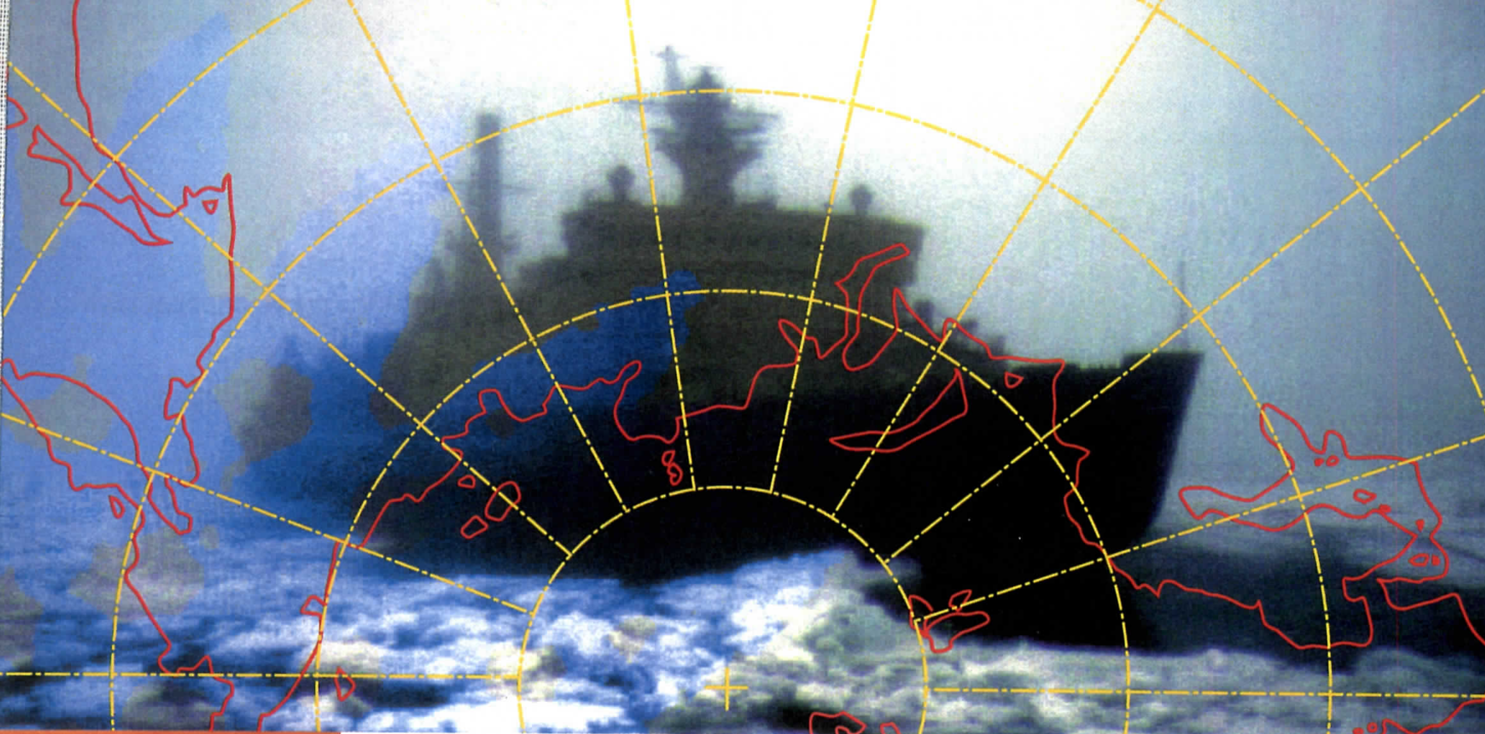

INSROP WORKING PAPER
NO. 131 - 1999, I.4.2

Development of the Databases on Natural Conditions of Navigation along the NSR

By S. Brestkin, V. Karklin et al.

INSROP International Northern Sea Route Programme

Central Marine Research & Design Institute, Russia

The Fridtjof Nansen Institute, Norway

Ship and Ocean Foundation, Japan

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Box C RS

Sub-Programme I: Natural Conditions and Ice Navigation

Project I.4.2: Development of the Databases on Natural Conditions of Navigation along the NSR

Supervisor: Sergey Brestkin and Valery Karklin, AARI

Title: **Development of the Databases on Natural Conditions of Navigation along the NSR**

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Date: 21 January 1999

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FOREWORD - INSROP WORKING PAPER

INSROP is a five-year multidisciplinary and multilateral research programme, the main phase of which commenced in June 1993. The three principal cooperating partners are **Central Marine Research & Design Institute (CNIIMF)**, St. Petersburg, Russia; **Ship and Ocean Foundation (SOF)**, Tokyo, Japan; and **Fridtjof Nansen Institute (FNI)**, Lysaker, Norway. The INSROP Secretariat is shared between CNIIMF and FNI and is located at FNI.

INSROP is split into four main projects: 1) Natural Conditions and Ice Navigation; 2) Environmental Factors; 3) Trade and Commercial Shipping Aspects of the NSR; and 4) Political, Legal and Strategic Factors. The aim of INSROP is to build up a knowledge base adequate to provide a foundation for long-term planning and decision-making by state agencies as well as private companies etc., for purposes of promoting rational decisionmaking concerning the use of the Northern Sea Route for transit and regional development.

INSROP is a direct result of the normalization of the international situation and the Murmansk initiatives of the former Soviet Union in 1987, when the readiness of the USSR to open the NSR for international shipping was officially declared. The Murmansk Initiatives enabled the continuation, expansion and intensification of traditional collaboration between the states in the Arctic, including safety and efficiency of shipping. Russia, being the successor state to the USSR, supports the Murmansk Initiatives. The initiatives stimulated contact and cooperation between CNIIMF and FNI in 1988 and resulted in a pilot study of the NSR in 1991. In 1992 SOF entered INSROP as a third partner on an equal basis with CNIIMF and FNI.

The complete series of publications may be obtained from the Fridtjof Nansen Institute.

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Introduction

As revealed by experience gained during the INSROP Phase I, the provision of hydrometeorological data to INSROP participants and their inclusion to the information system is connected with a number of legal, management, technological and financial aspects. The most acceptable variant of addressing this problem is a possibly wider use of the databases for international exchange included to the Global Sea-Ice Data Bank (WMO) in a complex with the specialized AARI databases set up under the national programs.

Based on the databases available at the AARI, a secondary database under the project was created. It can be used for updating the estimates of probability of some or other navigation conditions along the Northern Sea Route obtained from the Global Sea-Ice Data Bank.

The aims of the Project are as follows:

1. Development of the available AARI databases and creation on their basis a secondary database that may be potentially prepared for remote access for INSROP participants in the future. The actual setup of an operative remote access has however not been part of the project, but may become a reality in the future if necessary funds can be found.
2. Creation of reference tables containing the probabilistic characteristics of navigation conditions along the NSR.

Special attention in the Project was devoted to conversion of available databases to the Relational DBMS to provide the client-server operation mode.

1. Database Development

The following databases were used:
- ice observations from ships of opportunity and special shipborne ice observations;
- discontinuities in the ice cover;
- ice pressures in the ice cover.

The aforementioned databases were developed in the following directions:
- supplementing the databases with initial information;
- database conversion to the Relational DBMS "Oracle 7" that creates the conditions for client-server operation mode.

The databases contain generalized information, which was prepared for the remote access operation mode by means of SQL-queries and can be located in the AARI server.

1.1. Ice observations from ships of opportunity and special shipborne ice observations

Shipborne observations supplement satellite ice information as they differ in greater detailing and more accurately reflect the influence of the ice cover characteristics on shipping. A quantitative analysis of differences in ice conditions directly along the navigation route and in region-specific ice conditions is presented in INSROP WP No.23, 1995.

Shipborne observations can be divided into 2 types:
- observations from ships of opportunity that are contained in navigator's messages (reported every 4 hours) and in the reports of ships' masters and ship hydrologists;
- special shipborne ice observations within the framework of the AARI expedition programs (small-scale ice cover characteristics and ship motion operation parameters).

1.1.1. Database of ice observations from ships of opportunity

The initial database contains data on the hydrometeorological navigation conditions based on observations of the crews of icebreakers and ships in accordance with the shipping regulations along the Northern Sea Route six times a day (4, 6, 12, 16, 20 and 24 h, ship time).

The secondary database includes data collected during the following sea operations:

- cruise of the atomic icebreaker "Yamal" and the M/S "Yu. Dolgoruky" along the route Kara Gate Strait – Yenisey Bay, April 30-May 6, 1993;
- cruise of the atomic icebreaker "Yamal", the atomic icebreaker "Vaigach" and the M/S "Yu. Dolgoruky" along the route Yenisey Bay - Kara Gate Strait, May 6-9, 1993;
- cruise of the atomic icebreaker "Vaigach" and the M/S "I. Papanin" along the route Dikson – Vilkitsky Strait, May 18-20, 1993;
- cruise of the atomic icebreaker "Taimyr" and the M/S "Uikku" along the route Tiksi-Vilkitsky Strait, August 3-7, 1993;
- cruise of the atomic icebreaker "Rossiya" and the M/S "V. Tkachev" along the route Pevek-Tiksi, August 3-8, 1993.

The secondary database contains the following data:
- date and time of the cruise start/end in the uniform ice zone (UIZ);
- geographical coordinates of the cruise start/end in the UIZ;
- ice cover characteristics in the UIZ: total concentration, age categories, hummock and ridge concentration, ice melting stages and intensity of ice pressure;
- navigation route length in the UIZ.

1.1.2. Database of special shipborne ice observations

Database of special shipborne ice observations is based on the 20-year period (1977 to 1997) data collected by AARI specialists aboard ships and icebreakers navigating the NSR. The observations included determination of ice characteristics in the navigation region (within horizontal visibility), as well as directly en-route.

The initial shipborne observation database contains hydrometeorological and operation information about navigation in the uniform ice zones. A zone is considered uniform if the changes in all ice cover characteristics within this zone do not exceed the measurement accuracy.

The secondary database includes observation data collected during the following cruises:
- super earlier transit cruise of the atomic icebreaker "Rossiya" and the M/S Monchegorsk" along the route Port Murmansk-Port Pevek, May-June, 1986;
- experimental transit cruise of the M/S "Kandalaksha" along the route Port Yokohama – Port Kirkenes, August 1995;
- resupply cruise of the diesel/electric ship "Mikhail Somov", September 1996-January 1997;
- research expedition onboard the diesel/electric ship "Mikhail Somov", May 1997.

The secondary database contains the same characteristics that are enumerated in Section 1.1.1.

1.2. Discontinuities in the ice cover

The database on the discontinuity characteristics in the ice cover of the Chukchi, East-Siberian and Laptev Seas for April-June, October-December and the Kara Sea for April-May and November-December, which is created under the national programs was used (INSROP WP No. 68-1996, 1.4.1).

The secondary database includes mean monthly values of the following discontinuity characteristics:
- specific length;
- first orientation mode;
- second orientation mode
- frequency of occurrence of the first modal range;
- frequency of occurrence of the second modal range.

Definitions and calculation algorithms of these characteristics were outlined in INSROP WP No. 68-1996, 1.4.1. The number of observations included to the secondary database is presented in Table 1.1. The Table contains the number of charts, each of them presenting generalized data for 1 to 5 days.

Table 1.1.

Year	Months					
	April	May	June	October	Novembe r	December
Kara Sea						
1979	5	6	-	-	-	-
1980	6	5	-	-	-	-
1981	6	6	-	-	-	-
1982	-	3	-	-	16	17
1983	6	5	-	-	-	-
1984	-	15	-	-	19	-
1986	-	-	-	-	-	8
1987	-	10	-	-	-	-
1991	4	1	-	-	-	-
1992	7	-	-	-	-	-
1993	9	8	-	-	1	6
1994	6	5	-	-	7	8
1995	7	5	-	-	2	1
1996	8	2	-	-	-	6
1997	6	-	-	-	-	-
All years	70	71	-	-	45	46
Laptev, East-Siberian and Chukchi Seas						
1979	5	6	1	-	-	-
1980	6	6	4	5	5	6
1981	6	6	6	4	5	6

1982	-	7	28	21	29	27
1983	6	5	6	-	-	-
1984	-	17	1	31	19	-
All years	23	47	46	61	58	39

The generalized characteristics of discontinuities were calculated for the 50x50 km grid squares, which cover the whole of the ship navigation area along the routes selected within the WP 1 framework. The X-axis of the calculation grid is parallel to the 130°E meridian and the Y-axis is parallel to the 140°W meridian. The southward axis directions were assumed to be positive directions. In the adopted coordinate system the North Pole has the following coordinates $X_p= -650$ km, $Y_p=2150$ km (fig. 1.1).

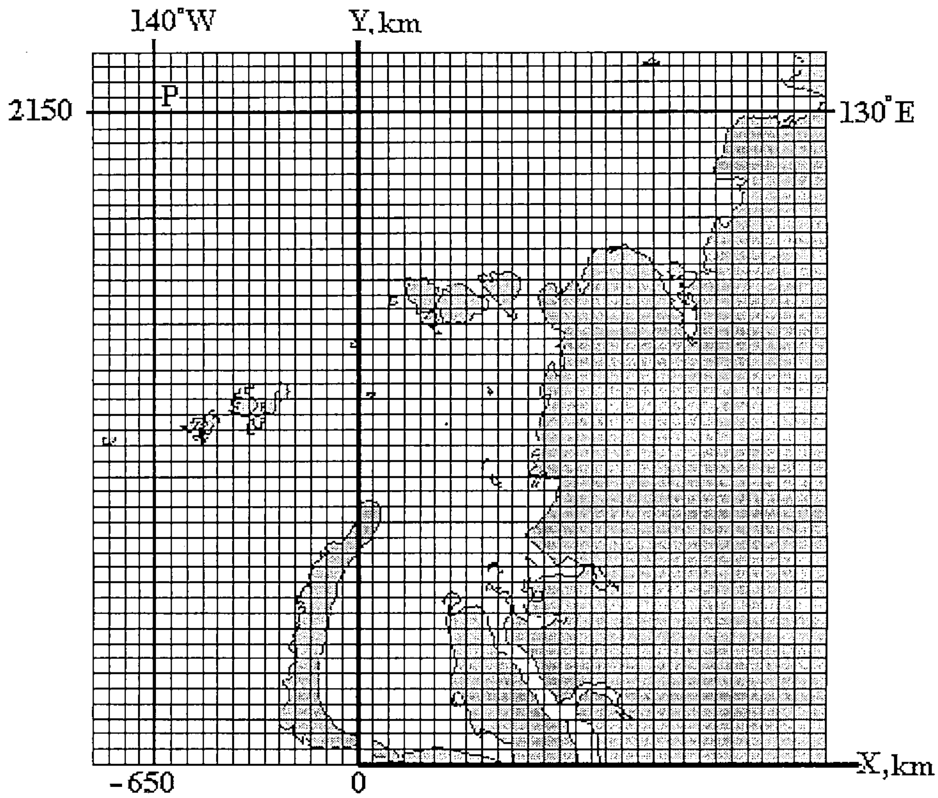


Fig. 1.1 Rectangular coordinate system. (P – North Pole, 0 – beginning of coordinates)

The angles that characterize the discontinuity orientation are read out from the positive X-axis direction counterclockwise from 0 to 180°.

1.3. Ice pressures in the ice cover

Ice pressure belongs to the most dangerous phenomenon for ships. However, due to difficulty of observations and measurements, its spatial distribution characteristics were insufficiently investigated with ice pressure observations being of occasional character. However, using the atmospheric pressure databases we can calculate the wind fields in the near-water layer and based on the empirical relations (Busuyev, Fedyakov, 1979), the probability of different intensity of ice pressures can be assessed with sufficient statistical reliability in the prescribed regions at the given time.

The wind fields at a 10 m height for four synoptic times were calculated on the basis of the data set of surface atmospheric pressure above the Arctic Basin at 1°× 1° grid points for 1960-1985. For this purpose, the calculation method formally adopted in Russia was applied (Handbook..., 1994).

In addition to wind, for calculating the probability of different ice pressure intensity the ice concentration data at 0°.5×0°.5 grid points and landfast ice boundaries at 0°.25×0°.25 grid points for 1960-1985 were used.

The following assumptions were adopted for calculating the probability of different pressure intensity:

- the ice cover has average hummock and ridge concentration for this 10-day period;
- ice concentration is equal to 9-10 tenths;
- the relationship between the quantity of ice of different age categories is within mean multiyear values.

For wind speeds derived from the air pressure fields, in each square the statistical distributions *P(B)* were calculated from the following formulas:

$$P(B) = n_1(x)/\Delta x N, \qquad (1)$$

where $n_1(x)$ is the number of parameters possessing the indication, N is the number of observations.

$$\{(x - \Delta x/2) < (V_i)_j < (x + \Delta x/2)\}, \qquad (2)$$

where Δx is the initial data grouping interval; V is the wind; i is the wind speed index, j is the wind direction index by 45° sectors.

Data on the wind direction are subdivided into 3 types: "onshore", "offshore" and "neutral". The wind type was established taking into account the location of the landfast ice boundary and ice concentration by eight points surrounding the calculation (central) point.

For calculation of the probability of different ice pressure intensity, the formula of full probability for the incompatible event groups was used:

$$P_{\rightarrow\leftarrow} = \sum_{k=1}^{n} P(B_k) \cdot \sum_{i=1}^{n} P(B_i) \cdot P(A_{ik}/B_{ik}), \qquad (3)$$

where: i is the wind speed range number and k is the wind type indicator, A and B refer to ice compression and wind, respectively.
The conventional probability $P(A_{ik} / B_{ik})$ was obtained from shipborne observation data.

The probabilistic estimates of ice pressure intensity were obtained for the routes selected in WP1 for the 1960-1985 period.

1.4. A brief description of the secondary database

The secondary database was arranged using the Relational Database Management System (RDBMS) "Oracle 7", which provides the client-server operation mode.

The creating server block the trial version of Oracle 7 Server Release 7.3.3.0.0, including the PL/SQL Release 2.3.3.0.0 language processor was used. The server was located on the Intel Pentium 166 Mz (RAM 32 Mb) platform under the management of the OS Microsoft Windows NT 4.0 Server (Build 1381) with the established Service Pack 3. The system uses the TCP/IP net protocol. The IP-address of the host machine is 195.19.196.32 (brestkin2.aari.ru).

The Oracle server maintains the user's interface Oracle SQL*Plus 3.3.3.0.0. For operation in the client-server mode a net software product Oracle SQL*Net Server 2.3.3.0.0 is used (the TCP/IP protocols are accessible through the Oracle TCP/IP Adapter 2.3.3.0.0 Oracle Names Pipes Oracle Names Server 2.0.3.0.0). There is also an access driver Oracle 7 32 bit ODBC Driver 2.0.3.1.1 in the system. For server management, Oracle Enterprise Manager 1.3.5 is used.

The secondary database has the Resolve TNSnames wgs_brestkin2_ORCL.world. The secondary database tables are located in the USER_Data Tablespace and belong to the "Master" UserScheme.

In order to simplify the procedure for creating the SQL-queries by the end user of the database as well as for reducing the quantity of transactions, necessary for obtaining the required information, the structure of tables and the presentation format of different data types were unified to a maximum.

Two tables were created for each information type. The first table contains information on the coordinates and observation dates. The second table contains the ice cover state characteristics. This database structure allows a flexible data selection by geographical regions and observation dates. It is also most suitable for further GIS use.

The Appendix to the Report includes simple SQL-query examples allowing one to obtain the values of prescribed characteristics belonging to the given regions, that are restricted by the geographical coordinate grid trapezium and to the prescribed date range.

The following date and coordinate formats were used. The coordinates (in degrees) for all data types are represented by the numbers with a fixed point containing two digits to the right of the decimal point

Dates of shipborne observations and calculated ice pressure values are presented in the DD-MON-YYYY format. Data on discontinuities are conventionally referred to the middle of each month. Hence, the observation dates are presented in the form of numerical month and year values in the NUMBER format.

Although the database has been prepared to answer SQL queries by remote access, the actual establishment of remote access has not yet been made. This has not been part of the project, but may become a reality in the future if necessary funds can be found.

1.4.1. Ice observations from ships of opportunity and special ice observations (table structure of the secondary database)

The tables contain 1680 records covering the 1986-1997 observations.

Coordinate table – Master.Histcoord (SYS_C00461 indices)

No.	Field name	Data type	Data description
1	Road	NUMBER(1)	Route No.
2	Type	CHAR	Observation type: S – special, T – ships of opportunity
3	Path	NUMBER(4)	Segment No.
4	Dates	DATE	Observation date
5	Times	VARCHAR(12)	Observation time
6	Lat	NUMBER(4,2)	Latitude
6	Lon	NUMBER(5,2)	Longitude

Table of characteristics – Master.Icehist (SYS_C00466 indices)

No.	Field name	Data type	Description
1	Route	NUMBER(1)	Route No.
2	Path	NUMBER(4)	Segment No.
3	Length	NUMBER(3,2)	Segment length
4	Cat1_1	NUMBER(3)	Frequency of occurrence of 0 concentration

5	Cat1_2	NUMBER(3)	Frequency of occurrence of 1/10-3/10 concentration
6	Cat1_3	NUMBER(3)	Frequency of occurrence of 4/10-6/10 concentration
7	Cat1_4	NUMBER(3)	Frequency of occurrence of 7/10-8/10 concentration
8	Cat1_5	NUMBER(3)	Frequency of occurrence of 9/10-10/10 concentration
9	Cat1_6	NUMBER(3)	Frequency of occurrence of 10/10 concentration
10	Cat2_1	NUMBER(3)	Frequency of occurrence of residual ice

No.	Field name	Data type	Description
11	Cat2_2	NUMBER(3)	Frequency of occurrence of thick first-year ice
12	Cat2_3	NUMBER(3)	Frequency of occurrence of medium first-year ice
13	Cat2_4	NUMBER(3)	Frequency of occurrence of thin first-year ice
14	Cat2_5	NUMBER(3)	Frequency of occurrence of young ice
15	Cat2_6	NUMBER(3)	Frequency of occurrence of nilas
16	Cat2_7	NUMBER(3)	Frequency of occurrence of ice absence
17	Cat3_1	NUMBER(3)	Frequency of occurrence of 0 hummock and ridge concentration
18	Cat3_2	NUMBER(3)	Frequency of occurrence of 1 point hummock and ridge concentration
19	Cat3_3	NUMBER(3)	Frequency of occurrence of 2 point hummock and ridge concentration
20	Cat3_4	NUMBER(3)	Frequency of occurrence of 3 point hummock and ridge concentration
21	Cat3_5	NUMBER(3)	Frequency of occurrence of 4 point hummock and ridge concentration
22	Cat3_6	NUMBER(3)	Frequency of occurrence of 5 point hummock and ridge concentration
23	Cat4_1	NUMBER(3)	Frequency of occurrence of 0 ice melting stage
24	Cat4_2	NUMBER(3)	Frequency of occurrence of 1 point ice melting stage
25	Cat4_3	NUMBER(3)	Frequency of occurrence of 1 point ice melting stage
26	Cat4_4	NUMBER(3)	Frequency of occurrence of 1 point ice melting stage
27	Cat4_5	NUMBER(3)	Frequency of occurrence of 1 point ice melting stage

28	Cat4_6	NUMBER(3)	Frequency of occurrence of 1 point ice melting stage
29	Cat5_1	NUMBER(3)	Frequency of occurrence of 0 ice pressure
30	Cat5_2	NUMBER(3)	Frequency of occurrence of 1 point ice pressure
31	Cat5_3	NUMBER(3)	Frequency of occurrence of 2 point ice pressure
32	Cat5_4	NUMBER(3)	Frequency of occurrence of 3 point ice pressure

1.4.2. Discontinuities in the ice cover (table structure of the secondary database)

The tables contain 18700 records covering the 1979-1996 observation period.

Coordinate table - Master.Breakupcoord (SYS_C00468 indices)

No.	Field name	Data type	Description
1	Numbers	NUMBER(5)	Observation Point No.
2	Lat	NUMBER(4,2)	Latitude
3	Lon	NUMBER(5,2)	Longitude

The calculated parameters table - Master.Icebreakup (SYS_C00470 indices).

No.	Field name	Data type	Description
1	Numbers	NUMBER(5)	Observation Point No.
2	Month	NUMBER(2)	Month
3	Year	NUMBER(4)	Year
4	Number of cases	NUMBER(3)	Number of observations
5	Long_mode	NUMBER(3)	Specific length (total discontinuity length in the square referred to the square area)
6	Count_mode	NUMBER(1)	Number of modal values of discontinuity orientation
7	First_mode	NUMBER(3)	1st mode orientation
8	Second_mode	NUMBER(3)	2d mode orientation
9	First	NUMBER(3)	1st mode frequency of occurrence
10	Second	NUMBER(3)	2d mode frequency of occurrence

1.4.3. Ice pressures in the ice cover (table structure of the secondary database)

The tables contain 264000 records covering the 1960-1986-observation period.

Coordinate table - Master.Comprescoord (SYS_C00473 indices)

No.	Field name	Data type	Description
1	Numbers	NUMBER(5)	Observation No.
2	Dates	DATE	Observation date
3	Lat	NUMBER(4,2)	Latitude
4	Lon	NUMBER(5,2)	Longitude

The calculated parameters table – Master.Icecompress (SYS_C00478 indices)

No.	Field name	Data type	Description
1	Numbers	NUMBER(5)	Observation No.
2	Ice	CHAR	*-absence, F-landfast ice, A – 10/10, 9/10-9/10 and 8/10-8/10 concentration

No.	Field name	Data type	Description
3	P_0_1	NUMBER(2,1)	Frequency of occurrence of 0-1 point pressure intensity
4	P_1	NUMBER(2,1)	Frequency of occurrence of 1 point pressure intensity
5	P_1_2	NUMBER(2,1)	Frequency of occurrence of 1-2 point pressure intensity
6	P_2	NUMBER(2,1)	Frequency of occurrence of 2 point pressure intensity
7	P_2_3	NUMBER(2,1)	Frequency of occurrence of 2-3 point pressure intensity
8	P_3	NUMBER(2,1)	Frequency of occurrence of 3 point pressure intensity

1.4.4. Examples of SQL-queries to the secondary database

Example 1. Sampling of the frequency of occurrence of 0 concentration for the trapezium between 69 and 70^0 latitude and 65 and 75^0 longitude.

```
SELECT Hiscord.road, hiscord.path, hiscord.dates, hiscord.times, hiscord.lat, hiscord.lon, icehistor.lenghth, icehistor.cat1_1
from master.hiscord, master.icehistor
where hiscord.path=icehistor.path AND hiscord.lat>69 AND hiscord.lat<70 AND hiscord.lon>65 and hiscord.lon<75
```

```
     ROAD       PATH DATES     TIMES              LAT        LON   LENGHTH    CAT1_1
--------- ---------- --------- ------------- --------- ---------- --------- ---------
       20         10 05-JAN-95  12:00:00         69.28      73.33 32.136845         0
       20         10 05-JAN-95  12:00:00         69.28      73.33       165         0
       20         10 05-JAN-95  12:00:00         69.28      73.33        52         0
       20         10 05-JAN-95  12:00:00         69.28      73.33        47         0
       20         10 05-JAN-95  12:00:00         69.28      73.33        20         0
       20         10 05-JAN-95  12:00:00         69.28      73.33        71         0
       20         10 05-JAN-95  12:00:00         69.28      73.33        18         0
       20         10 05-JAN-95  12:00:00         69.28      73.33        42         0
       20         10 05-JAN-95  12:00:00         69.28      73.33       192         0
       20         10 05-JAN-95  12:00:00         69.28      73.33       239         0
       20         10 05-JAN-95  12:00:00         69.28      73.33         9         0
       20         10 05-JAN-95  12:00:00         69.28      73.33        71         0
       20         10 05-JAN-95  12:00:00         69.28      73.33        29         0
       20         10 05-JAN-95  12:00:00         69.28      73.33        34       100
```

20	10	05-JAN-95 12:00:00	69.28	73.33	20.146449	0
20	10	05-JAN-95 12:00:00	69.28	73.33	23.260049	0
20	10	05-JAN-95 12:00:00	69.28	73.33	32.136845	0
20	10	05-JAN-95 12:00:00	69.28	73.33	18.145662	0
20	10	05-JAN-95 12:00:00	69.28	73.33	32.136845	0
1	245	24-DEC-96 3:00:00 AM	69.59	66.16	19.933239	0
1	246	25-DEC-96 6:00:00 PM	69.45	66.4	15.806853	0
1	247	25-DEC-96 8:00:00 PM	69.58	66.17	16.387031	0

Example 2. Sampling of the specific length of discontinuities for the trapezium between 70 and 72^0 latitude and 60 and 65^0 longitude for December 1986.

```
  1     SELECT   Breakupcord.numbers,   breakupcord.lat,   breakupcord.lon,   icebreak.month,
icebreak.year, icebreak.long_mode
  2  from master.breakupcord, master.icebreak
  3* where breakupcord.numbers=icebreak.numbers and breakupcord.lat>70 and breakupcord.lat<72
and breakupcord.lon>60 and breakupcord.lon<65 and icebreak.year=1986 and icebreak.month=12
```

NUMBERS	LAT	LON	MONTH	YEAR	LONG_MODE
583	71.91	62.46	12	1986	10
584	71.73	63.75	12	1986	22
586	71.66	60.64	12	1986	25
587	71.5	61.93	12	1986	999
588	71.33	63.2	12	1986	21
590	71.25	60.16	12	1986	60
591	71.09	61.43	12	1986	34
592	70.93	62.67	12	1986	23
595	70.69	60.94	12	1986	24

Example 3. Sampling of the frequency of occurrence of 2-3 point ice pressure intensity for the trapezium between 74 and 75^0 latitude and 135 and 140^0 longitude for the period November-December 1985.

```
  1     SELECT   comprescor.numbers,   comprescor.dates,   comprescor.lat,   comprescor.lon,
icecompres.P_2_3
  2  from master.comprescor, master.icecompres
  3* where comprescor.numbers=icecompres.numbers AND comprescor.lat>74 AND comprescor.lat<75
AND   comprescor.lon>135   AND   comprescor.lon<140   and   comprescor.dates>01-NOV-85   and
comprescor.dates<31-DEC-85
```

NUMBERS	DATES	LAT	LON	P_2_3
263026	23-OCT-85	74.37	139.08	0
263169	09-NOV-85	74.23	138.57	0
263170	09-NOV-85	74.37	139.08	0
263313	14-NOV-85	74.23	138.57	0
263314	14-NOV-85	74.37	139.08	0
263457	23-NOV-85	74.23	138.57	0
263458	23-NOV-85	74.37	139.08	0
263601	03-DEC-85	74.23	138.57	0
263602	03-DEC-85	74.37	139.08	0
263745	13-DEC-85	74.23	138.57	0
263746	13-DEC-85	74.37	139.08	0
263889	22-DEC-85	74.23	138.57	0
263890	22-DEC-85	74.37	139.08	0

2. Reference tables containing the probabilistic characteristics

The INSROP participants can use not only the databases in the remote access mode, but also the reference tables containing the probabilistic characteristics of navigation conditions along the NSR.
The reference tables contain monthly estimates of the frequency of occurrence of ranges of the following ice characteristics:

- ice concentration;
- ice thickness (by age gradations);
- modal orientation and specific length of discontinuities in the ice cover;
- ice pressure;
- dimensions of major polynyas;
- dates of landfast ice breakup;
- dates of stable ice formation; and
- dates of ice reaching 20-25 and 50 cm thickness.

2.1. Ice concentration

The frequency of occurrence of different ranges of total ice concentration was calculated on the basis of monthly averaged observation data for the period 1953 to 1994 for each of 20-mile segments in the segments selected in WP1 Project. The initial information for the period 1953 to 1979 period was obtained from airborne ice observation data, for the period 1980 to 1990 from airborne ice and satellite observations and for the period 1991 to 1994 from satellite observation data.

The probabilistic estimates for month of the year were obtained for five concentration ranges: 0, 1-3; 4-6; 7-8 and 9-10 (tenths).

The calculation results are presented in the form of ASCII files (**tbl_1.txt, tbl_2.txt, tbl_3.txt, tbl_4.txt**) containing tables 1, 2, 3 and 4.

Table 1 consists of the records including the following fields: route identifier (s – southern, n – northern); segment No.; latitude of the segment start; longitude of the segment start; latitude of the segment end; longitude of the segment end.

Table 2 consists of the records including the following fields: concentration range No.; initial range value; end range value.

Table 3 consists of the records including the following fields: segment No.; month, number of observations; frequency of occurrence of the first range (%); ...; frequency of occurrence of the fifth range (%) for the northern route.

Table 4 consists of the records including the following fields: segment No.; month; number of observations, frequency of occurrence of the first range (%); ...; frequency of occurrence of the fifth range (%) for the southern route.

2.2. Ice thickness (from age gradations)

The probabilistic characteristics of ice age gradations were calculated for the period 1953-1994 for 20-mile segments along the navigation routes selected in WP1 Project. As initial ice thickness data, mean weighted ice thickness in each segment was used, calculated in the wintertime from age ice gradations and in the summertime from data on ice melting stages during the process of melting. The calculation methods were developed in the framework of WP2 Project.

The probabilistic estimates were calculated for five ice thickness ranges 0-30, 30-70, 70-120, 120-200, 200-250 (cm) for each month of the year.
The calculation results are presented in the form of ASCII files (**tbl_1.txt, tbl_5.txt, tbl_6.txt, tbl_7.txt**) containing tables 1, 4 and 5.

Table 5 consists of the records including the following fields: ice thickness range No.; the initial range value; the end range value.

Table 6 consists of the records including the following fields: segment No.; month, number of observations; frequency of occurrence of the first range (%); ...; frequency of occurrence of the fifth range (%) for the northern route.

Table 7 consists of the records including the following fields: segment No.; month; number of observations, frequency of occurrence of the first range (%); ...; frequency of occurrence of the fifth range (%) for the southern route.

2.3. Modal orientation and specific length of discontinuities in the ice cover

The tables present distributions of the specific length of discontinuities and the first mode of their orientation. The calculations were performed by the 50x50 km grid squares, which cover the entire navigation area along the routes selected in the framework of WP1 Project. The distributions of characteristics in each square were calculated for the monthly periods for the Laptev, East-Siberian and Chukchi Seas from October to December and from April to June and for the Kara Sea from April to May and from November to December.

All calculations were performed on the basis of the database on discontinuities in the ice cover of the Arctic Seas described in section 1.2.

The calculation results are presented in the form of ASCII files (**tbl_8.txt, tbl_9.txt, tbl_10.txt, tbl_11.txt, tbl_12.txt**) containing Tables 8 – 12.

Table 8 consists of the records including the following fields: square No.; latitude of the square center; longitude of the square center.

Table 9 consists of the records including the following fields: specific length range No. in the distribution table; lower range limit (m/km2); upper range limit (m/km2).

Table 10 consists of the records including the following fields: square No.; month; number of discontinuity observations in the given square; frequency of occurrence of the first specific length range (%); ...; frequency of occurrence of the fifth specific length range (%).

Table 11 consists of the records including the following fields: range No. of the first discontinuity orientation mode in the distribution table; the lower range limit (degrees); the upper range limit (degrees).

Table 12 consists of the records including the following fields: square No.; month; number of discontinuity observations in the given square; total length of discontinuities (km) within the modal range of the first orientation mode; frequency of occurrence (%) of the first mode of discontinuity orientation within the first range of the distribution table; frequency of occurrence (%) of the first mode of discontinuity orientation within the second range of the distribution table; ... frequency of occurrence (%) of the first mode of discontinuity orientation within the ninth range of the distribution table;

In the event the discontinuities were not recorded in some square, in tables 10 and 12 the "observation number" field contains 3 zeros, whereas in all subsequent fields, the number 999.9 is given.

If the square is in the landfast ice zone, then in Tables 10 and 12, the "observation number" field contains the number 888 and in the frequency of occurrence fields – 999.9. In Table 12 the fields of "total length of discontinuities" contain in this case 3 zeros.

2.4. Ice pressures in the ice cover

The mean multiyear values of different pressure intensity probabilities are given for the 20-mile route segments selected within the framework of WP1 Project.

As initial data, the calculated mean monthly values of ice pressure intensity

for the period 1960-1985 were used. The calculation method is described in section 1.3. The calculation results are presented in the form of ASCII files (**tbl_13.txt - tbl_36.txt**), containing Tables 13 – 36 (a separate table for each month).
Tables 13-24 consist of the records including the following fields: route segment No.; latitude of the segment start; longitude of the segment start; frequency of occurrence of 0-1 point pressure intensity; frequency of occurrence of 1 point pressure intensity; frequency of occurrence of 1-2 point pressure intensity; frequency of occurrence of 2 point pressure intensity; frequency of occurrence of 2-3 point pressure intensity; frequency of occurrence of 3 point pressure intensity for the northern route.

Tables 25-36 consist of the records including the following fields: route segment No.; latitude of the segment start; longitude of the segment start; frequency of occurrence of 0-1 point pressure intensity; frequency of occurrence of 1 point pressure intensity; frequency of occurrence of 1-2 point pressure intensity; frequency of occurrence of 2 point pressure intensity; frequency of occurrence of 2-3 point pressure; frequency of occurrence of 3 point pressure intensity for the southern route.

The absence of information is presented by zero values of probability of all pressure intensities.

2.5. Dimensions of major polynyas

The polynyas include areas of open water and young ice up to 30 cm thick, as well as zones of very open and open ice with not more than 5 tenths concentration located between the landfast ice boundary and close drifting ice floes. The use of polynyas for shipping depends on their temporary stability, which is estimated by the frequency of occurrence of polynyas (the percentage ratio of the cases with the presence of polynyas to the total number of observations in the region). At the frequency of occurrence of more than 75% the polynyas are considered as recurring polynyas, 50-74% as stable and less than 50% - occasional. Figure 2.1 schematically outlines the location of the regions of polynya formation.

During the pre-satellite period, observations of polynyas were carried out occasionally and belonged predominantly to the period of the maximum development of landfast ice – March-May. Satellite obsevations allowed regular tracing of the development of polyñyas from the landfast ice formation to the onset of spring-summer melting. That is why the tables contain data obtained from satellite imagery.

For polynya characteristics (length average width), the ice charts of the scale of 1:5000000 were used.

The statistical characteristics of 18 polynyas were determined from satellite data for the second 10-day period of each month from November to June (11, 12, 1, ..., 6) over the period 1978-1995.

The calculation results are presented in the form of ASCII files (**tbl_37.txt, tbl_38.txt**), containing tables 37 and 38.

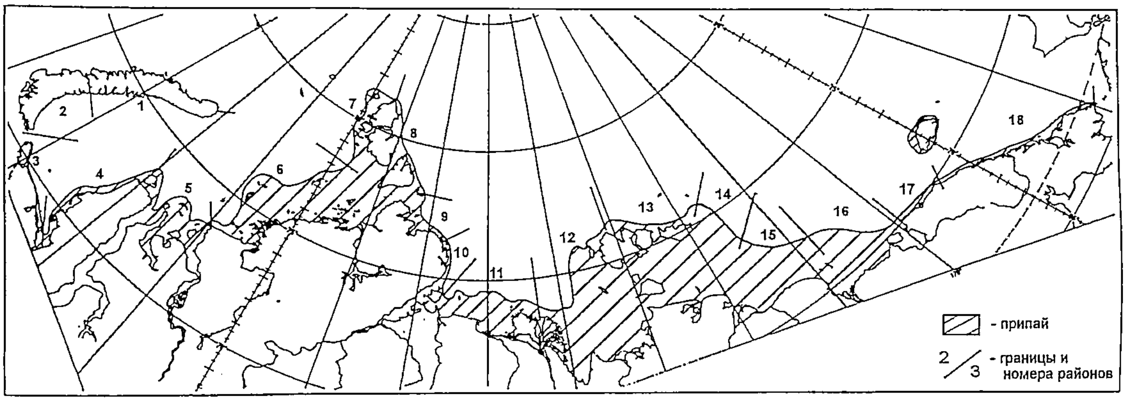


Fig. 2.1. Location of the polynya formation regions

1 – Northern Novozemelskaya; 2 – Southern Novozemelskaya; 3 – Amderminskaya; 4 – Yamalskaya; 5 – Ob'-Yeniseyskaya; 6 – Central Kara; 7 – Western Severozemelskaya; 8 – Eastern Severozemelskaya; 9 – Northeastern Taimyrskaya; 10- Eastern Taimyrskaya; 11 – Anabaro-Lenskya; 12 – Western Novosibirskaya; 13 –Northern Novosibirskaya; 14 – Eastern Novosibirskaya (west); 15 – Eastern Novosibirskaya (east); 16 – Aionskaya; 17 – Western Chukotskaya; 18 – Eastern Chukotskaya.

Table 37 consists of the records including the following fields: polynya No.; polynya name, mean latitude of the polynya geometric center; mean longitude of the polynya geometric center.

Table 38 consists of the records including the following fields: month, polynya No.; number of observation years; frequency of occurrence of polynya (%); average length (km), maximum length (km); minimum length (km); average width (km); maximum width (km); minimum width (km).

2.6. Dates of landfast ice breakup

The final landfast ice breakup date corresponds to the time when landfast ice is divided into drifting ice over the entire region.

Along the NSR, 19 regions were defined differing in the character of landfast ice formation and breakup /INSROP Working Paper [1] 10-1995/. The location of the regions is given in Figure 2.2.

The series of landfast ice breakup dates in each region were obtained from data of ice airborne and satellite observations for the period 1949-1997. Based on these data, average dates and frequency of occurrence of 10-day periods were calculated and the earliest and the latest dates were selected.

The calculation results are presented in the form of ASCII files **(tbl_39.txt, tbl_40.txt, tbl_41.txt)** containing Tables 39, 40 and 41.

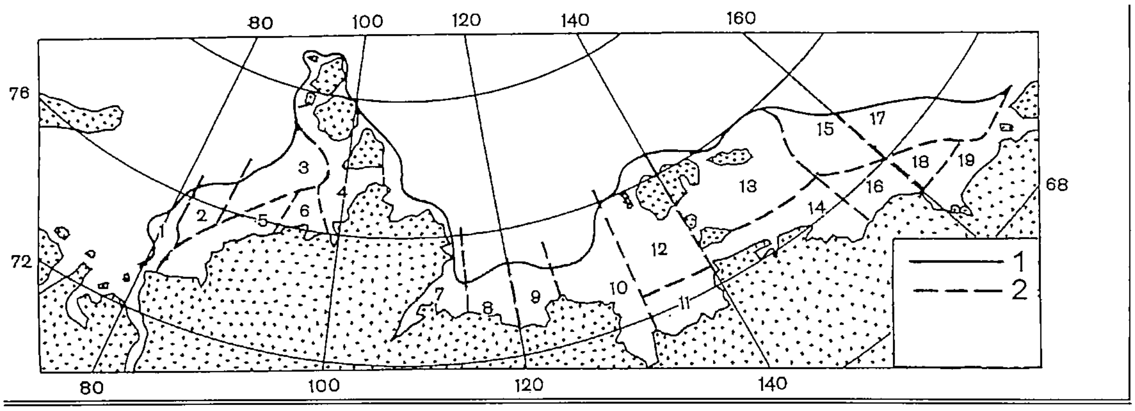


Fig. 2.2. Location of landfast ice breakup regions
1 – maximum landfast ice boundary,
2 – boundaries of the regions.

Table 39 consists of the records including the following fields: region No.; latitude of its center; longitude (eastern) of its center; average date of final landfast ice breakup; the earliest date; the latest date.

Table 40 consists of the records including the following fields: No. of the range of landfast ice breakup dates; the lower range limit; the upper range limit.

Table 41 consists of the records including the following fields: region No.; number of observations; frequency of occurrence of the first range (%); ... frequency of occurrence of the thirteenth range (%); region No;

For recording the dates the dd.mm format is used.

2.7. Dates of stable ice formation

The date after which the autumn ice formation occurs continuously is assumed to be the onset of stable ice formation.

The frequency of occurrence of the stable ice formation dates was calculated for the same 19 regions as for the final landfast ice breakup dates (Fig. 2.2). As initial information, the charts of isochrones of annual stable ice formation dates for 1940-1985 were used based on visual airborne ice reconnaissance data. In addition, the ice charts based on satellite imagery over the period 1968-1994 were used, as well as data from polar stations.

The accuracy of determining the onset of stable ice formation comprises 1 day at polar stations and 2-3 days in the open sea.

The calculation results are presented in the form of ASCII files **(tbl_39.txt, tbl_42.txt, tbl_43.txt, tbl_44.txt**) containing Tables 39, 42, 43 and 44.

Table 42 consists of the records including the following fields: region No.; average date of stable ice formation; the earliest date; the latest date.

Table 43 consists of the records including the following fields: No. of the range of stable ice formation dates; the lower range limit (stable ice formation dates); the upper range limit.

Table 44 consists of the records including the following fields: region No.; number of observations; frequency of occurrence of the first range (%); ... frequency of occurrence of the seventh range (%).

For recording the dates the dd.mm format is used.

2.8. Dates of ice reaching the 20-25 cm and 50 cm thickness

The frequency of occurrence of the dates of ice reaching the 20-25 cm and 50 cm thickness was calculated for the same 19 regions as for the final landfast ice breakup dates (Fig. 2.2). As initial information, the ice charts based on visual airborne ice reconnaissance data for the period 1946 to 1985 were used, as well as the ice charts based on satellite imagery during the successive period.

The calculation results are presented in the form of ASCII files **(tbl_39.txt, tbl_45.txt, tbl_46.txt, tbl_47.txt, tbl_48.txt, tbl_49.txt, tbl_50.txt)** containing Tables 39, 45-50.

Table 45 consists of the records including the following fields: region No.; average date of ice reaching the 20-25 cm thickness; the earliest date; the latest date.

Table 46 consists of the records including the following fields: No. of the range of dates of ice reaching the 20-25 cm thickness; the lower limit of the first range; the upper limit of the first range.

Table 47 consists of the records including the following fields: region No.; number of observations; frequency of occurrence of the first range of dates of ice reaching the 20-25 cm thickness (%); ... frequency of occurrence of the seventh range (%).

Table 48 consists of the records including the following fields: region No.; average date of ice reaching the 50 cm thickness; the earliest date; the latest date.

Table 49 consists of the records including the following fields: No. of the range of dates of ice reaching the 50 cm thickness; the lower range limit; the upper range limit.
Table 50 consists of the records including the following fields: region No.; number of observations; frequency of occurrence of the first range of dates of ice reaching the 50 cm thickness (%); ... frequency of occurrence of the eighth range of dates of ice reaching the 50 cm thickness (%).

For recording the dates the dd.mm format is used.

References

1. Buzuyev A.Ya., Fedyakov V.Ye. A probabilistic estimate of the frequency of occurrence of the conditions under which wind-induced ice pressure can arise. – Proc./AARI, 1979, V.364.
2. Handbook, for the see hydrological forecasts, 1994, Gidrometeoizdat, St. Petersburg, 525 p.

Review

of INSROP discussion paper

"Development of the Databases on Natural Conditions of Navigation along the NSR" by Brestkin et al., AARI

by Alfred Tunik
ABS, 2 WTC, 106th Floor, New York, NY 10048, USA

The discussion paper outlines the contents and structure of the INSROP electronic database to provide probabilistic characteristics of ice conditions on NSR. For such a specialized database description, its quality might be as good as the database itself. Completeness of the database can hardly be assessed explicitly from this description, but there are good reasons to agree that the shipborne observations and satellite images are to be, as they are, the core of the database. However, airborne observations should not be neglected as well. Regular ice reconnaissance flights during spring and fall seasons, conducted for many years in the 1970's-80's by Hydrometeorological Service and reported in many archives including AARI, constitute a very important piece of database. Its inclusion into the database should be greatly encouraged.

A strong point of the paper is that it addresses databases on polynyas and ice compression – factors which greatly affect navigation but little studied both physically and statistically.

A weak point – more attention should be paid to data on ice thickness

The paper should also be credited for recognizing the difference between the route-specific and region-specific ice conditions. The former can be obtained only from shipborne observations, while the latter can be obtained from satellite, airborne and shipborne observations but at different regional scales. The authors, however, should be encouraged to advance further from merely mentioning the difference into distinguishing quantitatively between rote-specific and region-specific the statistical characteristics.

There are a few comments to improve the text.

The definition of uniformity in the last sentence of second paragraph of 1.1.2. seems to be confusing ("change" or "do not change"?) – please clarify.

The explanation of grid coordinate axes, given in the end of 1.2 is unclear. A figure should be added to illustrate.

Formulae in 1.3 are useless unless all notations are well defined – definitions are missing for P(B), N, A, B with their subscripts.

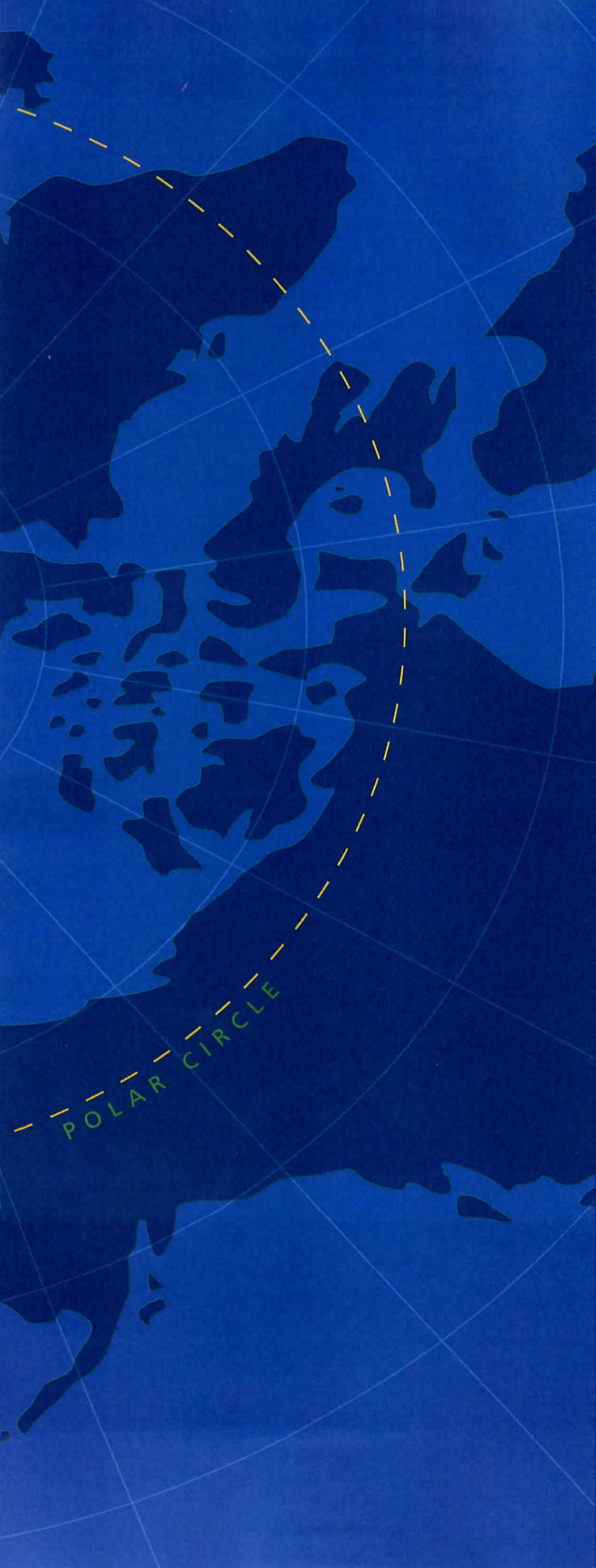
Ice thickness gradations in 2.2 (second paragraph) are slightly different from those of WMO: 120-180 and 180-250 in WMO, but 120-200 and 200-250 in the paper. Is there a special reason for this? If not, the WMO gradations are preferable.

Dear Dr. Tunik,

Thank you for your comments that will allow us to improve the Report under Project 1.4.2. "Development of the databases on natural conditions of navigation along the NSR".

Our answers will be in the same order as your questions:

1. We agree with you that airborne observation data should be used as well. This was taken into account from the very beginning at the stage of writing the Project Outline. The Introduction to the Report stresses that the database to be created should be used in a complex with the databases for international exchange included to the Global Sea-Ice Data Bank (WMO). This bank contains airborne ice reconnaissance data from 1953 through 1990.
2. We agree with your comment on the importance of ice thickness data. However, we considered it undesirable to use data of direct ice thickness measurements, as in most NSR regions these measurements were made only episodically. Only ice age observations were made along the entire NSR on a regular basis. They can be used for ice thickness calculation. This issue was discussed in detail in INSROP WP No. 121-1998. The ice age data over the entire observation period are contained in the Global Sea-Ice Data Bank (WMO).
3. In accordance with your proposal, we included reference to INSROP WP No. 23-1995, 1.5.5 to the Report that contains the results of the quantitative analysis of the difference in ice conditions directly along the navigation route and region-specific ice conditions.
4. The last sentence in the second paragraph of Section 1.1.2 was changed taking into account your comment.
5. As you have proposed, Section 1.2 includes now a figure illustrating the grid coordinate axes.
6. We have supplemented Section 1.3 with the definitions of the parameters you mentioned.
7. We are not aware of the WMO documents containing ice thickness gradations 120-180 cm and 180-250 cm. We used as a guidance the officially adopted "WMO Sea-Ice Nomenclature" (WMO-No. 259. TP. 145, 1970, Geneva).



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 Nippon 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.