other national and international programs should be used to a maximum. It is desirable that the main efforts of investigators under this subproject be aimed at supplementing and adapting the databases that are most important for addressing the INSROP goals taking into account their specific features. First of all, it is necessary to pay attention to those databases that will provide an assessment of the probability of some conditions or other on different NSR segments at minimum labour and time consumption for their preparation. Further, provided there is sufficient funding, other bases that are of interest for the INSROP participants can also be prepared.

The main directions of the activities under the subproject were selected on the basis of existing understanding of the influence of different environmental characteristics on navigation conditions along the NSR and by analysing the state of the information base of the AARI.

The first of these directions is the development of technologies for using climatic (general) databases, including Global Sea Ice Data Bank, in the interests of INSROP. These bases differ by being most complete and include time series of the most important characteristics over the whole of the region in question for a multiyear period. They allow estimating the probability of some conditions or other (in particular, a probability for occurrence of open water, open and close ice, ice of a prescribed age category), averaged by prescribed spatial and temporal intervals). And it is necessary to take into account that the conditions on the route of ships moving selectively can considerably differ from mean conditions that are recorded in the general database. The corresponding transition functions can be obtained as a result of a combined use of general databases and the database where shipborne ice observations on an opportunity basis are systematized.

The second direction is the development of the database on ice thickness measurements and related characteristics (draft, ice elevation above sea level, geometry of hummocked formations, snow depth, etc.). The importance of this work can be justified as follows:

The navigation conditions along the NSR are governed to a great extent by ice thickness distribution. The general databases contain data on ice age categories and on their basis ice thickness distribution can be approximately estimated. However, the accuracy of such estimates is insufficient since typical thicknesses of most difficult ice of one and the same age gradation (first-year thick, second-year and multiyear) can significantly differ depending on the region and season. Only data of direct ice thickness measurements can provide correct evidence. But, unfortunately, they are non-uniform and fragmentary. The database constructed on their basis will not provide a representative regime estimate like a general database. However, its use will allow obtaining a specified function of transition from ice age category to ice thickness distribution for each specific case (of prescribed region and period of the year).

The third direction is creation of the database on discontinuities in ice cover. This work is directly related to the problem of extending the navigation period. Actually, it is well known that in the presence of a sufficient number of discontinuities en route it is possible for ships to navigate in anomalously early (spring) and anomalously late (fall and winter) periods. The database on discontinuities can be used for assessing economic effectiveness of transit shipping taking into account the perspectives for extending the navigation period, as well as for specifying navigation dates and variants for planning of marine operations.

The fourth direction is connected with the need for estimating the probability of pressures of differing intensity when navigating in close ice. Without taking into account pressures the characteristics of navigation conditions, especially from the point of view of a risk assessment cannot be considered to be satisfactory. Similar to the case with ice thickness, the data on actually observed pressures available at the AARI are not sufficient for regime estimates. However, on the basis of these data the dependencies of a degree of pressures on external conditions can be obtained. If the transition functions are available, the database on atmospheric pressure can be used for estimating the probability of pressure.

Thus, for estimating the conditions of transit navigation it is proposed to use climatic (general) databases that are included into the Global Sea Ice Data Bank along with the databases:

- on shipborne ice observations on an opportunity basis (to obtain the transition functions from mean 10-day conditions by grid squares to the conditions along the navigation route of ships);
- on ice thickness measurements and related characteristics (to specify the relationship between ice thickness distribution and age categories);
- on discontinuities in ice cover (to estimate a probability for using discontinuities en route);
- on atmospheric pressure (to estimate a probability of pressures of differing intensity).

The enumerated databases are being formed in the framework of national programs that are carried out at the AARI. The aim of subproject I.4.1.3 is their adaptation and supplement in the interests of INSROP, as well as development of the technology for a composite use of these databases for probabilistic estimates of navigation conditions on different segments of the NSR. The Report presents the results obtained at stage II that are of an intermediate character, since the work will be continued in 1995-1996.

1 ORGANIZATION PRINCIPLES FOR USING THE DATA ON ICE AND HYDRO-METEOROLOGICAL CONDITIONS IN THE REGION OF THE NORTHERN SEA ROUTE

The main data archive of ice, meteorological and hydrological observations in the Arctic Seas is centered at the State Scientific Center the "Arctic and Antarctic Research Institute" (AARI). Recently, the issues of making these data available for some Norwegian and Japanese INSROP projects have become of particular importance.

The position of the AARI on this problem is presented below.

The hydrometeorological data is the property of the State, millions of US dollars have been spent on their collection and processing and their general amount cannot be just passed to anyone. The transfer is possible only in restricted amounts within the framework of joint projects in accordance with the requirements of these projects within the limits permitted by law and the instructions of the respective Agencies. In all cases it is preferable to provide the results of statistical processing of the data available at the AARI to foreign partners. The transfer of primary hydrometeorological information does not meet the interests of the Russian Side. Moreover this is not desirable since the interpretation and processing of the observation data, the largest portion of which is quite specific, can be performed most correctly by the AARI specialists.

In order to define the mechanism of access to the information base of the AARI for the INSROP participants it is necessary to take into account its state and perspectives of development. The Report of stage I under Project I.4.1 contains the characteristics of primary data, data sets on computer media and databases, estimates of their volume, quality and organization level available at the AARI. An analysis of this description shows that the data formalization is in most cases laborious and cannot be fulfilled within the budget of Subproject I.4.1.3 that is only NOK 150 000 . It is necessary to redistribute the funds or transfer to the Russian Side (the AARI) part of the finances of the projects that are interested in data submitting (in the framework of umbrella contracts). The lists of required data, time frames, financing volumes, averaging scales of characteristics, boundaries of regions and other details should be agreed upon in the course of direct contacts with the investigators under project.

In some cases the information transfer will be impossible due to legal restrictions and restrictions of the Agencies or it will be not desirable from the viewpoint of the long-term interests of the Russian Side. The following principles should be observed for a successful solution to the main objectives of the Program that require the use of the AARI data:

- in all cases, when possible, we should speak about the transfer of the results of statistical processing of primary information, rather than about the transfer of primary information (time series with high spatial resolution, charts, etc.);
- time series that are not planned for transfer or are not ready for transfer can be replaced by reconstructed series using known means, dispersions and physical variability limits of characteristics;
- it is desirable to request the AARI to resolve the problems that obviously require the primary data that are not to be transferred. The AARI has all necessary primary information, as well as unique experience of processing and analysing this information and of its assessment on the basis of navigation conditions along the NSR and practical support to marine operations.

The Report of stage I noted that the databases on natural conditions should be included in the INSROP Information System on a shared basis. This means that the databases containing primary information will remain in those institutions where they are created. The staff of these institutions will maintain, supplement, and develop software and use the databases for meeting the requests (including the requests of INSROP participants), preparation of information letters and recommendations. And to meet the requirements of the INSROP projects, generalized specialized information and evidence on the contents of initial databases will be mainly provided.

Such an approach renders the development of separate databases and of the information system of the AARI as a whole to be of particular importance.

At present the AARI is carrying out systematic work on the formation of the hydrometeorological databases by elements. A local computation network, the core of which consists of three computer class "work stations", is being created for all main departments of the institute. Testing of GIS "Arcinfo" and DBMS "Oracle" is being performed. Thus, the Russian Side has all that is necessary for the formation of the shared database and a geographical information system that can also be used in the interests of INSROP..However, at present the work is far from being completed. This is one of the obstacles to presenting the necessary data to the executors of the project. As has already been mentioned, the transfer of primary information is not in the interests of the Russian Side and statistical processing is still laborious and time-consuming.

An increase in financing of the corresponding INSROP projects, allocation of additional funds for purchasing the equipment, making the software for GIS, developed in the framework of Project I.3.1, available for the Russian Side can significantly expedite the creation of the information system of the AARI. Depending on the real contribution of INSROP the participants of the Program will enjoy the rights of privileged users of this information system that can be stipulated in advance.

2 CLASSIFICATION OF THE AARI DATA ACCORDING TO THE POSSIBILITY OF THEIR USE IN THE INTERESTS OF THE INSROP PROJECTS

In connection with a large non-uniformity of information and the varying viewpoints of the respective specialists about the possibilities for its transfer it is very difficult to give a definite answer to this question. However, taking into account the importance of the problem it was decided to make an attempt to provide such an answer. And the presented classification reflects the opinions of the executors and the supervisor of the Project and must be considered to be only one of the possible standpoints

All information of the AARI can be arbitrarily divided into five types by the availability and readiness for transferring to the executors of the INSROP project.

The first type includes data prepared for international exchange and included into the Global Digital Sea Ice Data Bank - data on total ice concentration and partial concentration of ice of different age gradations with a spatial spacing not more than 15x15 sea miles for the period from January 1972 to December 1991.

The second type includes data on technical media permitted to be published and transferred to foreign partners on agreed upon terms:

- degree of ice decay, 1953-1980,
- amount of hummocking, 1953-1980.

The third type includes data on technical media that are not permitted for open publishing and transfer to foreign partners:

- cracks, leads and fractures (over the Kara Sea - January-March 1981-1987 and 1992-1993, April-May 1979-1993, over the Laptev and East-Siberian Seas - January-March 1981-1983, April-June 1979-1983, October-December 1980-1982, over the Chukchi Sea -January-March 1979, 1981 and 1983, April-June 1979-1983, October-December 1980-1982;

- fast ice boundaries, 1933-1990; mean monthly data (10-day period data for some years);
- data obtained at hydrological stations along the NSR (tidal currents, 1930-1989).

The fourth type includes non-formalized data (on paper media) that are allowed for open publishing and transfer to foreign partners:

- dimensions of drifting floes 1963-1976 (data of special surveys);
- ice drift (coordinates of automated buoys in the northern regions of the Chukchi and East-Siberian Seas for the period 1979-1990 at 24 h intervals, coordinates of radio markers in the East-Siberian Sea for the period 1953-1975 at 5-10 day intervals, coordinates of 9 drifting stations "North Pole" are available for the northern regions of the East-Siberian Sea for the period 1957-1981 at 1-7 day intervals);
- sea surface temperature (mean seasonal - summer, winter);
- surface water salinity (mean seasonal - summer, winter);
- surface air temperature (mean monthly);
- surface atmospheric pressure (mean monthly);
- precipitation (mean by seasons);
- wind direction and speed (for 4 observation times).

The last three items of this section refer to 33 stations of the WMO system.

The fifth type includes non-formalized data (on paper media) that are not permitted for open publishing and transfer to foreign partners:

- ice thickness in the Arctic, 1937 -1991;
- pressures, 1960 - 1988 during the period of airborne ice reconnaissance and from shipborne data;
- cracks, leads and fractures (there are more than 2000 films of radar ice surveys from aircraft in all Arctic seas for the period from 1968 to 1992);
- wave height, 1950-1991;
- temperature and salinity of water surface, 1950-1994;

- level height, 1956-1990;
- surface atmospheric pressure (mean monthly);
- precipitation (mean by seasons);
- wind speed and direction (by 4 observation times).

The last three items refer to the stations along the NSR that are not included in the WMO system.

As is evident from the above list, a significant portion of the information necessary for the implementation of INSROP projects (first of all for GIS creation) cannot be submitted to a foreign partner in the near future. In order to test the mechanisms for manipulating geographically linked data by means of Arc/Info GIS the AARI used files containing gridded characteristics averaged by seasons or months. The examples of such data are given in Annexes. Annex 1 contains coordinates of regular grid points with a spacing of 2.5^{0} by latitude and 5^{0} by longitude. Annex 2 contains mean water surface temperatures and salinities for summer and winter in geographical grid points. Annex 3 presents mean monthly air temperatures in geographical grid points.

3 DEVELOPMENT OF TECHNOLOGIES FOR USING CLIMATIC (GENERAL) DATABASES FOR ESTIMATING NAVIGATION CONDITIONS

The technologies for using climatic (general) databases including Global Sea Ice Data Bank (GSIDB) are being developed within the framework of INSROP according to the following directions:

- development of software for sampling ice characteristics along the prescribed section within the prescribed band;
- estimate of errors in the use of the information selected from climatic databases for estimating ice conditions by routes;
- further testing of the mechanism for an indirect assessment of physical characteristics of ice cover that are of navigational importance;

The software for sampling of ice characteristics was developed taking into account:

- specific features of archiving and methods for access to climatic data;
- a possibility for using different variants for prescribing sampling location;
- the need for subsequent interfacing with INSROP GIS.

The developed software represents an additional modulus to the already existing program of visualization and viewing of climatic databases.

The software for sampling of ice characteristics along the prescribed section or within the prescribed band fulfils the following functions:

- prescription of spatial position of the section or band is made:
- interactively by output of the chart of the region to the monitor screen and by plotting of the section or band on it;
- by entry of the parameters of rectangular or geographical coordinates of the turning points of the section (band limits) into a special file;
- automatically when processing enquiries (including GIS enquiries) where the sampling band of a width equal to spatial resolution of the databases is identified by an axis line;
- prescription of the time period, sampling interval in time and space that can be larger or smaller than spatial and temporal resolution of climatic databases;

- sampling and accumulation of data referring to one or several charts (matrices) by nodes (can be made by a 4-point interpolation or by choosing a value of the characteristics from the nearest matrix node);
- processing and output of the result to external file in the form:
- values of ice characteristics by nodes;
- values of the characteristics averaged by uniform (prescribed) segments of the section or band and length (areas) of these segments.

When using climatic (general) databases for navigation purposes it is necessary to take into account that actual (or current) ice characteristics on a specific route can significantly differ from the values of the characteristics averaged by 10-day periods and grid squares that are entered into the general databases. Obtaining of corresponding transition functions should be based on a joint analysis of general databases and databases of observations on an opportunity basis, as well as on knowledge of spatial distribution of data errors.

The Global Sea Ice Data Bank combines information from two sources: the National Data Center for Snow and Ice (NDCSI) of the USA and the Center for Ice and Hydrometeorological Information (CIHMI) of the AARI.

The NDCSI data obtained by processing multichannel microwave satellite observations have an error of ice characteristics uniformly distributed in space. However, only data for the period from the end of the 70s have absolute errors that can be considered to be acceptable.

The CIHMI data are obtained mainly by interpolation in time and space of the data of visual and instrumental airborne-, shipborne and coastal observations. Their error corresponds to the observation accuracy only within the limits of the band of airborne surveys. However, the indicated data differ by a much longer series, as compared with the NDCSI data.

In order to assess errors of estimating total ice cover concentration by data of general databases and compare them with observation data of ships of opportunity special technology was developed and applied. It includes the following main elements:

- sampling of the data of CIHMI and NDCSI from climatic database within a 50-km survey band along standard routes of airborne reconnaissance, as well as beyond this band (grid of standard routes of airborne reconnaissance flights is given in Fig. 1);
- a comparative analysis of the data of the CIHMI and NDCSI and identification of a spatial distribution of a relative error of the CIHMI data as a result of the effects of data interpolation and extrapolation;

- selection of data of measurements by ships of opportunity that are within the airborne reconnaissance band and between the bands;
- a comparative analysis of data and determination of transition functions from the data of general databases to the conditions along the navigation route (separately for data belonging to the airbone reconnaissance band and beyond it).

At present series of characteristics that have evident navigational significance but are very difficult to be physically interpreted are centered in climatic databases. Of obvious interest appears to be a possibility for an indirect estimate of physical ice cover characteristics that are difficult to be measured in mass from the data of general databases. Thus, for example, general databases on concentration of ice of different age gradations, degree of destruction, amount of hummocking and amount of snow on ice cover (taking into account data on marine meteorology) can be used for assessing:

- mean weighted and effective thickness of ice cover;
- strength characteristics of ice cover (Young's modulus);
- interaction characteristics of snow and ice cover with the ship's hull.

As transfer functions, empirical relations that are contained in published materials on methods can be used. One of the most important problems is to specify these relations. As has already been mentioned, most effective for this is to systematize data of direct measurements of physical characteristics in the form of a database.

Fig. 2 presents the result of processing information that is contained in the secondary database of mean weighted ice cover thickness in the form of a multiyear estimate of ice cover thickness of a 25% probability. The secondary database is formed on the basis of the GSIDB using partial concentrations of sea ice of different age gradations.

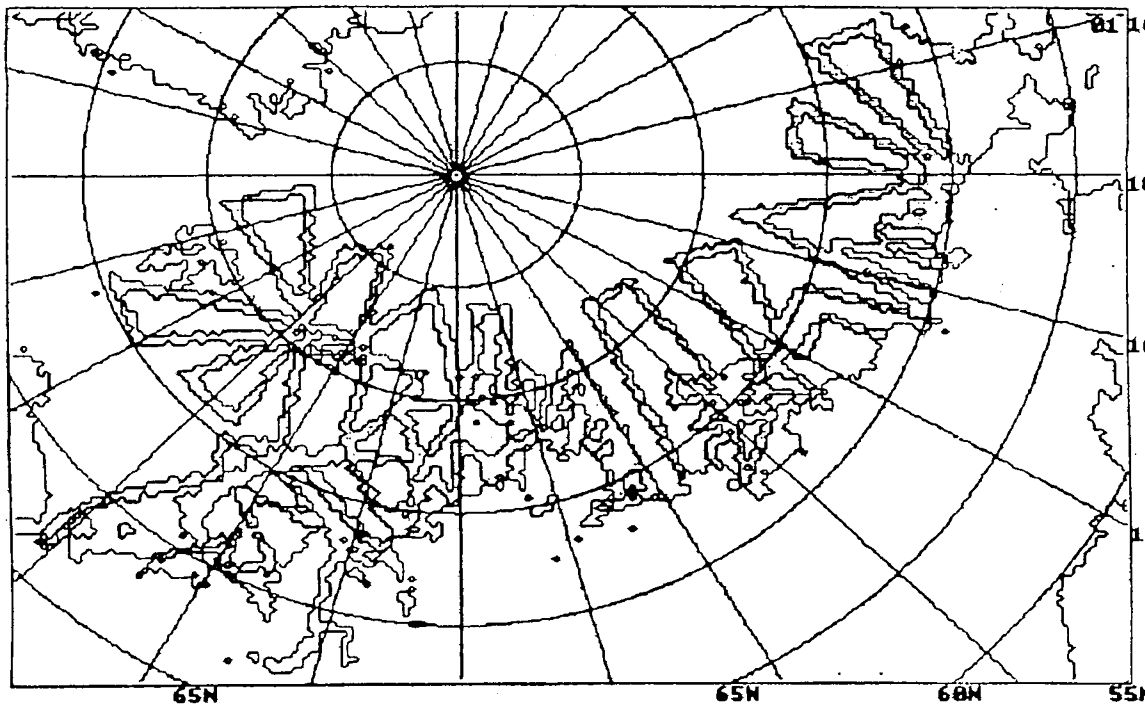

Fig. 1. The NSR coverage by data of standard airborne observations under condition of a 50 km survey width

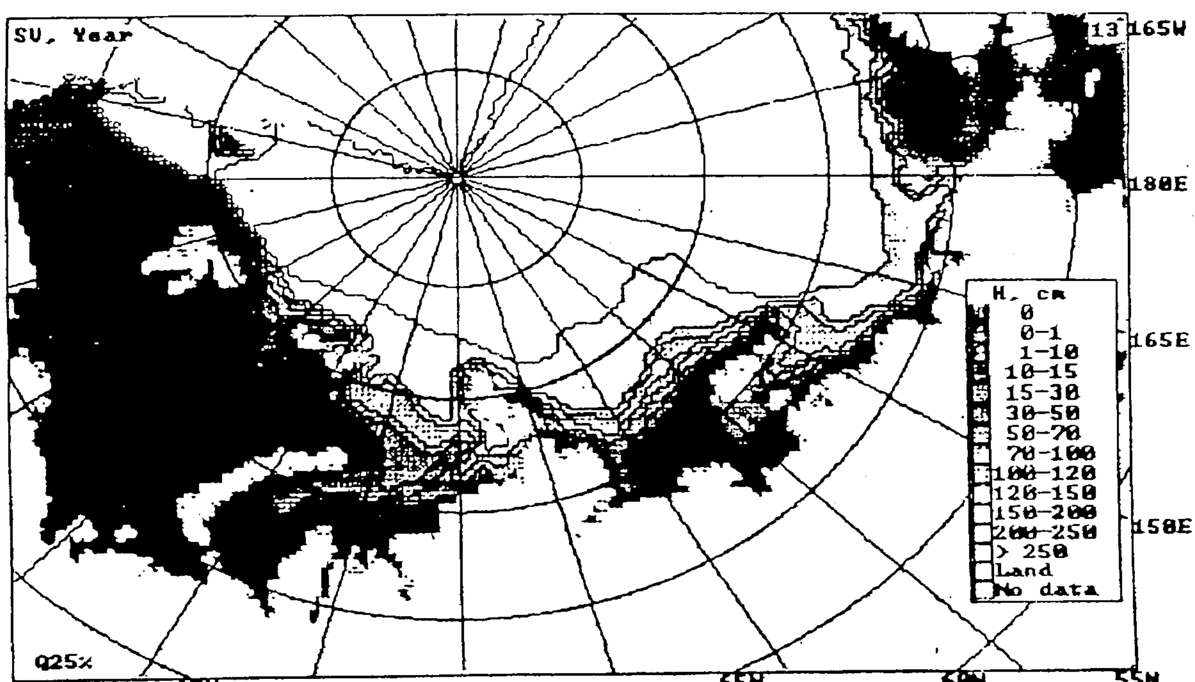

Fig. 2. Multiyear estimate of mean weighted ice cover thickness of a 25% probability

4 FORMATION OF THE DATABASE ON ICE THICKNESS MEASUREMENTS AND RELATED CHARACTERISTICS

There are wide possibilities in Russia for creating the indicated database. In addition to observation data from submarines, a vast amount of the results of direct measurements of ice thickness and related characteristics (draft, ice elevation above sea level, snow height on the ice, etc.) in the Arctic Ocean for a long observation period can be used.The formation of the database is financed mainly by national programs. Activities in the framework of INSROP include entry of information for the regions of transit navigation, development of software for obtaining transitions functions from ice age to its thickness (for any prescribed period and region) and adaptation of the database to the Data Base Management System (DBMS) ORACLE that is compatible with the geographical information system (GIS) Arc/Info.

At the initial stage a catalogue of the data available at the AARI has been prepared. It indicates that data differ by a large non-uniformity in a set of observations, accuracy, spatial-temporal interval, scale of the geographical region covered, etc. For example, spatial spacing of data can vary from a meter (the nuclear submarine data) to several hundred kilometers (data of the "Sever" expeditions). Time coverage can vary from a 10-day period to several decades, spatial scales of the observation region - from dimensions of one ice floe to several thousand kilometers.

An important feature of initial data that is necessary to take into account both for forming the database and for its use is that accuracy, spatial-temporal interval and averaging scales vary on a wide range in thickness determinations. Also, thickness observations are carried out mostly on an opportunity basis or as additional. The data obtained do not form independent samplings. For example, shipborne data on an opportunity basis refer mainly to ice zones of decreased thickness (since ship usually moves selectively) and do not always characterize natural variability of these characteristics in the given region.

Experience of processing and analysing observation data on ice thickness and related characteristics allows formulating the main requirements to the database that is being created:

- a possibility for combining information on different characteristics estimated by different methods for a large time period in different regions of the Arctic Ocean, as well as information on data collection methods and their accuracy;

- a possibility for integration of data obtained by different means with a different accuracy and details;
- a possibility for a spatial-temporal data interpolation;
- a possibility for a quick sorting and grouping of data by any combination of indications (by values of characteristics, by data collection methods, by regions and periods);
- a possibility for database expansion by adding new structural branches or by using additional information (also from other databases);
- a possibility for using external software means (standard and specially created) for data analysis and graphical representation;
- a possibility for processing standard and (non- standard) enquiries.

The implementation of the enumerated requirements depends on the database structure. In the case under description an approach is used at which the information in the database is divided into groups organized by hierarchy. The groups of the lower level that contain values of characteristics are combined by groups of higher levels and necessary associated information is entered into them. It includes: geographical and time reference, measurement method, accuracy, interval, ice cover general characteristics (amount of hummocking, degree of decay, age categories, etc.), source and form for storage of primary observation data.

The relationships between separate groups and inside each group are determined by type ONE-TO-MANY. The upper hierarchy level contains information that is general for all measurements made in the course of one survey. Under the term "survey" one understands a complex of operations for obtaining values of ice characteristics that are carried out during a restricted time period using the same methods and similar instruments (for measurung and determining coordinates of the measurement points). Several surveys can be made during one expedition. The second hierarchy level is related to fixed points (survey points for which geographical coordinates are determined). The third level -information refers to measurement points. Each of the fixed points is related to one or several measurement points. Each measurement point is connected with several measurements made in this point.

Each information group is supplied with keys. This provides a flexible access to data UP-DOWN and DOWN-UP, a minimum redundancy (repeating) of information, simplicity in data change and transformation, as well as realizaton of the relationship by the type MANY-TO-MANY.

The structure of such type provides a universal access to information - a possibility for selecting the information groups and separate characteristics by any set of indications. Such structure is open, i. e. it can be easily extended and it is particularly important in our case. The information can be added inside each group. New information groups can be added at any hierarchy level.

The information that is contained in the database for the time of the Report is enumerated below.

The Tables characterizing features of the survey on the whole (the upper hierarchy level) contain evidence on time and place of the survey, number of regions where measurements were made, types and methods of observations, information sources and place of its storage, accuracy of the geographical reference of fixed points and measurement points, as well as comments characterizing features of observations.

The Tables of the second level contain data on a part of the survey referring to one fixed point: geographical coordinates of the points, region index, date of measurements, technique for reference of the measurement points.

The Tables of the third level contain coordinates (rectangular, polar) of the measurement points.

At the fourth (lower) hierarchy level there are tables that contain values of ice characteristics. And a separate Table corresponds to each characteristic:

- ice type (drifting/ fast ice);
- ice concentration;
- ice age category;
- amount of ice hummocking;
- degree of ice decay;
- ice thickness;
- ice draft;
- ice elevation above sea level;
- snow depth;
- hummock height;
- hummock thickness;
- hummock draft;

- puddle depth;
- ice melting rate;
- ice growth rate;

Also, the database contains additional Tables with reference information necessary for filling in the main Tables:

- indices of the survey selectivity;
- indices of the survey types;
- indices of the methods for measuring ice characteristics;
- coordinates of the boundaries of geographical regions;
- indices and names of regions;
- indices and names of polar stations;
- indices of ice characteristics (type, age category, amount of hummocking, degree of decay).

A suitable creation of the database meeting the above requirements depends on a correct choice of the DBMS that should provide for:

- simplicity of using;
- high performance;
- a possibility for a networking and multitasking operation modes;
- relation to external softwares;
- a suitable user's graphic interface.

The database on ice thickness measurements and related characteristics is being created on the basis of the DBMS PARADOX which has the following disadvantages from the point of view of the INSROP goals:

- incompatibility with the Arc/Info package on whose basis the INSROP GIS is being formed;
- incompatibility with the UNIX operation system on whose basis a local computation network of the AARI is being constructed;
- presence of restrictions with regard to the information volume.

This governs the need for transition to the ORACLE DBMS that is free of the indicated deficiencies.

5 SHIPBORNE ICE OBSERVATION DATA

The main purpose of the database of shipborne ice observation data from the point of view of the INSROP goals is to specify the functions of transition from the values of characteristics averaged by squares to the values of these characteristics on the motion route of ships. As has been mentioned, such transition is necessary for using the climatic (general) databases to estimate navigation conditions along the Northern Sea Route. However, with forming and supplementing the indicated database its separate significance will increase because of the presence in it of the representative evidence on such characteristics whose observation is not of a systematic character. First of all, this concerns ice thickness.

Shipborne observations on an opportunity basis constitute a significant portion in a total amount of direct ice thickness measurements, especially for the regions of the NSR. Also, they are most informative for estimating navigation conditions as they do not require corrections for a selectivity of the route.

Shipborne ice observations were performed by the AARI expeditions aboard icebreakers escorting transport vessels along the NSR, during special high latitudinal research cruises in the Arctic Basin, as well as during tourist voyages of nuclear icebreakers to the North Pole (Fig. 3).

It can be said that systematic ice observations in the Arctic, both on an opportunity basis and special ones aboard icebreakers and ships, began in 1960. In total, observations were carried out 10 000 times. And along the motion route relatively uniform zones by a set of ice characteristics were identified. Time, coordinates of the beginning and end of zones and values of ice characteristics determined from ship by means of established methods were recorded. Most interesting among the characteristics estimated in the interests of INSROP appears to be the amount of hummocking and degree of ice decay, snow cover depth and partial concentration of ice of different thickness ranges or different age categories.

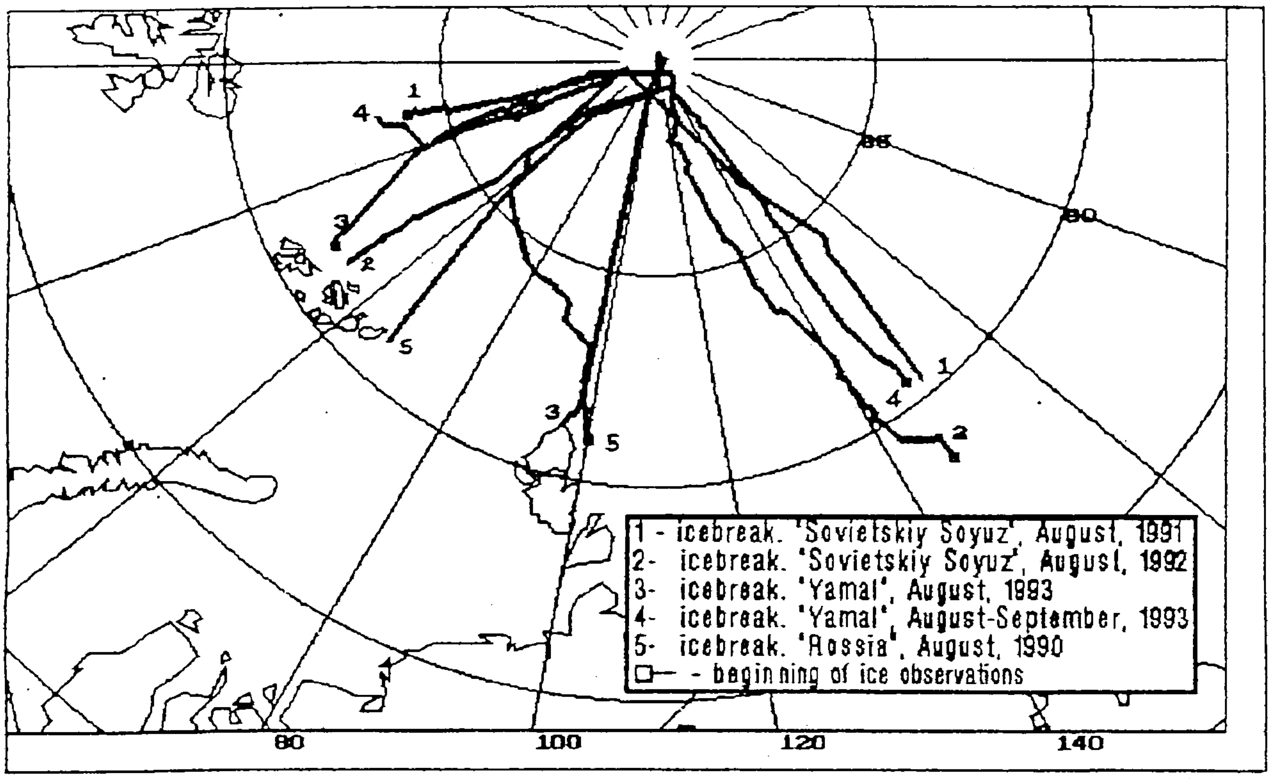

Fig. 3. Segments of the routes of transport cruises of the Russian nuclear powered icebreakers in the Arctic Basin that carried out ice observations

The database of shipborne ice observations is being formed using a ready software medium developed for the database of ice thickness measurements and related characteristics in whose structure necessary changes and additions are introduced.

For entry of shipborne data a number of special agreements were adopted. The observations made during one marine operation are considered to refer to one "survey". The name "observation point" is assigned to the points of the beginning and end of a uniform zone. The indexing of the observation points has the form "survey number/ uniform zone number". For distinguishing shipborne ice observations a new indication "shipborne route survey" has been introduced in the table. Each observation point in the Tables has corresponding values of geographical coordinates, ice type (drifting or fast ice) and values of ice characteristics (amount of hummocking, degree of decay, snow depth). For entry of partial concentrations of ice of different age gradations a new Table "Concentration" has been introduced. It uses special indices "observation point index/ age gradation index". A new Table "mimimum ice thickness has been created for entry of lower limits of corresponding ranges of ice thickness. The upper thickness limits for corresponding ranges are entered into the already existing Table "ice thickness".

At present the main amount of shipborne ice observations are stored in the archives of the AARI in the form of the expedition Reports. The work is being performed to create intermediate archives on magnetic media and for entry of the observation data into the database of ice thickness measurements and related characteristics. By the time of the Report the database includes shipborne observations onboard the nuclear icebreaker "Sibir' that made a through voyage in 1978 over all seas of the Russian Arctic Seas.

6 JUSTIFICATION OF THE TECHNOLOGY FOR USING DATA ON DISCONTINUITIES IN THE ICE COVER FOR ESTIMATING NAVIGATION CONDITIONS ALONG THE NSR

An important feature of sea ice cover in the warm period of the year is presence of discontinuities (cracks, leads and fractures) that are formed due to a non-uniform field of the ice drift rate. Discontinuities are often used for escort of ships by icebreakers under heavy ice conditions.

Thus, in the middle of October of 1954 the diesel-electric ship "Yenisey" was escorted from Pevek to the eastern multiyear ice boundary in the Chuckhi Sea by a system of discontinuities through compact ice. In late May-early June 1978 the navigation route of the nuclear icebreaker "Sibir'" and diesel-electric ship "Kapitan Myshevsky" was selected along the high-latitudinal route from the Barents Sea to the Bering Strait taking into account discontinuities en route. At the end of October-November 1983 transport ships were escorted by icebreakers under conditions of anomalously heavy ice conditions in the eastern Arctic (at the western approaches to the Long strait) taking into account a system of discontinuities.

Thus, historical experience shows that there is a principal possibility for extending the navigation period along the NSR in spring and in late autumn due to the use of discontinuities in ice cover.

For specifying this possibility (finding a probability for trafficability of the whole NSR on anomalously early and anomalously late dates) it is necessary to estimate the probability of the density of discontinuities along the route on limiting segments. This objective can be resolved on the basis of the database on discontinuities in ice cover that is being created at the AARI. The database has original software allowing estimates of a total length of discontinuities whose orientation is in a prescribed interval, by regular grid squares for any prescribed period of the year (10-day period). The calculation should be peformed by monthly periods for all years the information on which was entered into the database. A ratio of the cases when favourable conditions were observed over the whole of the route to their total number can be assumed to be the required probability of the route trafficability in the month under consideration.

There is a vast amount of observation data containing evidence on discontinuities in ice cover. They include satellite data, underwater hydroacoustic profiling data, aerophotography, visual airborne reconnaissance data, data of aircraft radar surveys. A systematic purposeful processing of these materials collected over a long period has not yet been done. Regime generalizations were obtained only by aircraft visual observation data. These estimates are of great interest, however, because of imperfect methods for data acquisition they are rather subjective, especially with regard to such an important element, as orientation of discontinuities.

At present, of all the initial information sources only TV images and "Meteor" and "NOAA" IR images received in direct transmission mode are used. The predominant use of these data is governed by a number of reasons. First of all, satellite images provide the largest coverage of the ice cover area. Secondly, they are received on a regular basis. Thirdly, they allow a sufficiently accurate determination of the orientation of discontinuities. Further, other data will be used for supplementing the databases. A composite analysis of data of different resolution will allow obtaining equations of transition from density of large discontinuities that are indicated on satellite images to density of all shipping discontinuities.

The considered database can be used for estimating a possibility for transit navigation along the NSR in the late fall (November) and spring (April-June) provided there are representative data on limiting route segments. This governs the choice of the information whose entry into the database should be organized in the framework of INSROP first of all.

In November navigation of transport vessels escorted by nuclear icebreakers in the regions where remaining ice is absent does not present any problems. Escorting of ships by icebreakers among close remaining ice is connected with great difficulties. In these cases a possibility for using discontinuities en route attains a primary importance. This takes place when heavy ice conditions are formed in the late fall in the north-eastern Kara Sea, western Laptev Sea, eastern East-Siberian Sea and western Chukchi Sea.

Transit navigation along the NSR in spring can be made on the basis of a combined use of flaw zones of young ice and open water that have a different degree of development and stability and of a system of discontinuities in ice cover on separate route segments (Fig. 4).

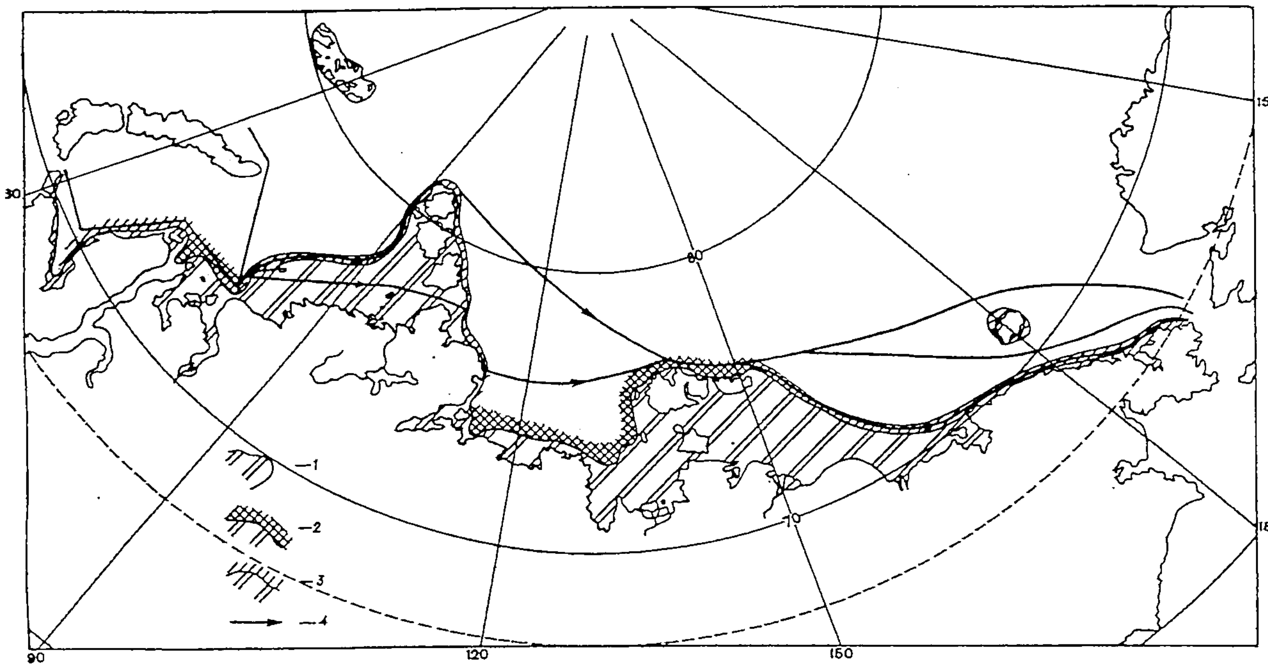

Fig. 4. Possible routes of transit navigation of icebreakers and transport vessels in spring.
1 -fast ice; 2 - quasistationary flaw zones of young ice and open water;
3 - non-stationary flaw zones of young ice and open water; 4 - transit navigation routes

In the south-western Kara Sea icebreakers escort ships all winter using Yamal'skaya and Ob'-Yeniseyskaya zones of young ice. In the absence of the Yamal'skaya zone of young ice ships navigate either along the western coast of the Yamal peninsula and then toward Dikson or north of the Zhelaniya cape taking into account systems of discontinuities in these regions (Fig. 4).

In the north-eastern Kara Sea transit navigation can be either along the unstable flaw zone of young ice or along the channel broken in fast ice by icebreakers.

In the Laptev Sea possible variants of transit navigation of icebreakers and transport ships in spring can be routes from the Arctic cape or from the eastern coast of the Taimyr peninsula toward a quasistationary flaw zone of young ice north of the New-Siberian Islands (Fig...). A preliminary analysis of available few observation data indicates the presence of large and extended discontinuities along the route. Further accumulation of primary information on discontinuities in ice cover of the Laptev Sea will allow revealing a stability in the orientation of discontinuities and determining air pressure situations at which the formation of discontinuities along the route is possible.

The East-Siberian Sea is the most unfavourable region for transit navigation in spring.A large amount of multiyear ice that is very strong makes impossible travel in Aion ice massif at increased amount of hummocking. Icebreaker with transport ship in this region can navigate along fast ice from the Vil'kitsky island to the Aion Island and further along the Chuckchi coast using divergence of drifting ice from fast ice (Fig. 4). A flaw polynya is formed here very rarely being very narrow and unstable. Sailing along fast ice in this region is often rather difficult. An alternative is navigating by a high-latitudinal variant by large discontinuities oriented from north-west to south-east (Fig. 4). The stability of orientation and density of these discontinuities, conditions for their formation, the most favourable periods (months) for their use in practical purposes can be determined while further developing the database on discontinuities. Also, an optimal route of exiting to the Chukchi Sea (north of the Vrangel Island or through the Long Strait) can be revealed.

It should be noted that experience of ice navigation from the west to the east with a combined use of flaw polynyas or zones of young ice, channel in fast ice of the north-eastern Kara Sea and discontinuities in drifting ice has been already gained.

Thus, in order to estimate a possibility for extending the period of transit navigation the entry of the information on large discontinuities into the database is necessary for the following regions:

- northern and central Laptev Sea;
- East-Siberian Sea;
- the Long strait and northern Chukchi Sea.

Let us consider an example of using the database on discontinuities in ice cover for estimating navigation conditions in the south-western Kara Sea in April.

The information on this region for 5 years by grid squares 50x50 km was entered. Processing softwares allow calculating generalized characteristics of discontinuities for each square:

- specific length;
- modal orientation;
- occurrence of a modal interval.

A specific length is a measure of density of discontinuities and it is equal to the ratio of total length of discontinuities to the zone area (grid square). The largest values of a specific length of discontinuities are noted in the central regions of the south-western Kara Sea.

A modal orientation of discontinuities is a direction to which a maximum density of the probability of their orientation corresponds. Within the regions of the south-western Kara Sea there are observed regions with a uni-modal and bi-modal distribution of the orientation of discontinuities.

A spatial distribution of generalized characteristics of discontinuities in the south-western Kara Sea in April from data over 5 years is given in Fig. 5-7.

In the eastern half of the region located between Novaya Zemlya in the west, Yamal peninsula and Bely Island in the east the prevailing direction of discontinuities coincides with a general direction of the routes of ships on the NSR segment the Kara Gate-Dikson. A possibility for using discontinuities in this region for shipping is governed by their enhanced density and high occurrence frequency of modal orientation.

The probability of using discontinuities is also quite high in the region located south-east of the northern tip of Novaya Zemlya where the shipping route Zhelaniya cape-Dikson passes. A prevailing orientation of discontinuities here also corresponds to a great extent to the motion direction of ships.

Processing and analysis of information on discontinuities on the basis of multiyear data will allow delineating the regions and periods with a different stability in the orientation of discontinuities, their enhanced and reduced density.

A stable preservation of the orientation of discontinuities in some regions can be used for planning of sailing routes of icebreakers and transport vessels, including transit cruises along high-latitudinal routes. For the regions with a large variability of the characteristics of discontinuities methods for their forecasting with different periods in advance that are being developed at the AARI can be applied.

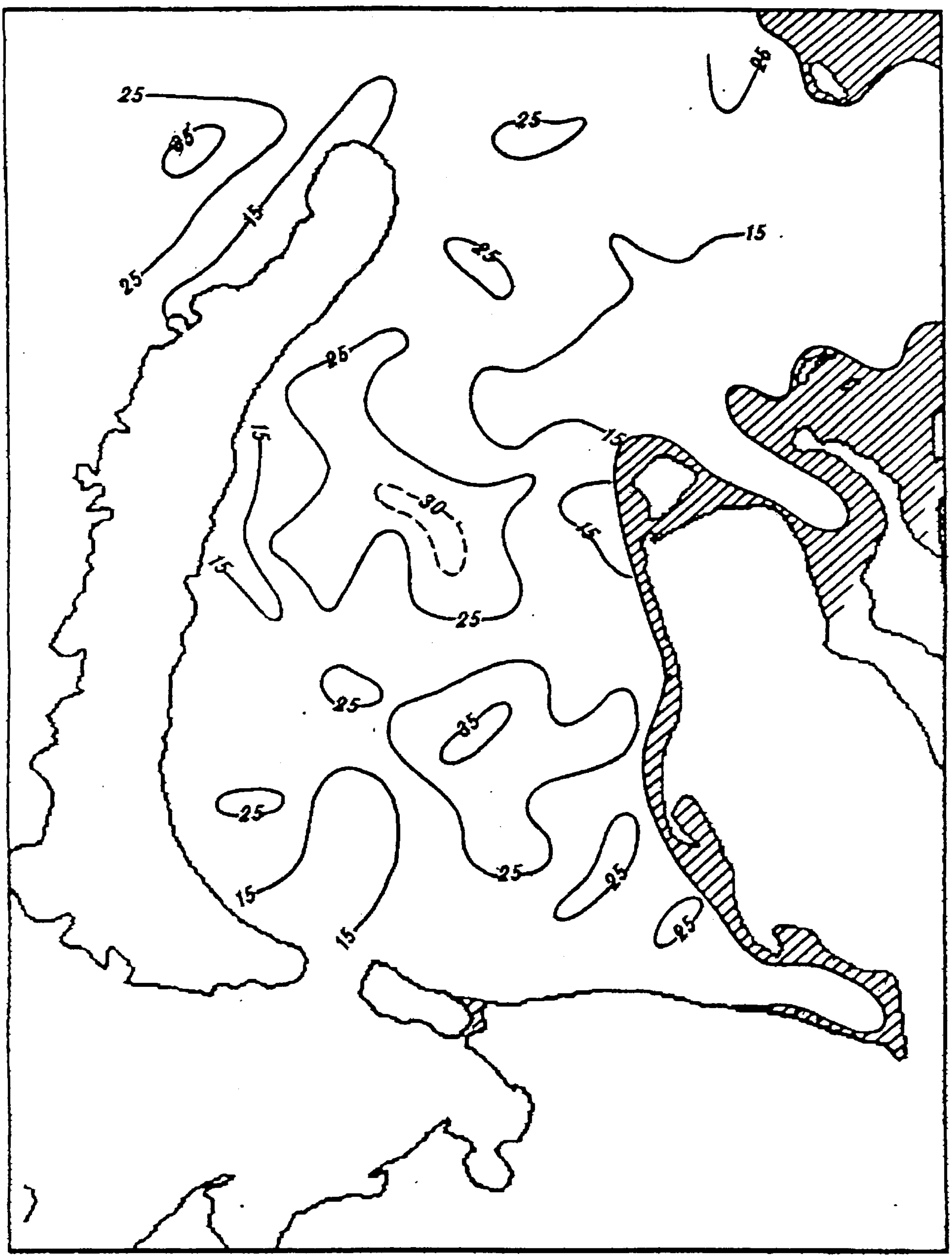

Fig. 5. A specific length of discontinuities in ice cover of the south-western Kara Sea in April averaged over 5 years

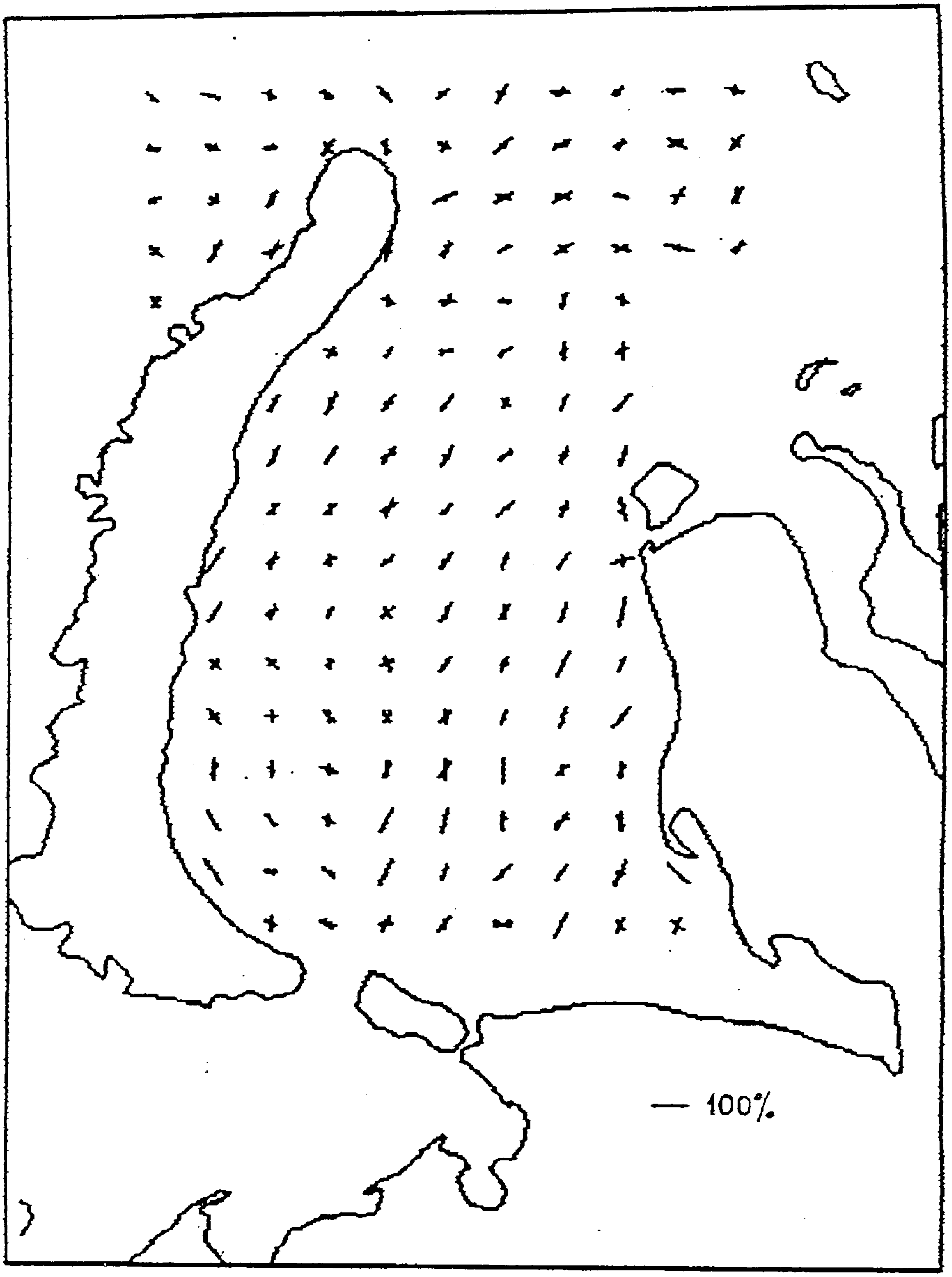

Fig. 6. Modal orientation of discontinuities in ice cover of the south-western Kara Sea in April on the basis of data for 5 years

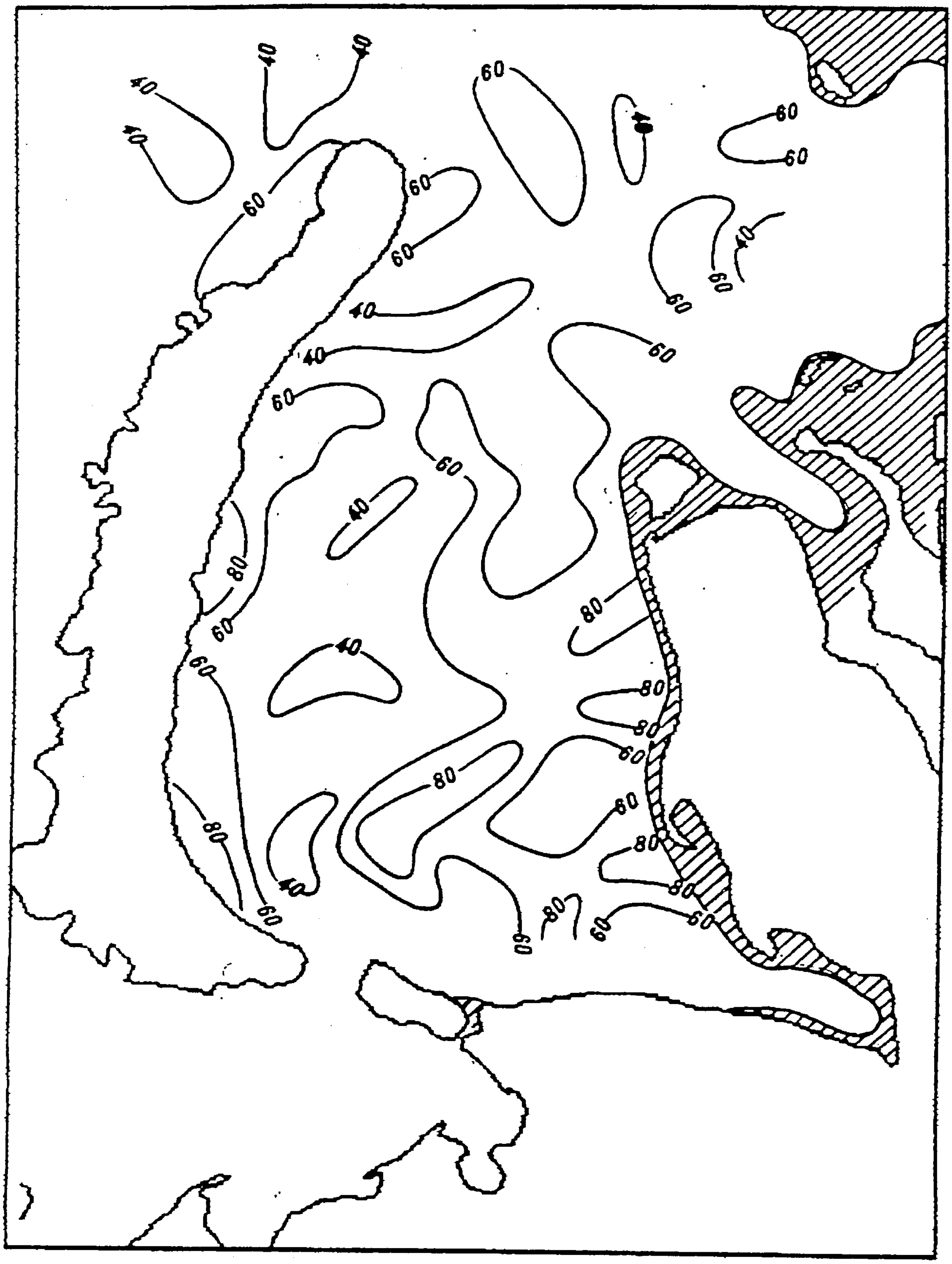

Fig. 7. Occurrence frequency of a modal interval of orientation of discontinuities in ice cover of the south-western Kara Sea in April on the basis of data for 5 years

ANNEX

Coordinates of the geographical grid points

ANNEX I

Grid point	λ	φ	Grid point	λ	φ	Grid point	λ	φ
1	55.00	82.50	41	110.00	80.00	81	165.00	77.50
2	60.00	82.50	42	115.00	80.00	82	170.00	77.50
3	65.00	82.50	43	120.00	80.00	83	175.00	77.50
4	70.00	82.50	44	125.00	80.00	84	180.00	77.50
5	75.00	82.50	45	130.00	80.00	85	185.00	77.50
6	80.00	82.50	46	135.00	80.00	86	190.00	77.50
7	85.00	82.50	47	140.00	80.00	87	195.00	77.50
8	90.00	82.50	48	145.00	80.00	88	55.00	75.00
9	95.00	82.50	49	150.00	80.00	89	60.00	75.00
10	100.00	82.50	50	155.00	80.00	90	65.00	75.00
11	105.00	82.50	51	160.00	80.00	91	70.00	75.00
12	110.00	82.50	52	165.00	80.00	92	75.00	75.00
13	115.00	82.50	53	170.00	80.00	93	80.00	75.00
14	120.00	82.50	54	175.0	80.00	94	85.00	75.00
15	125.00	82.50	55	180.00	80.00	95	90.00	75.00
16	130.00	82.50	56	185.00	80.00	96	95.00	75.00
17	135.00	82.50	57	190.00	80.00	97	100.00	75.00
18	140.00	82.50	58	195.00	80.00	98	105.00	75.00
19	145.00	82.50	59	55.00	77.50	99	110.00	75.00
20	150.00	82.50	60	60.00	77.50	100	115.00	75.00
21	155.00	82.50	61	65.00	77.50	101	120.00	75.00
22	160.00	82.50	62	70.00	77.50	102	125.00	75.00
23	165.00	82.50	63	75.00	77.50	103	130.00	75.00
24	170.00	82.50	64	80.00	77.50	104	135.00	75.00
25	175.00	82.50	65	85.00	77.50	105	140.0	75.00
26	180.00	82.50	66	90.00	77.50	106	145.00	75.00
27	185.00	82.50	67	95.00	77.50	107	150.00	75.00
28	190.00	82.50	68	100.00	77.50	108	155.00	75.00
29	195.00	82.50	69	105.00	77.50	109	160.00	75.00
30	55.00	80.00	70	110.00	77.50	110	165.00	75.00
31	60.00	80.00	71	115.00	77.50	111	170.00	75.00
32	65.00	80.00	72	120.00	77.50	112	175.00	75.00
33	70.00	80.00	73	125.00	77.50	113	180.00	75.00
34	75.00	80.00	74	130.00	77.50	114	185.00	75.00
35	80.00	80.00	75	135.00	77.50	115	190.00	75.00
36	85.00	80.00	76	140.00	77.50	116	195.00	75.00
37	90.00	80.00	77	145.00	77.50	117	55.00	72.50
38	95.00	80.00	78	150.00	77.50	118	60.00	72.50
39	100.00	80.00	79	155.00	77.50	119	65.00	72.50
40	105.00	80.00	80	160.00	77.50	120	70.00	72.50

ANNEX 1 (continued)

Grid point	λ	φ	Grid point	λ	φ	Grid point	λ	φ
121	75.00	72.50	161	130.00	70.00	201	185.00	67.50
122	80.00	72.50	162	135.00	70.00	202	190.00	67.50
123	85.00	72.50	163	140.00	70.00	203	195.00	67.50
124	90.00	72.50	164	145.00	70.00	204	55.00	65.00
125	95.00	72.50	165	150.00	70.00	205	60.00	65.00
126	100.00	72.50	166	155.00	70.00	206	65.00	65.00
127	105.00	72.50	167	160.00	70.00	207	70.00	65.00
128	110.00	72.50	168	165.00	70.00	208	75.00	65.00
129	115.00	72.50	169	170.00	70.00	209	80.00	65.00
130	120.00	72.50	170	175.00	70.00	210	85.00	65.00
131	125.00	72.50	171	180.00	70.00	211	90.00	65.00
132	130.00	72.50	172	185.00	70.00	212	95.00	65.00
133	135.00	72.50	173	190.00	70.00	213	100.00	65.00
134	140.00	72.50	174	195.00	70.00	214	105.00	65.00
135	145.00	72.50	175	55.00	67.50	215	110.00	65.00
136	150.00	72.50	176	60.00	67.50	216	115.00	65.00
137	155.00	72.50	177	65.00	67.50	217	120.00	65.00
138	160.00	72.50	178	70.00	67.50	218	125.00	65.00
139	165.00	72.50	179	75.00	67.50	219	130.00	65.00
140	170.00	72.50	180	80.00	67.50	220	135.00	65.00
141	175.00	72.50	181	85.00	67.50	221	140.00	65.00
142	180.00	72.50	182	90.00	67.50	222	145.00	65.00
143	185.00	72.50	183	95.00	67.50	223	150.00	65.00
144	190.00	72.50	184	100.00	67.50	224	155.00	65.00
145	195.00	72.50	185	105.00	67.50	225	160.00	65.00
146	55.00	70.00	186	110.00	67.50	226	165.00	65.00
147	60.00	70.00	187	115.00	67.50	227	170.00	65.00
148	65.00	70.00	188	120.00	67.50	228	175.00	65.00
149	70.00	70.00	189	125.00	67.50	229	180.00	65.00
150	75.00	70.00	190	130.00	67.50	230	185.00	65.00
151	80.00	70.00	191	135.00	67.50	231	190.00	65.00
152	85.00	70.00	192	140.00	67.50	232	195.00	65.00
153	90.00	70.00	193	145.00	67.50			
154	95.00	70.00	194	150.00	67.50			
155	100.00	70.00	195	155.00	67.50			
156	105.00	70.00	196	160.00	67.50			
157	110.00	70.00	197	165.00	67.50			
158	115.00	70.00	198	170.00	67.50			
159	120.00	70.00	199	175.00	67.50			
160	125.00	70.00	200	180.00	67.50			

Sea surface temperature (t°) in grid points (summer)

ANNEX 2

Grid point	t°	Grid point	t°	Grid point	t°	Grid point	t°	Grid point	t°	Grid point	t°
1	-1.40	41	-1.15	81	-1.60	121	5.00	161	9999	201	2.12
2	-1.40	42	-1.23	82	-1.63	122	5.00	162	9999	202	4.18
3	-1.83	43	-1.25	83	-1.59	123	9999	163	9999	203	9999
4	-1.27	44	-1.28	84	-1.56	124	9999	164	9999	204	9999
5	-1.17	45	-1.28	85	-1.54	125	9999	165	9999	205	9999
6	-1.05	46	-1.30	86	-1.53	126	9999	166	9999	206	9999
7	-1.00	47	-1.35	87	-1.52	127	9999	167	3.00	207	9999
8	-1.00	48	-1.40	88	4.75	128	9999	168	1.45	208	9999
9	-1.12	49	-1.50	89	9999	129	9999	169	1.25	209	9999
10	-1.23	50	-1.58	90	2.00	130	9999	170	0.80	210	9999
14	-1.57	54	-1.62	94	2.60	134	9999	174	3.91	214	9999
15	-1.60	55	-1.61	95	9999	135	9999	175	9999	215	9999
16	-1.64	56	-1.60	96	9999	136	1.75	176	9999	216	9999
17	-1.64	57	-1.59	97	9999	137	0.65	177	9999	217	9999
18	-1.64	58	-1.58	98	9999	138	-0.23	178	9999	218	9999
19	-1.64	59	1.58	99	9999	139	-1.00	179	9999	219	9999
20	-1.64	60	1.35	100	1.20	140	-1.12	180	9999	220	9999
21	-1.64	61	1.25	101	1.10	141	-1.20	181	9999	221	9999
22	-1.64	62	1.12	102	1.90	142	-1.00	182	9999	222	9999
23	-1.65	63	1.08	103	3.00	143	0.05	183	9999	223	9999
24	-1.65	64	0.62	104	1.10	144	0.52	184	9999	224	9999
25	-1.64	65	-0.08	105	9999	145	1.25	185	9999	225	9999
26	-1.64	66	-0.25	106	0.47	146	5.20	186	9999	226	9999
27	-1.64	67	-0.50	107	9999	147	5.00	187	9999	227	9999
28	-1.63	68	-0.50	108	-0.86	148	4.92	188	9999	228	9999
29	-1.62	69	-0.46	109	-1.18	149	9999	189	9999	229	9999
30	-1.30	70	-0.50	110	-1.37	150	9999	190	9999	230	9999
31	-1.00	71	-0.62	111	-1.52	151	9999	191	9999	231	5.72
32	-0.83	72	-0.50	112	-1.52	152	9999	192	9999	232	9999
33	-0.65	73	-0.35	113	-1.45	153	9999	193	9999		
34	-0.55	74	0.15	114	-1.25	154	9999	194	9999		
35	-0.40	75	0.63	115	-1.12	155	9999	195	9999		
36	-0.25	76	0.04	116	-0.93	156	9999	196	9999		
37	-0.32	77	-0.50	117	9999	157	9999	197	9999		
38	9999	78	-1.08	118	2.50	158	9999	198	9999		
39	-0.85	79	-1.25	119	4.04	159	9999	199	9999		
40	-1.04	80	-1.42	120	9999	160	9999	200	9999		

Sea surface temperature (t°) in grid points (winter) ANNEX 2 (continued)

Grid point	t°	Grid point	t°	Grid point	t°	Grid point	t°	Grid point	t°	Grid point	t°
1	-1.85	41	-1.78	81	-1.71	121	-1.25	161	9999	201	-1.73
2	-1.85	42	-1.77	82	-1.73	122	-1.25	162	9999	202	-1.85
3	-1.85	43	-1.75	83	-1.71	123	9999	163	9999	203	-1.50
4	-1.85	44	-1.73	84	-1.68	124	9999	164	9999	204	9999
5	-1.85	45	-1.71	85	-1.66	125	9999	165	9999	205	9999
6	-1.85	46	-1.68	86	-1.64	126	9999	166	9999	206	9999
7	-1.85	47	-1.65	87	-1.63	127	9999	167	-1.20	207	9999
8	-1.84	48	-1.63	88	-1.80	128	9999	168	-1.35	208	9999
9	-1.83	49	-1.62	89	9999	129	9999	169	-1.50	209	9999
10	-1.82	50	-1.63	90	-1.82	130	9999	170	-1.66	210	9999
11	-1.81	51	-1.65	91	-1.73	131	9999	171	-1.77	211	9999
12	-1.80	52	-1.66	92	-1.50	132	-1.16	172	-1.83	212	9999
13	-1.78	53	-1.67	93	-1.35	133	-1.02	173	-1.85	213	9999
14	-1.76	54	-1.67	94	-1.37	134	9999	174	-1.82	214	9999
15	-1.74	55	-1.66	95	9999	135	9999	175	9999	215	9999
16	-1.72	56	-1.65	96	9999	136	-1.08	176	9999	216	9999
17	-1.71	57	-1.65	97	9999	137	-1.18	177	9999	217	9999
18	-1.70	58	-1.65	98	9999	138	-1.41	178	9999	218	9999
19	-1.68	59	-1.85	99	9999	139	-1.55	179	9999	219	9999
20	-1.67	60	-1.85	100	-1.74	140	-1.64	180	99999	220	9999
21	-1.65	61	-1.84	101	-1.73	141	-1.72	181	9999	221	9999
22	-1.65	62	-1.82	102	-1.70	142	-1.75	182	9999	222	9999
23	-1.65	63	-1.80	103	-1.58	143	-1.75	183	9999	223	9999
24	-1.66	64	-1.70	104	-1.30	144	-1.75	184	9999	224	9999
25	-1.66	65	-1.67	105	9999	145	-1.77	185	9999	225	9999
26	-1.67	66	-1.67	106	-1.33	146	-1.58	186	9999	226	9999
27	-1.67	67	-1.71	107	9999	147	-1.72	187	9999	227	9999
28	-1.67	68	-1.74	108	-1.52	148	-1.69	188	9999	228	9999
29	-1.67	69	-1.78	109	-1.59	149	9999	189	9999	229	9999
30	-1.87	70	-1.81	110	-1.67	150	9999	190	9999	230	9999
31	-1.87	71	-1.82	111	-1.72	151	9999	191	9999	231	-1.85
32	-1.86	72	-1.80	112	-1.74	152	9999	192	9999	232	9999
33	-1.85	73	-1.78	113	-1.71	153	9999	193	9999		
34	-1.82	74	-1.74	114	-1.68	154	9999	194	9999		
35	-1.79	75	-1.68	115	-1.68	155	9999	195	9999		
36	-1.76	76	-1.58	116	-1.67	156	9999	196	9999		
37	-1.75	77	-1.55	117	9999	157	9999	197	9999		
38	9999	78	-1.59	118	-1.80	158	9999	198	9999		
39	-1.76	79	-1.63	119	-1.68	159	9999	199	9999		
40	-1.75	80	-1.67	120	9999	160	9999	200	9999		

Salinity of surface water layer (S‰), (summer) ANNEX 2 (continued)

Grid point	S‰	Grid point	S‰	Grid point	S‰	Grid point	S‰	Grid point	S‰	Grid point	S‰
1	3310	41	3000	81	3021	121	1800	161	9999	201	2820
2	3305	42	3006	82	3005	122	1800	162	9999	202	3105
3	3275	43	3000	83	2992	123	9999	163	9999	203	2850
4	3232	44	2980	84	2980	124	9999	164	9999	204	9999
5	3200	45	2962	85	2975	125	9999	165	9999	205	9999
6	3170	46	2960	86	2965	126	9999	166	9999	206	9999
7	3145	47	2960	87	2960	127	9999	167	1650	207	9999
8	3120	48	2975	88	3282	128	9999	168	1820	208	9999
9	3100	49	2990	89	9999	129	9999	169	2100	209	9999
10	3082	50	3008	90	2765	130	9999	170	2500	210	9999
11	3060	51	3015	91	2100	131	9999	171	2855	211	9999
12	3046	52	3020	92	1875	132	0800	172	3100	212	9999
13	3040	53	3015	93	1780	133	1100	173	3115	213	9999
14	3038	54	3010	94	1725	134	9999	174	3018	214	9999
15	3035	55	3007	95	9999	135	9999	175	9999	215	9999
16	3030	56	3003	96	9999	136	1785	176	9999	216	9999
17	3030	57	3002	97	9999	137	1950	177	9999	217	9999
18	3032	58	3002	98	9999	138	2500	178	9999	218	9999
19	3037	59	3300	99	9999	139	2875	179	9999	219	9999
20	3040	60	3267	100	2360	140	2930	180	9999	220	9999
21	3042	61	3227	101	2330	141	2935	181	9999	221	9999
22	3040	62	3168	102	2155	142	2958	182	9999	222	9999
23	3037	63	3050	103	1865	143	3032	183	9999	223	9999
24	3032	64	2800	104	1587	144	3000	184	9999	224	9999
25	3030	65	2745	105	9999	145	2980	185	9999	225	9999
26	3027	66	2747	106	1950	146	3310	186	9999	226	9999
27	3025	67	2730	107	9999	147	2900	187	9999	227	9999
28	3025	68	2700	108	2760	148	2470	188	9999	228	9999
29	3025	69	2600	109	2940	149	9999	189	9999	229	9999
30	3270	70	2750	110	2990	150	9999	190	9999	230	9999
31	3260	71	2900	111	2987	151	9999	191	9999	231	3100
32	3250	72	2910	112	2973	152	9999	192	9999	232	9999
33	3220	73	2860	113	2973	153	9999	193	9999		
34	3200	74	2760	114	2978	154	9999	194	9999		
35	3160	75	2600	115	2962	155	9999	195	9999		
36	3130	76	2600	116	2940	156	9999	196	9999		
37	3100	77	2730	117	9999	157	9999	197	9999		
38	9999	78	2870	118	3025	158	9999	198	9999		
39	3015	79	2960	119	2750	159	9999	199	9999		
40	2980	80	3002	120	9999	160	9999	200	9999		

Salinity at sea surface (S‰) in grid points (winter) ANNEX 2 (continued)

Grid point	S‰	Grid point	S‰	Grid point	S‰	Grid point	S‰	Grid point	S‰	Grid point	S‰
1	3408	41	3285	81	3090	121	1900	161	9999	201	3140
2	3408	42	3250	82	3085	122	1900	162	9999	202	3252
3	3405	43	3200	83	3070	123	9999	163	9999	203	3250
4	3402	44	3145	84	3050	124	9999	164	9999	204	9999
5	2382	45	3107	85	3040	125	9999	165	9999	205	9999
6	3364	46	3075	86	3035	126	9999	166	9999	206	9999
7	3345	47	3058	87	3020	127	9999	167	2200	207	9999
8	3325	48	3040	88	3455	128	9999	168	2500	208	9999
9	3318	49	3048	89	9999	129	9999	169	2655	209	9999
10	3305	50	3057	90	3390	130	9999	170	3020	210	9999
11	3285	51	3065	91	3270	131	9999	171	3170	211	9999
12	3245	52	3075	92	3000	132	2000	172	3252	212	9999
13	3180	53	3065	93	2500	133	1700	173	3270	213	9999
14	3150	54	3045	94	2535	134	9999	174	3260	214	9999
15	3137	55	3040	95	9999	135	9999	175	9999	215	9999
16	3125	56	3035	96	9999	136	2000	176	9999	216	9999
17	3118	57	3035	97	9999	137	2250	177	9999	217	9999
18	3108	58	3035	98	9999	138	2580	178	9999	218	9999
19	3095	59	3453	99	9999	139	2850	179	9999	219	9999
20	3087	60	3458	100	3030	140	2975	180	9999	220	9999
21	3080	61	3458	101	3075	141	3118	181	9999	221	9999
22	3075	62	3450	102	3040	142	3183	182	9999	222	9999
23	3068	63	3270	103	2850	143	3208	183	9999	223	9999
24	3060	64	3145	104	2550	144	3220	184	9999	224	9999
25	3060	65	2945	105	9999	145	3210	185	9999	225	9999
26	3060	66	2820	106	2415	146	3430	196	9999	226	9999
27	3060	67	2900	107	9999	147	3390	187	9999	227	9999
28	3062	68	3110	108	2780	148	3325	188	9999	228	9999
29	3065	69	3150	109	2990	149	9999	189	9999	229	9999
30	3375	70	3175	110	3060	150	9999	190	9999	230	9999
31	3385	71	3210	111	3112	151	9999	191	9999	231	3250
32	3382	72	3210	112	3115	152	9999	192	9999	232	9999
33	3380	73	3160	113	3108	153	9999	193	9999		
34	3365	74	3110	114	3100	154	9999	194	9999		
35	3325	75	2975	115	3080	155	9999	195	9999		
36	3218	76	2840	116	3045	156	9999	196	9999		
37	3195	77	2812	117	9999	157	9999	197	9999		
38	9999	78	2947	118	3408	158	9999	198	9999		
39	3260	79	3020	119	3295	159	9999	199	9999		
40	3290	80	3067	120	9999	160	9999	200	9999		

Mean monthly air temperature (t°), January

ANNEX 3

Grid point	t°	Grid point	t°	Grid point	t°	Grid point	t°	Grid point	t°	Grid point	t°
1	-23.8	41	-29.0	81	-30.0	121	-24.4	161	9999	201	-22.2
2	-24.2	42	-28.8	82	-30.0	122	-27.0	162	9999	202	-19.8
3	-25.2	43	-28.8	83	-30.0	123	9999	163	9999	203	-20.6
4	-26.0	44	-28.8	84	-30.1	124	9999	164	9999	204	9999
5	-26.8	45	-29.0	85	-30.1	125	9999	165	9999	205	9999
6	-27.2	46	-29.2	86	-30.1	126	9999	166	9999	206	9999
7	-28.0	47	-29.4	87	-30.2	127	9999	167	-30.4	207	9999
8	-28.2	48	-29.6	88	-11.8	128	9999	168	-30.2	208	9999
9	-28.4	49	-29.8	89	9999	129	9999	169	-28.3	209	9999
10	-28.5	50	-30.0	90	-18.6	130	9999	170	-26.3	210	9999
11	-28.6	51	-30.7	91	-21.2	131	9999	171	-23.9	211	9999
12	-29.1	52	-30.8	92	-23.2	132	-32.0	172	-22.4	212	9999
13	-29.2	53	-30.8	93	-25.4	133	-31.4	173	-21.6	213	9999
14	-29.3	54	-31.2	94	-27.0	134	9999	174	-23.4	214	9999
15	-29.4	55	-31.4	95	9999	135	9999	175	9999	215	9999
16	-29.5	56	-31.6	96	9999	136	-31.6	176	9999	216	9999
17	-29.7	57	-31.8	97	9999	137	-30.8	177	9999	217	9999
18	-29.9	58	-32.0	98	9999	138	-29.4	178	9999	218	9999
19	-30.1	59	-14.4	99	9999	139	-27.9	179	9999	219	9999
20	-30.2	60	-16.0	100	-31.0	140	-27.0	180	9999	220	9999
21	-30.6	61	-18.0	101	-29.8	141	-25.9	181	9999	221	9999
22	-30.9	62	-20.2	102	-29.8	142	-25.0	182	9999	222	9999
23	-31.2	63	-22.6	103	-30.0	143	-24.8	183	9999	223	9999
24	-31.4	64	-25.6	104	-30.0	144	-24.6	184	9999	224	9999
25	-31.8	65	-26.4	105	9999	145	-25.1	185	9999	225	9999
26	-32.0	66	-28.2	106	-30.6	146	-14.6	186	9999	226	9999
27	-32.4	67	-28.4	107	9999	147	-18.0	187	9999	227	9999
28	-32.6	68	-28.6	108	-29.6	148	-20.8	188	9999	228	9999
29	-32.8	69	-28.6	119	-29.0	149	9999	189	9999	229	9999
30	-21.2	70	-28.8	110	-28.8	150	9999	190	9999	230	9999
31	-22.0	71	-30.0	111	-28.4	151	9999	191	9999	231	-15.9
32	-22.5	72	-29.8	112	-28.2	152	9999	192	9999	232	9999
33	-23.3	73	-29.5	113	-28.0	153	9999	193	9999		
34	-24.8	74	-29.6	114	-27.9	154	9999	194	9999		
35	-26.2	75	-29.4	115	-27.9	155	9999	195	9999		
36	-27.2	76	-29.6	116	-28.0	156	9999	196	9999		
37	-28.2	77	-29.2	117	9999	157	9999	197	9999		
38	9999	78	-29.2	118	-18.2	158	9999	198	9999		
39	-28.4	79	-29.8	119	-20.2	159	9999	199	9999		
40	-29.8	80	-29.9	120	-22.3	160	9999	200	9999		

APPENDIX

REVIEW

National Research Council Canada
Conseil national de recherches Canada

Institute for Environmental Research and Technology
Institut de technologie et de recherche environnementales

Ottawa, Canada
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NRC·CNRC

DOCUFAX

Date : 4 June 1995

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Page: 1 of 6

Re/Objet : Review of Project I.4.1

Attached please find my review of Project I.4.1.

Regards,

Project I.4.1 Content of Database

General Review

The report provides a good overview of the environmental factors which affect ice navigation on the Northern Sea Route, and the compilation or organization of databases for these factors. The focus is on those factors which are most critical to establishing probabilities of ice transit through the Northern Sea Route. Four databases were identified; (i) general climatic (open water, ice coverage, ice age), (ii) ice thickness (draft, freeboard, ridging, snow cover), (iii) discontinuities (leads, polynyas, ice decay), and (iv) pressure. The databases address the pertinent factors.

A very thorough description of AARI data of interest to INSROP has been provided. The format, quality, frequency, duration, location and availability of the data are presented. The data selected for inclusion appears to be most appropriate to the task of assessing shipping through the Northern Sea Route.

A methodology has been developed for reducing general climatic data and transforming it to data on ice characteristics and physical properties relevant to ice navigation. The data base of this information is in a format which lends itself to subsequent interfacing to the INSROP GIS, and consequently to assessing various routing options. More direct data from actual field measurement of ice thickness are an important addition to the database. These data have to be treated with care since they are not sampled in a random fashion.

Shipborne ice observation data is a key component to relating ice characteristics to actual vessel performance in ice. The database is an important constituent in predicting vessel performance in various ice conditions. The amount of ridging and the degree of ice decay are identified as being of particular interest.

Finding the path of least ice is every bit as important as knowing the maximum resistance which ice or ice ridges can present to transit of a vessel. Use of discontinuities or leads can result in significant extension at the beginning and end of the normal shipping season. AARI has developed software to determine the length and orientation of discontinuities. A more complete description of the software would be very interesting.

All in all the report demonstrates that the authors have a very realistic grasp of the factors which are important in assessing ice navigation. When the data bases are completed they will be a very useful tool in assessing the probabilities of successful ice navigation through the Northern Sea Route.

Project I.4.1 Content of Database

Specific Comments

p. 7; The discussion of the cost of obtaining data is not appropriate for this type of technical report. Simply say which data are available freely and which is not. This section reads like a negotiation for more funds.

p. 9; There is a fundamental question for INSROP, should the databases and GIS be developed to run on PCs or higher level UNIX machines.

p. 34; The heading for the columns in the table should clearly indicate "Grid Point", "Long.", and "Lat.", also that the units are in degrees and minutes. I think normal convention for specifying a location is to give latitude first, then longitude. Should grid point 59 be 55°00′ long and 77°50′ lat? Perhaps it should be 77°30′ lat.

The report is missing conclusions. Also there should be an abstract or summary at the beginning of the report.

The final report for this project should have an appendix with a brief description of the software and hardware requirements needed to utilize the databases. I tried to access the databases on the diskette sent to me on PARADOX 3.5 with no success.

INTRODUCTION

The main aim of the Subproject is to form databases on ice, meteorological and hydrological conditions for different segments of transit navigation along the NSR. They are necessary for substantiating a possibility and perspectives of international shipping along the NSR, retrospective analysis of effectiveness and safety of shipping in different seasons, modelling of the motion of ships in ice.

transit

At the first stage the content of the databases that can be used in the interests of the program was preliminarily defined, a brief description of the data available at the AARI was prepared and their volume, quality and organization level were estimated. These data allow a conclusion that the AARI has available regime meteorological information that in principle meets the requirements of the program goals, but much of this information is contained on paper media. The work for creating all necessary databases is beyond the scope of this subproject both with regard to time frames and financing.

In this connection a correct choice of priorities is of special importance. Our view point is that for estimating the conditions of transit navigation using different scenarios, the databases that are created at the AARI in the interests of other national and international programs should be used to a maximum. It is desirable that the main efforts of investigators under this subproject be aimed at supplementing and adapting the databases that are most important for addressing the INSROP goals taking into account their specific features. First of all, it is necessary to pay attention to those databases that will provide an assessment of the probability of some conditions or other on different NSR segments at minimum labour and time consumption for their preparation. Further, provided there is sufficient funding, other bases that are of interest for the INSROP participants can also be prepared.

The main directions of the activities under the subproject were selected on the basis of existing understanding of the influence of different environmental characteristics on navigation conditions along the NSR and by analysing the state of the information base of the AARI.

- a comparative analysis of the data of the CIHMI and NDCSI and identification of a spatial distribution of a relative error of the CIHMI data as a result of the effects of data interpolation and extrapolation;
- selection of data of measurements by ships of opportunity that are within the airborne reconnaissance band and between the bands;
- a comparative analysis of data and determination of transition functions from the data of general databases to the conditions along the navigation route (separately for data belonging to the airbone reconnaissance band and beyond it).

At present series of characteristics that have evident navigation significance but are very difficult to be physically interpreted are centered in climatic databases. Of obvious interest appears to be a possibility for an indirect estimate of physical ice cover characteristics that are difficult to be measured in mass from the data of general databases. Thus, for example, general databases on concentration of ice of different age gradations, degree of destruction, amount of hummocking and amount of snow on ice cover (taking into account data on marine meteorology) can be used for assessing:

- mean weighted and effective thickness of ice cover;
- strength characteristics of ice cover (Young's modulus);
- interaction characteristics of snow and ice cover with the ship's hull.

As transition functions empirical relations that are contained in published materials on methods can be used. One of the most important problems is to specify these relations. As has already been mentioned, most effective for this is to systematize data of direct measurements of physical characteristics in the form of a database.

Fig. 2 presents the result of processing information that is contained in the secondary database of mean weighted ice cover thickness in the form of a multiyear estimate of ice cover thickness of a 25% probability. The secondary database is formed on the basis of the GSIDB using partial concentrations of sea ice of different age gradations.

transfer function would be better terminology. I suggest you change it here and elsewhere throughout the report.

Transit navigation along the NSR in spring can be made on the basis of a combined use of flaw zones of young ice and open water that have a different degree of development and stability and of a system of discontinuities in ice cover on separate route segments (Fig. 4).

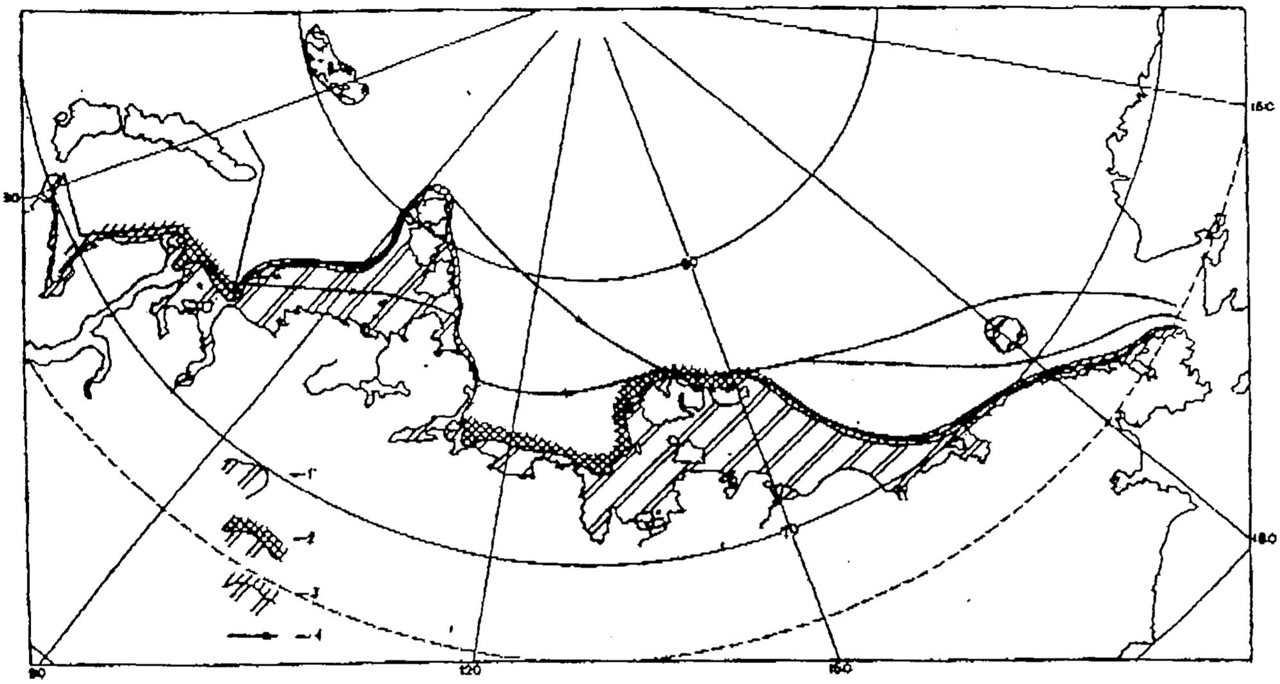


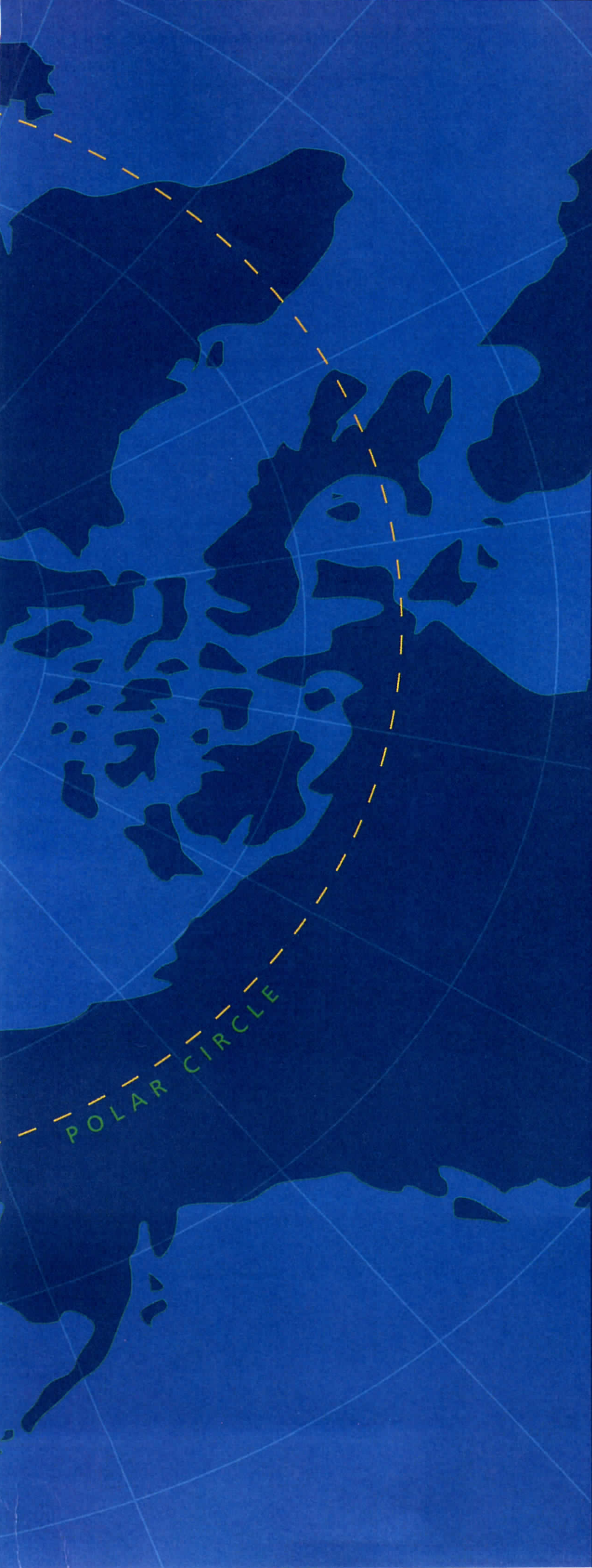
Fig. 4. Possible routes of transit navigation of icebreakers and transport vessels in spring.
1 -fast ice; 2 - quasistationary flaw zones of young ice and open water;
3 - non-stationary flaw zones of young ice and open water; 4 - transit navigation routes

In the south-western Kara Sea icebreakers escort ships all winter using Yamal'skaya and Ob'-Yeniseyskaya zones of young ice. In the absence of the Yamal'skaya zone of young ice ships navigate either along the western coast of the Yamal peninsula and then toward Dikson or north of the Zhelaniya cape taking into account systems of discontinuities in these regions (Fig. ..).

Fig N. missing

In the north-eastern Kara Sea transit navigation can be either along the unstable flaw zone of young ice or along the channel broken in fast ice by icebreakers.

In the Laptev Sea possible variants of transit navigation of icebreakers and transport ships in spring can be routes from the Arctic cape or from the eastern coast of the Taimyr peninsula



The three main cooperating institutions of INSROP

Ship & Ocean Foundation (SOF), Tokyo, Japan.

SOF was established in 1975 as a non-profit organization to advance modernization and rationalization of Japan's shipbuilding and related industries, and to give assistance to non-profit organizations associated with these industries. SOF is provided with operation funds by the Sasakawa Foundation, the world's largest foundation operated with revenue from motorboat racing. An integral part of SOF, the Tsukuba Institute, carries out experimental research into ocean environment protection and ocean development.

Central Marine Research & Design Institute (CNIIMF), St. Petersburg, Russia.

CNIIMF was founded in 1929. The institute's research focus is applied and technological with four main goals: the improvment of merchant fleet efficiency; shipping safety; technical development of the merchant fleet; and design support for future fleet development. CNIIMF was a Russian state institution up to 1993, when it was converted into a stockholding company.

The Fridtjof Nansen Institute (FNI), Lysaker, Norway.

FNI was founded *in 1958 and is based at* Polhøgda, the home of Fridtjof Nansen, famous Norwegian polar explorer, scientist, humanist and statesman. The institute spesializes in applied social science research, with special focus on international resource and environmental management. In addition to INSROP, the research is organized in six integrated programmes. Typical of FNI research is a multidisciplinary approach, entailing extensive cooperation with other research institutions both at home and abroad. The INSROP Secretariat is located at FNI.