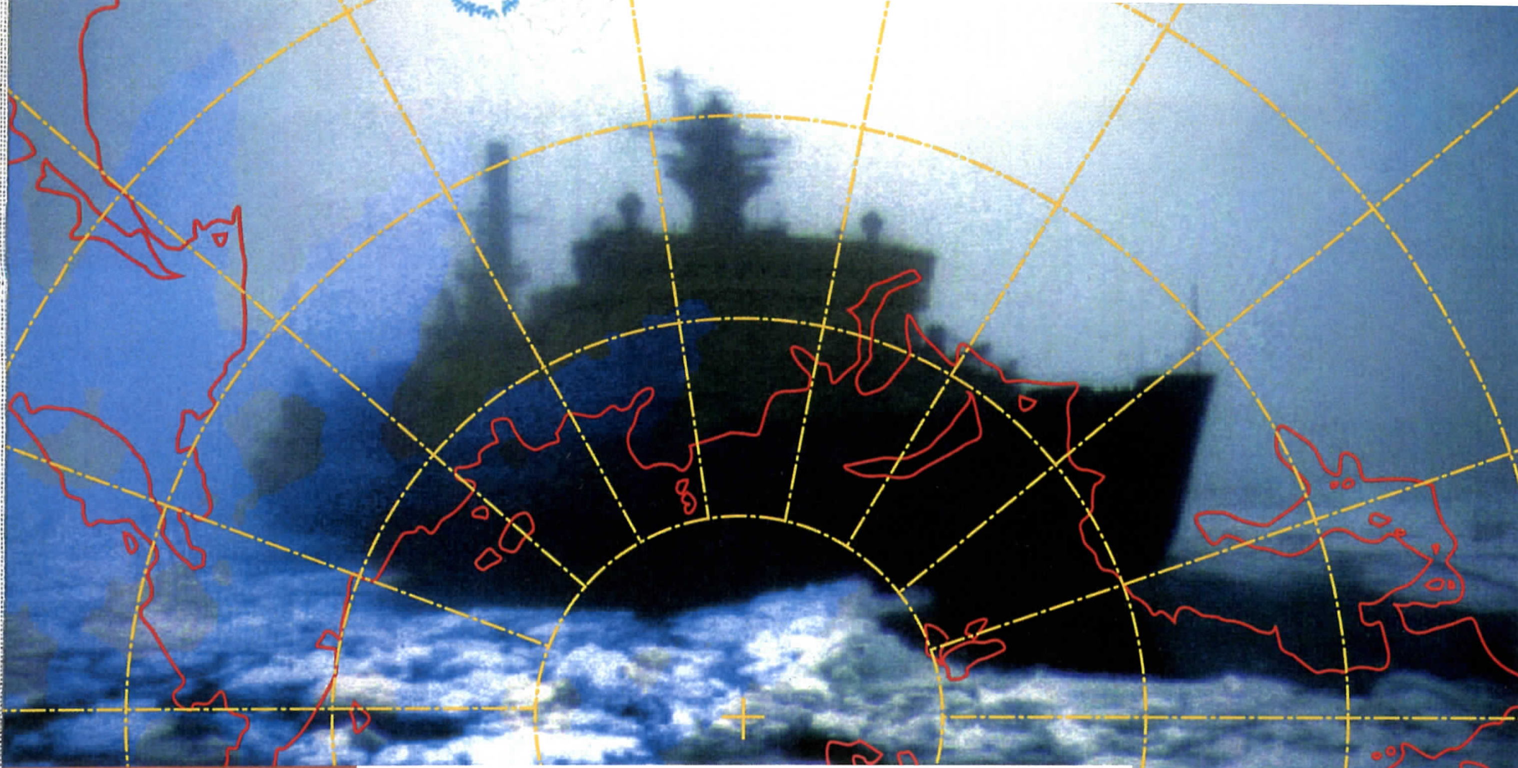

INSROP WORKING PAPER
NO. 35-1996, I.5.1

Content of Database, Planning and Risk Assessment

Volume 2 - 1994 project work

Sylvi Vefsnmo, Stig Magnar Løvås, Anders Backlund and Erkki Ranki

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. 35-1996

Sub-programme I: Natural Conditions and Ice Navigation.

Project I.5.1: Content of Database, Planning and Risk Assessment.
Volume 2 - 1994 project work.

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

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

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.

SPONSORS FOR INSROP

- Nippon Foundation/Ship & Ocean Foundation, Japan
- The government of the Russian Federation
- The Norwegian Research Council
- The Norwegian Ministry of Foreign Affairs
- The Norwegian Ministry of Industry and Energy
- The Norwegian Ministry of the Environment
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- Arctic & Antarctic Research Institute, Russia
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TITLE

INSROP Natural Conditions and Ice Navigation

Project I.5.1: Content of database, planning and risk assessment

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CLIENT(S)

Fridtjof Nansen Institute

REPORT NO.	CLASSIFICATION	CLIENT'S REF.	
STF60F95085	Restricted	Henning Simonsen	
CLASS. FRONT PAGE	**ISBN**	**PROJECT NO.**	**NO. OF PAGES/APPENDICES**
Open		605568	43/4
ELECTRONIC FILE CODE		**DISCIPLINARY RESPONSIBILITY**	
F:\HOME\VEFSNMO\INSROP\I51-FORS.W60		Sylvi Vefsnmo	
FILE CODE	**DATE**	**RESPONSIBLE SIGNATURE**	
	1996-01-15	Sylvi Vefsnmo Sylvi Vefsnmo	

ABSTRACT

In 1994, Project I.5.1 was scheduled to provide data sources on the physical environment and to implement a basic dataset on ice cover into INSROP GIS. Further the project included a study of risk assessment of ship in ice operation as well as identification of different accident scenarios. In order to assess how pollution from NSR shipping will impact the environment, statistical oil drift models was given priority instead of operational oil drift models for local areas as outlined in the original plan.

Sources of meteorological and oceanographic data for the NSR area have been identified. Due to Russian rules some of the desired data are restricted. Some of the physical environment data are already implemented into INSROP GIS and analyzed. However, the primarily part of the physical data needed for the assessment of the feasibility of opening the NSR are not implemented. As a first dataset on physical environment data in INSROP GIS, daily SSM/I sea ice data for the period July 1987 to December 1991 has been implemented with a spatial resolution of 25 km x 25 km. Maps showing probability distribution of different ice concentration classes are presented for each month of the year.

In order to assess how pollution from NSR shipping will impact the environment, a statistical model will be applied to provide drift tracks of the pollutants. Appropriate input data to the model are identified and will be delivered by AARI. The report also includes a study of risk assessment of ship in ice operation as well as identification of different accident scenarios.

KEYWORDS	ENGLISH	NORWEGIAN
GROUP 1	Environment	Miljø
GROUP 2	Arctic	Arktis
SELECTED BY AUTHOR(S)	Northern Sea Route	Nordøstpassasjen
	Navigation in ice	Navigering i is

PREFACE

The main purpose of INSROP Sub-programme I "Natural Conditions and Ice Navigation" is to provide essential supporting information on climatic variability and ice navigability which is needed for the assessment of the feasibility of opening the NSR to international shipping with an extended navigation season.

The 1993 activity of Project I.5.1 concentrated on specification of requirements to the database including important parameters to navigation in ice, relevant parameters for efficient icebreaker assistance, data sources and numerical models. Oil spill combat was also briefly discussed in relation to the risk assessment.

In 1994, Project I.5.1 was scheduled to provide data sources on the physical environment and to implement a basic dataset on ice cover into INSROP GIS. Further the project included a study of risk assessment of ship in ice operation as well as identification of different accident scenarios. In order to assess how pollution from NSR shipping will impact the environment, statistical oil drift models was given priority instead of operational oil drift models for local areas as outlined in the original plan.

In April 1995 a workshop was arranged between supervisors and key personnel from Project I.3.1, I.3.4, I.5.1 and I.5.5 as well as the Russian Coordinator of Sub-programme I. The purpose of the workshop was to present status and plans for the GIS work, to prepare a schedule for delivery of Russian data and to discuss scientific cooperation within 1995 projects and preparations for IST'95 in Tokyo. Several discussions on the status of the content of the AARI data bases, the INSROP agreement, and amount of work to provide needed data to Norwegian INSROP projects took place during the meeting. Due to the present status of the databases at AARI, and the personell and financial resources required to prepare statistics and databases for access to INSROP, it seems unrealistic to populate INSROP GIS with all necessary data during 1995. A separate data project is recommended to be initiated in order to populate INSROP GIS with the necessary physical environment data.

The proposed activities within Project I.5.1 in 1995 include statistical analyses of physical parameters affecting transit sailing as well as specific analyses along given sailing routes. Due to limited fundings in 1995, Project I.5.1 will not proceed in 1995, but some of the proposed activities will be carried out as parts of the GIS Project I.3.1.

Dr. Robert Frederking at the National Research Council in Ottawa has reviewed the report and the project review is enclosed in Appendix D. The authors are grateful to the reviewer and all the comments have been taken into consideration when finalizing the report.

Trondheim, 15 January 1996

Sylvi Vefsnmo

Sylvi Vefsnmo
Project Manager

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SUMMARY

In 1994, Project I.5.1 was scheduled to provide data sources on the physical environment and to implement a basic dataset on ice cover into INSROP GIS. Further the project included a study of risk assessment of ship in ice operation as well as identification of different accident scenarios. In order to assess how pollution from NSR shipping will impact the environment, statistical oil drift models was given priority instead of operational oil drift models for local areas as outlined in the original plans.

INSROP GIS is a tool for building up the knowledgebase for the NSR region and for transferring information to the decision makers. Based on the requirements to physical environment data from the Norwegian projects within the different INSROP Sub-programmes, a list of necessary data have been worked out. Due to Russian rules some of the desired data are restricted. The main data archive of ice, meteorological and oceanographic data for the Arctic Seas is centered at the State Scientific Centre AARI. The hydrometeorological data is property of state and the transfer of such data is restricted. Transfer of statistical data within joint project work are however allowed.

Information about the sea ice conditions, the meteorological and oceanographic conditions along the NSR are mainly based on satellite, shipboard helicopter, fixed-wing aircraft, shore-based and drifting ice stations, drifting buoys and ship-board observations. Sources of meteorological and oceanographic data for the NSR area have been identified. Some of the physical environment data are already implemented into INSROP GIS and analyzed. However, the main part of the physical data needed for the assessment of the feasibility of opening the NSR is not implemented. It is recommended to initiate a separate data project covering delivery of physical environment data not included in other INSROP projects. Due to delays with delivery of physical environment data, efforts have been made to identify alternative sources and to specify the analysis methods to be applied when analyzing the physical environment data with use of INSROP GIS.

As a first dataset on physical environment data in INSROP GIS, daily SSM/I sea ice data with a spatial resolution of 25 km x 25 km for the period July 1987 to December 1991 has been analyzed. The data have been acquired from the National Snow and Ice Data Center in Boulder on CD-ROMs. Maps showing probability distribution of different ice concentration classes are presented for each month of the year. Since the time period covered by SSM/I ice data are very limited, the variability analysis will most probably not be representative for the large annual variations. Due to high temporal resolution of the dataset, it may serve as a "reference" dataset when evaluating the quality of other datasets for ice concentration to be implemented into INSROP GIS.

The AARI Sea Ice Database covering the period 1972-90 with a temporal resolution of 10 days will be implemented into INSROP GIS during the 1995 project work of Project I.3.1. The analysis of the two datasets should be compared in order to evaluate the representativeness of the short period 1987-91 compared to the period 1972-90. A trend analysis of the AARI Sea Ice Database should also be performed in order to study the possibility to extend the navigation season. The summer season for the region occurs roughly from June to September, when the ice cover melts significantly, diminishing in both extent and strength. The greatest seasonal fluctuation occurs at the east and west ends of the route. This is due to the influence of ocean currents moving northward from warmer Atlantic Ocean in the west and the Bering Sea in the east, which accelerate the ice decay in the spring and retard the freeze-up in the fall.

In order to assess how pollution from NSR shipping will impact the environment, a statistical model will be applied to provide drift tracks of the pollutants. The recommended statistical oil drift model is based on a trajectory concept, i.e. the model simulates drift and weathering of oil slicks, represented as individual points of mass released at different times within the available historical time series of wind speed and ice coverage data.

Based on the requirement of input data to the statistical oil drift model, appropriate Russian data sources are identified and should be provided by AARI. Due to Russian rules some data are not allowed to be transferred to foreign users. Time series of wind speed and direction are not allowed to be transferred and the analysis have to be based on monthly statistics. The Markov chain method has to be used to construct historical wind records. The monthly averaged background current are allowed to be transferred as well as the AARI Global Sea Ice Database, which both fulfil the input requirements to the statistical oil drift model.

The statistical analysis will show the conflicts between oil versus shorelines and ice-covered areas for the region of concern. The statistical oil drift model will be run for oil spills along a "standard" navigation route with a spacing of about 30-40 km. This method will map the concequences of oil spills from a ship on a regional scale. For regions with high navigation risk and vulnerable resources the oil spill modell will be run with a higher resolution than for the regional analysis. The analysis will be run for different times of the year in order to reflect the seasonal variations.

Sailing the NSR represents a potential hazard to the environment, personal safety and damage on vessels. A major concern is the possible impact on the environment from accidental oil spills either from cargo or bunker fuel. Shallow waters and areas with heavy ice conditions are potential navigation risk areas.

Murmansk Shipping Company has performed an analysis of ship accident data for the time period 1954-90. Information from the Western and Eastern Arctic Marine Operation staffs as well as investigations of accidents results carried out by AARI and CNIIMF have been used in the analysis. More than 800 accident cases were considered and the analysis were grouped according to the ships ice class and to their ice-breakers assistance. Statistical analysis shows that the eastern part of the NSR has a greater accidental risk than the western part. The major ship damages occur during heavy ice conditions and with ships of ULA and L1 classes. The majority of ice damages on ships of L1 class occur during assistance from ice-breakers. The ships of ULA class are most frequently situated to damages when sailing alone. In the Arctic seas about 40 % of the damages occur in the Kara Sea where the intensity of sailing is highest. About 20 % of the accidents occur in the Laptev Sea and the East Siberian Sea while only about 14 % occur in the Chukchi Sea. The analyses also show that most of the accidents occur at the end of the navigation period (August-September). The analysis shows an increase in damages during periods with favourable ice conditions. The main reasons for that may be the high number of ships with low ice class, high number of ships sailing alone and reduced attention of the navigators.

1. INTRODUCTION

The main purpose of INSROP Sub-programme I "Natural Conditions and Ice Navigation" is to provide the essential supporting information on climatic variability and ice navigability which is needed for the assessment of the feasibility of opening the NSR to international shipping with an extended navigation season.

When addressing the possibility of establishing an economically attractive maritime traffic in the NSR, the question of ice conditions and their influence on navigation arise immediately. Important elements such as sailing distances, average speed, icebreaker capacity and transport regularity depends on the ice conditions and will influence the attractiveness of commercial NSR shipping. Transit of the NSR is today limited to the period July-October mainly due to severe ice conditions. To make the NSR really an international sea route the length of the operational season must be substantially prolonged. New ice breaker and ship technology, together with improved navigational systems, will give possibilities for extending the navigational period. Regularity is another key factor to NSR profitability. Irregularity might occur due to rapid changes in the ice and weather conditions as well as to inefficient coordination of convoys and ice-breaker support.

The 1993 activity of Project I.5.1 concentrated on specification of requirements to the database including important parameters to navigation in ice, relevant parameters for efficient icebreaker assistance, data sources and numerical models. Oil spill combat was also briefly discussed in relation to the risk assessment. The 1993 activity was reported in Løset and Vefsnmo (1994).

In 1994, Project I.5.1 was scheduled to provide data sources on the physical environment and to implement a basic dataset on ice cover into INSROP GIS. Further the project included a study of risk assessment of ship in ice operation as well as identification of different accident scenarios. In order to assess how pollution from NSR shipping will impact the environment, statistical oil drift models are given priority instead of operational oil drift models for local areas as outlined in the original plan.

The work performed during 1994, have been divided into the following activities:

1) Identification of data sources on the physical environment
2) Implemention of a basic dataset on ice cover into INSROP GIS
3) Selection of statistical oil drift model
4) Evaluation of risk assessment of ship in ice operation

The report is divided into 6 chapters where Chapter 2 gives an overview of data sources for physical environment conditions. The overview shows both raw data as well as statistical data available from Russia and via Internet. Chapter 3 shows the statistical analysis of the daily SSM/I ice concentration data. In order to simulate the environmental concequences during an oil spill situation, a statistical oil drift model concept for ice-infested waters is recommended and described in Chapter 4. A study of risk assessment of ship in ice operation as well as identification of different accident scenarios is described in Chapter 5. Chaper 6 provides an overview of references applied in the present study.

2. PHYSICAL ENVIRONMENT DATA

2.1 Content and requirement of physical data

The physical environment parameters important for transit sailings were selected at the workshop arranged in Trondheim (November 1993) and presented in Løset and Vefsnmo (1994). However, the spatial and temporal resolution of the different parameters were not discussed. The temporal and spatial requirement of the parameters are mainly based on the requirements from Sub-programmes II and III. The purpose of Sub-programme I is also to provide general information on climatic variability of the physical conditions along the NSR.

The major natural limiting factors for transit sailing are the ice conditions and the water depth. The ice conditions along the NSR are extremely dynamic, leading to large annual, seasonal and regional variations. In winter the success of the voyages will mainly depend on the polynyas and the discontinuities in the drifting ice. The length of the season and the average speed through the NSR are key factors to the NSR profitability. Transit of the NSR is today limited to the period July-October mainly due to severe ice conditions. To make the NSR really an international sea route the length of the operational season must be substantially prolonged. New icebreaker and ship technology, together with improved navigational systems, will give possibilities for extending the navigational period. Regularity is another key factor to NSR profitability. Irregularity might occur due to rapid changes in the ice and weather conditions as well as to inefficient coordination of convoys and icebreaker support. Such information are important input to the economical evaluations in Sub-programme III.

The Environmental Impact Assessment (EIA) study in Sub-programme II focuses on a selected set of scenarios for NSR activities and evaluates the possible environmental impacts of increased use of the NSR as a shipping route. The possible impacts from the planned activity are divided into two main categories. One is impacts from an operational point of view, the other is impacts from possible accidents. The operational and accidental approach are principally the same, even though the impact factors and the ecological components differ in valuation. The environmental impacts in the operational scenarios are characterized by low intensity, but depending on shipping regularity the duration of the impact may be more or less continuous. The environmental impacts in the accidental scenarios are characterized by high intensity in a short period and with long quiet periods in between. The accidental scenario is closely related to the operational scenario as the sailing route and the physical environment conditions are the same. The accidental scenarios will involve a risk assessment of the operational scenarios to determine high risk areas and seasons. This information is to be provided by Sub-programme I and are to be included in the requirements to the physical environment data.

Kværner Masa-Yards has performed a study on natural conditions influencing design of vessels operating in the NSR area and is reported in Appendix A. The study mainly focuses on parameters needed for:

- design of icebreaking / ice strengthened vessels for operation along the NSR
- evaluation of transit speed of a vessel / required power to achieve a certain speed
- route planning / speed evaluation onboard a vessel in the NSR

The dimensioning of ships, regarding strength of parts influenced by ice, is today in many cases governed by the rules of different classification societies. In this extent they are similar to any open water vessel. However, the degree of knowledge in dimensioning of vessels operating in ice covered waters is not at the same level as it is for open water vessels. This fact leads to an increased need of case-by-case dimensioning of vessels operating along routes like the NSR. The two main tasks in the dimensioning sense are the hull and the propulsion shaft line, including the propeller.

The main environment features affecting the dimensioning of above mentioned components are

- multi-year ice (both sea ice and glacial ice)
- ridges (multi-year / first year)
- grounded features
- compressive ice

The need for speed determination of a ship in the design phase is mainly concentrated to two different tasks:

- Determination of required propulsion power for a ship operating in specified maximum ice conditions.
- Determination of the speed of a ship, with a certain propulsion power and hull form, in varying ice conditions along a selected route as part of transportation cost calculations.

The environmental parameters needed when determining the transit speed of a vessel in varying ice conditions are:

- level ice
  - thickness
  - flexural strength
  - thickness of snow cover
  - coverage
  - size of floes
- ridges
  - number of ridges per kilometres
  - total height
  - porosity
- compression
  - compressive force (pressure)
- channels
  - channel thickness
  - strength of ice in channel
- general
  - spatial variation (extent of different ice conditions)
  - seasonal variation
  - existence of leads

The parameters having the greatest influence on the transit speed are:

- level ice thickness
- ridge size and frequency
- ice compression

Especially when larger vessels, with long parallel midbodies, are considered, the level of compression in the ice has a drastic effect on the transit speed. The importance of the other parameters is smaller, partly because their values are more predictable and the variations smaller.

Based on the purpose of Sub-programme I and the requirements from the other Sub-programmes, a list including requirements to physical environment data was delivered to CNIIMF in November 1994 and is enclosed in Appendix B. The datalist was divided into 6 parts which included the following subjects:

- Meteorological data
- Oceanographic data
- Ice and snow data
- Main river dynamics
- Ships movement in ice
- Damages on ships

Most of the physical data important for transit navigation are situated at AARI, but due to Russian rules some of the desired data are restricted. So far none of the specified data in Appendix C have been delivered to INSROP by AARI. The restriction of Russian data is described in Section 2.2.

In early April 1995 a workshop was arranged at AARI between Norwegian and Russian supervisors of INSROP Projects I.3.1, I.3.4, I.4.1, I.5.1 and I.5.5. The purpose of the workshop was to present status and plans for the GIS work, to prepare a schedule for delivery of physical data and to discuss scientific cooperation within 1995 projects and preparations for IST'95 in Tokyo. A strategy for the exchange of physical environment data was discussed. For data that are not permitted for transfer to foreign parties, secondary data bases (i.e. statistics) must be prepared. Several discussions on the status of the content of the AARI data bases, the INSROP agreement, and amount of work to provide needed data to Norwegian INSROP projects took place during the meeting. Due to the present status of the data bases at AARI, and the personell and financial resources required to prepare statistics and data bases for access to INSROP, it seems unrealistic to populate INSROP GIS with all necessary data during 1995. A priority list (Part I) including the most important data allowed for transfer to foreign parties, and serving as a first part of the transfer of Russian data, was worked out during the meeting. A minutes of the meeting is given in Appendix C. Later, in cooperation with the Russian experts at AARI, a more detailed list has been worked out and is shown in Table 2.1. A separate data project will be initiated in order to populate INSROP GIS with necessary physical environment data.

Table 2.1 Requirements of physical environment data.

No	Characteristics	Data to be transferred	Regions	Temporal resolution	Observation years
1	Ocean background current	Monthly mean climatological background current	NSR region	Months I,.......,XII	
2	Sea surface temperature	Monthly mean	NSR region	Months I,.......,XII	1960-94
3	Sea surface salinity	Monthly mean	NSR region	Months I,.......,XII	1960-94
4	River runoff	Monthly mean	Ob', Yenisey, Lena, Indigirka, Kolyma	Months I,.......,XII	1961-89
5	Atmospheric pressure	Monthly mean	NSR region	Months I,.......,XII	1964-94
6	Air temperature	Minimum , maximum and average	NSR region	Months I,.......,XII	1964-94
7	Wind speed	Monthly mean, occurence frequency of the speed ranges of the wind of predominant direction	NSR region	Months I,.......,XII	1964-94
8	Predominant wind direction	Occurence frequency of the ranges (45°) of mean monthly wind directions	NSR region	Months I,.......,XII	1964-94
9	Ice drift speed	Mean drift speed Maximum drift speeds of all directions	Chuckchi, East-Siberian andLaptev Seas. S/W of Kara Sea	Months VII,...,IX V,VI	1953-76
10	Ice drift directions	Occurence frequency of the ranges (45°) of mean ice drift directions	Chuckchi, East-Siberian andLaptev Seas. S/W of Kara Sea	Months VII,...,IX V,VI	1953-76
11	Ice drift	Resulting ice drift for 2-3 days in straits	Long, Sannikov, Vil'kitsky Strait	VII,....,X	1969-76
12	Amount of hummocking	Minimum , maximum and average	NSR region	Months I,.......,XII	1953-91

13	Ice thickness	Minimum , maximum and average monthly values	NSR region	Months I,.......,XII	1953-91
14	Cracks, leads and fractures	Monthly mean of number and size	NSR region (50 km resolution	Months I,.......,XII	
15	Ridges	Ridge concentration, ridge height and width	NSR region	Months I,.......,XII	
16	Freeze-up dates	Mean freeze-up dates and deviations	Long, Sannikov, Vil'kitsky, Kara Gate straits		1940-93
17	Break-up dates of fast ice	Mean break-up dates and deviations	Long, Sannikov, Vil'kitsky, Kara Gate straits		1940-93
18	Historical sailing routes	Type of ship, spatial and temporal information	NSR region		
19	Ship accidents	Ship, place, time, causes and concequences	NSR region		

2.2 Russian data sources and availability

INSROP GIS is a tool for building up the knowledgebase and for transferring information to the decision makers. Due to Russian rules some of the desired data are restricted. The main data archive of ice, meteorological and oceanographic data for the Arctic Seas is centered at the State Scientific Centre AARI. The hydrometeorological data is property of state and the transfer of such data is restricted. Transfer of statistical data within joint project work are however allowed. The AARI data have been classified into 5 categories (Brestkin et al.,1995):

1) Databases prepared for international use and included into Global Digital Sea Ice DataBank:
   - total and partial sea ice concentration for the period January 1972 - December 1990.

2) Digital data to be published and transferred to foreign partners
   - degree of ice decay (1953-80)
   - amount of hummocking (1953-80)

3) Digital data not to be published and transferred to foreign partners
   - cracks, leads and fractures
   - fast ice boundaries (monthly mean, 1933-90)

- tidal currents (1930-89)

4) Non-digital data open for publishing and transfer to foreign partners
   - size of ice floes (1963-76)
   - ice drift data
   - sea surface temperature (mean summer and winter condition)
   - surface water salinity (mean summer and winter condition)
   - surface air temperature (monthly mean)
   - surface atmospheric pressure (monthly mean)
   - precipitation (seasons mean)
   - wind direction and speed (4 times per day)

   The last three items refer to 33 stations included into the WMO system.

5) Non-digital data not open for publishing and transferring to foreign partners
   - ice thickness (1937-91)
   - pressures (1960-88)
   - cracks, leads and fractures (radar ice surveys, 1968-92)
   - wave height (1950-91)
   - surface water temperature and salinity (1950-94)
   - sea level height (1956-90)
   - surface atmospheric pressure (monthly mean)
   - precipitation (seasons mean)
   - wind speed and directions (4 times per day)

The last three items refer to stations along the NSR not included into the WMO system.

2.3 Other available physical data

Information about the sea ice condition, the meteorological and oceanographic conditions along the NSR are mainly based on satellite, shipboard helicopter, fixed-wing aircraft, shore-based and drifting ice stations, drifting buoys and ship-board observations. Since the delivery of physical data from AARI is delayed, efforts have been given to identify other sources, both within Russia, via international databases and available atlases. Table 2.2 shows an overview of available atlases of the Arctic basin. The atlases are not in digital form and are therefore not suited for implementation into INSROP GIS unless the maps are digitized. The atlases give however an general overview of the variability of the natural conditions for the region. The "Environmental Atlas of the Pechora Sea" includes information of icebergs, ice cover, hydrology and climatology.

An extended survey in international databases via Internet has been performed in order to populate INSROP GIS with physical environment information important for transit navigation. Both meteorological, oceanographic and geophysical data are available via Internet, on tape and on CD-ROMs. A preliminary list of available data and a short description of the datasets are given below as well as the contact addresses. Figure 2.1 gives an overview of the WMO stations available via Internet.

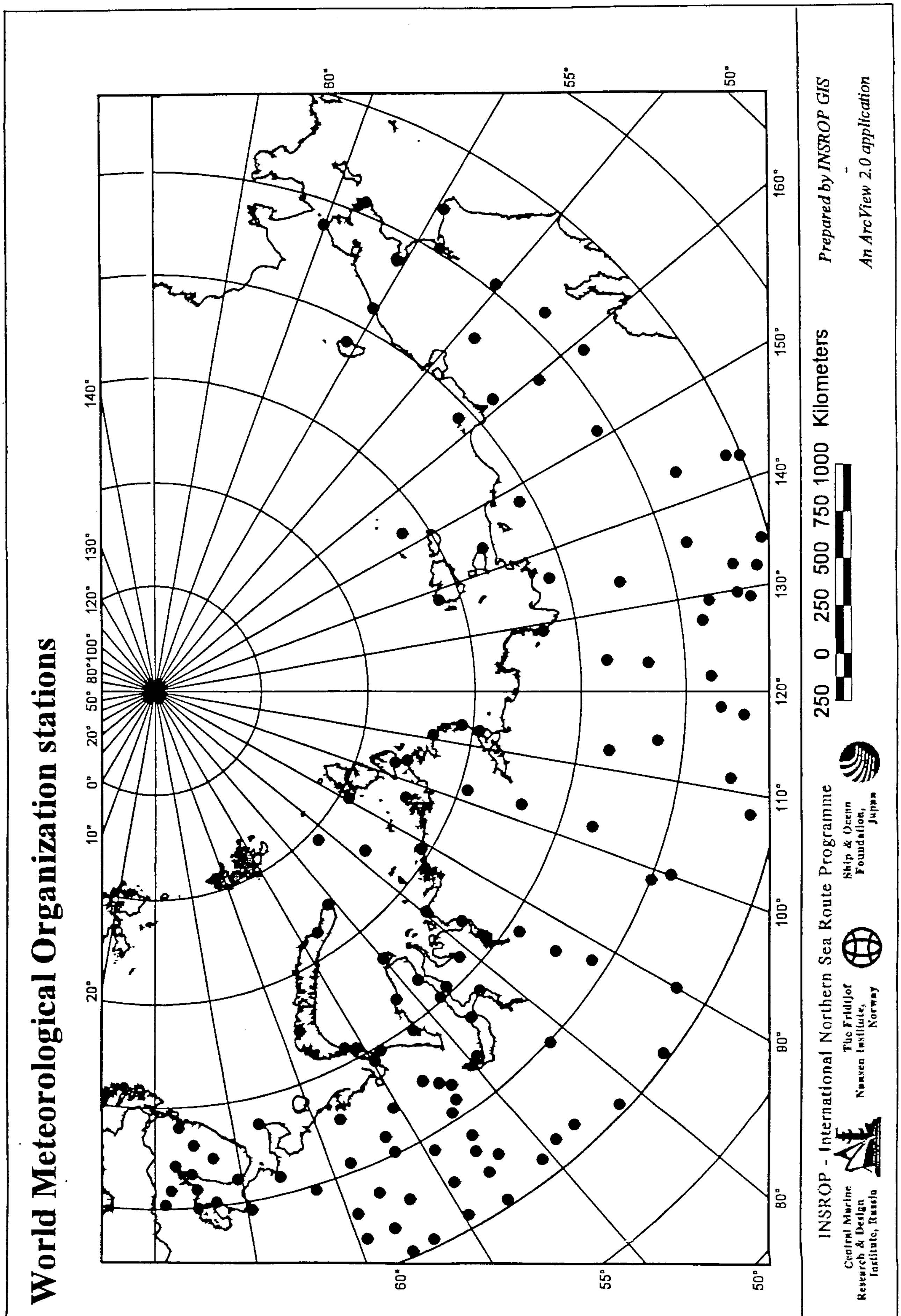

Figure 2.1 World Meteorological Organization Stations.

Table 2.2 Atlases of the Arctic Basin (Mulherin et al., 1994)

Title	Author	Publisher
Arctic and Antarctic Sea Ice (1978-87)	Gloersen et al. (1992)	NOAA, Washington
World Ocean Atlas-Volume 3: Arctic Ocean	S. G. Gorshkov (1983)	Pergamon Press
Surface Climate of the Arctic Basin	A. D. Hastings (1971)	Ft. Belvoir, Va
Atlas of the Polar Regions	Jones and Bartlett Publishing, Inc (1981)	Jones and Bartlett Publishing
Climates of the Polar Regions, Vol.14 of the World Survey of Climatology	S. Orvig (1970)	Elsevier Publishing Co.
Atlas- Morphometric Characteristics of Ice and Snow in the Arctic Basin	I. P. Romanov (1993)	AARI
Ice Cover of the Arctic Basin	I. P. Romanov (1993)	AARI
The Atlas of the Arctic	A. F. Treshnikov (Ed.) (1985)	AARI
Climatic Atlas of the Outer Continental Shelf Waters and Coastal Regions of Alaska	W. A. Brower, Jr. et al. (1988)	National Climate Data Center
Alaska Marine Ice Atlas	LaBelle et al. (1983)	Arctic Environmental Info and data center
Sea Ice Climatic Atlas	U.S. Naval Oceanography Command Detachment	U.S. Naval Oceanography Command Detachment
Environmental Atlas of the Pechora Sea	CANATEC Consultants	CANATEC Consultants

Meteorological Data

- *US Navy Marine Climatic Atlas of the World*
  The major elements include air and sea temperature, dewpoint temperature, scalar wind speed, sea level pressure, wave height and wind roses. The data are summerized with user-defined 1 and 5 degree grid areas covering the global marine environment.
  The summaries are produced using predominantly ship data collected between 1854-1969. Contact: National Climatic Data Center.

- *International Station Meteorological Climate Summary*
  Detailed climatological summaries for about 2200 locations worldwide. Contact: National Climatic Data Center.

- *Historical Arctic Rawinsonde Archive (1947-87)*
  Contains over 1.2 million vertical soundings of temperature, pressure, humidity and wind representing all available rawinsonde ascents from Arctic land stations poleward of 65 degrees North. Contact: National Snow and Ice Data Center (NSIDC).

- *NOAA Baseline Climatological Dataset*
  Monthly station temperature data. Contact: National Climatic Data Center

Oceanographic Data

- *Global Ocean Temperature and Salinity Data.*
  Temperature and salinity in the world ocean for about 1900-1990. Contact: National Oceanographic Data Center

- *Arctic Ocean Buoy Data*
  12 hourly interpolated pressure, temperature, position and ice velocity

- *Levitus' Climatological Atlas of the World Ocean*
  Global ocean analyzed grids for annual mean, seasonal mean, and monthly mean climatologies (1900-92). The parameters included are sea surface temperature, temperature below the surface and salinity. Contact: National Oceanographic Data Center.

Sea Ice Data

- *AARI 10 Days Sea Ice Charts for the Arctic Ocean*
  Digitized sea ice concentrations and stages of developments from integrated sea ice charts generated from the operation division of AARI. The charts are produced through the assimilation and analysis of visual and instrumental aircraft observations and satellite data acquired by AARI over 10 days period. The data are compiled on 1:1.5 million, 1:2 million and 1:5 million equiangular stereographic and mercator projections at resolutions of 0.1 km for aircraft survey and less than 4 km for satellite imageries. The data cover the time period 1972-90.

- *International Ice Patrol Iceberg Data (1960-)*
  The data contains information of iceberg location since 1960.

- *DMSP F8 SSM/I Sea Ice Concentration Grids for Polar Regions (1987-93)*
  The data consists of daily first-year, multi-year and total ice concentration on 25 x 25 km polar stereographic grids.

- *DMSP F8 SSM/I Monthly Averaged Sea Ice Concentration grids*
  Monthly averaged data on a 25 x 25 km polar stereographic grid.

- *Nimbus-7 SSMR Polar Radiances and Arctic Sea Ice Concentration (1978-87)*
  The data contain gridded brightness temperature and sea ice concentration on 25 x 25 km polar stereographic grids for the period October 1978- August 1987.

- *Eastern Arctic Ice, Ocean and Atmosphere CEAREX*
  The data contains sea ice acceleration, deformation and stress, hydrography, meteorology, bathymetry from CEAREX.

All the ice data are available from the National Snow and Ice Data Center in Boulder.

Arctic River Data

- *Global Atmospheric Water Balance and Runoff from Large River Basin*
  For the rivers Ob and Lena mean annual discharge are computed as well as monthly evaporation

A physical characteristics of the Siberian river system is given in North (1991) and Table 2.3 gives a summary of important characteristics which affects its ability to provide transportation.

Table 2.3 Physical characteristics of Siberian rivers

	Ob	Yenisey	Lena	Amur
Length (km)		4102	3650	
Depths guaranteed (m)	2.5-3.0	1.0 (upper) 7.0 (below Igarka)	1.0-3.0	0.85-1.5
Navigable (km)	3650	3487	4125	2824
Navigation season (days)	100-140 (gulf)	181 (mounth of Angara)	129 (Osetrovo)	186 (Khabarovsk)
Max discharge (m^3/s)	43 400	154 000		

2.4 Conclusions and recommendations

Kværner Masa-Yards has performed a study of natural conditions influencing design of vessels operating in the NSR area. The study mainly focuses on parameters needed for:

- design of icebreaking / ice strengthened vessels for operation along the NSR
- evaluation of transit speed of a vessel / required power to achieve a certain speed
- route planning / speed evaluation onboard a vessel in the NSR

Based on the requirements to physical environment data from the Norwegian projects within the different INSROP Sub-programmes, a list of necessary data have been worked out. Due to Russian rules some of the desired data are restricted. The main data archive of ice, meteorological and oceanographic data for the Arctic Seas is centered at the State Scientific Centre AARI. The hydrometeorological data is property of state and the transfer of such data is restricted. Transfer of statistical data within joint project work are however allowed.

Information about the sea ice condition, the meteorological and oceanographical conditions along the NSR are mainly based on satellite, shipboard helicopter, fixed-wing aircraft, shore-based and drifting ice stations, drifting buoys and ship-board observations. An overview of available atlases of the Arctic basin is given. The atlases are not in digital form and are therefore not suited for implementation into INSROP GIS otherwise the maps are digitized. The atlases give however an general overview of the variability of the natural conditions for the region. An extended survey in databases via Internet has been performed in order to populate INSROP GIS with physical environment information important for transit navigation. Both meteorological, oceanographic and geophysical data are available via Internet, on tape and on CD-ROMs. A preliminary list of available data and a short description of the datasets are given.

Some of the physical environmental data are already implemented into INSROP GIS and analyzed. However, the primarily part of the physical data needed for the assessment of the feasibility of opening the NSR are not implemented. It is recommended to initiate a separate data project covering delivery of physical environment data not included into other INSROP projects. Along with the data project the implementation of the free avaliable data via Internet will be started. Most of the free available ice data are implemented and the effort should be made to implement the monthly and annual statistical analysis of data from the WMO and oceanographic stations along the NSR.

3. STATISTICAL ANALYSIS OF SEA ICE DATA

3.1 Sea ice data

As a first dataset on physical environment data, daily SSM/I data for the period July 1987 to December 1991 has been implemented. The SSM/I sea ice concentrations for the polar regions are gridded in the polar stereographic projection at a resolution of 25 km x 25 km. The data have been received from the National Snow and Ice Data Center in Boulder on CD-ROMs. The DMSP SSM/I sea ice concentration grids are derived from the SSM/I Brightness Temperature grids which are presented as raster images mapped to a polar stereographic grid. The sea ice concentration CD-ROM volume contains two sets of grids, one generated using the NASA Team algorithm (Cavalieri et al., 1984) and the second using an algorithm developed by Comiso (Comiso, 1986).

The NASATEAM directory contains both total and multi-year ice concentration in percent. The algorithm uses three gridded brightness temperature channels: 19 GHz vertical polarization, 19 GHz horizontal, and 37 GHz vertical. Ice concentrations are calculated using the gradient ratio (19GHz vertical and 37 GHz vertical data) and polarization ratio (19 GHz vertical and 19 GHz horizontal). The gradient ratio is also employed by the algorithm to minimize the calculation of "false" concentration due to atmospheric moisture.

The COMISO directory contains only total sea ice concentration. The algorithm is a technique based on the distribution of radiometrically distinct clusters in multi-spectral parameter space. In the central arctic region, the 37 GHz channels are used exclusively because effects of spatially varying physical temperature are very slight and the brightness temperatures of consolidated ice at these two channels are very highly correlated. The vertically polarized 37 and 19 GHz data are used in seasonal sea ice regions because they are more effective in filtering out atmospheric effects in the marginal ice zone and open ocean, and in accounting for surface effects in first year ice areas.

3.2 Analysis method

The studied area for the analysis has been limited to an area extending eastwards from 0°E to 210°E and above 60°N. The original SSM/I data existed in Hierarchical Data Format (NCSA,1989). All the data were first converted to BIP format for import into ARC/INFO as ARC/INFO GRIDs.

The developed INSROP GIS analysis tool creates the following monthly datasets from the daily SSM/I ice concentration data:

- minimum total ice concentration
- mean total ice concentration
- medium total ice concentration
- aximum total ice concentration
- probability of ice concentration > 10 %
- probability of ice concentration > 40 %
- probability of ice concentration > 70 %

Grid cells with concentration values less than 10 % are considered as open waters and are not used in the analysis.

3.3 Variability analysis of sea ice conditions along the NSR

In order to study the long and short term feasibility of opening the NSR for permanent maritime traffic and to investigate the concequences of such traffic, the variability of the physical environmental parameters is of vital importance. The variability analysis can be used to predict transit time for particular classes of ship through the NSR for any month of the year.

The ice conditions along the NSR are extremely dynamic, leading to large annual, seasonal and regional variations. Large ice fields observed in the same regions each summer are called ice massifs and the Taymyrskiy, Ayonskiy and Vrangelevskiy massifs are the most important obstacles to ship traffic along the NSR since the massifs contains significant concentrations of multi-year ice and frequently heavily hummocked ice is present (see Figure 3.1). Table 3.1 shows general information about the environmental conditions of the Arctic Seas along the NSR.

The total sea ice concentration based on the COMISO algorithm have been used for the variability analysis. The analyzed period is relatively short and the results give only an indication of the variability of the ice conditions during the 4-5 years period. A trend analysis of the Barents Sea ice conditions showed a principal cycle of about 10-12 years. This Barents Sea analysis included weekly data from 1966-90 and pointed out the years 1968 and 1989 as years with extreme ice conditions (Vefsnmo et al., 1992). The analysis of the SSM/I ice data only includes a short time period and will not be representative for the NSR ice conditions variability in a longterm perspective. Figures 3.2-3.5 show the probability for ice concentration greater than 70 % on a monthly basis (January, April, September, October) based on the analysis of the SSM/I ice data. In November to April the probability of ice concentration greater than 70 % is almost 100 % along the traditional sailing routes. The minimum ice extent is in August/September. The summer season for the region occurs roughly from June to September, when the ice cover melts significantly, diminishing in both extent and strength. The greatest seasonal fluctuation occurs at the east and west ends of the route. This is due to the influence of ocean currents moving northward from warmer Atlantic Ocean in the west and the Bering Sea in the east, which accelerate the ice decay in the spring and retard the freeze-up in the fall. The ice massifs Taymyrskiy, Severnaya Zemlya, Ayonskiy and Vrangelevskiy are all visible on the maps with ice concentration greater than 70 %.

In the *Kara Sea* the ice formation starts in September in the northern sea regions and in October in the southern part. From October to May almost the entire sea is covered with ice of different type and stage of development. The coastal zone is occupied by fast ice which is non-uniformly developed. Seaward of the stranded ice there is a zone of open water or young ice. The region of the flaw polynyas are the Amderma and Yamal polynyas in the south-western sea part and the Ob'-Yenisey polynya in the south. In the spring period the drift in the Kara Sea has a prevailing direction westward and southward while in summer mainly to the south-west and south. There is quite an extensive ice exchange of the Kara Sea with the Barents Sea through the Karskiye Vorota strait.The mean ice inflow to the Kara Sea in winter months (December-April) is about 98 000 km^2 and the export to the Barents Sea is about 21 000 km^2. The volume of ice export through the Vil'kitsky strait into the Laptev Sea is about 50 km^3 (Pavlov et al., 1993).

The *Laptev Sea* has the largest expance of fast ice in the world from January to June. The fast ice thickness typically reaches 200 cm due to mean midwinter air temperature of -30 °C and can grow up to 250 cm during severe winters (Mulherin et al., 1994). The amount of old ice in the Laptev Sea is limited due to wind directions and ocean currents. The total area of summer melt is particularly extensive due to the reduced amount of old ice. In the western part the ice drift is southwards and large masses of ice are deposited along the coast of Severnaya Zemlya and the Taymyr Peninsula. Along with the eastward ice deposition from the Kara Sea, the Vil'kitskogo Strait and the Taymyr coast present a serious challenge to navigation at all times of the year.

The *East-Siberian Sea* is the shallowest of the Eurasian seas. The broad continental shelf allows fast ice, averaging from 170-200 cm thick, to extent as far as 500 km outward from the coast. In winter the prevailing wind direction is from south producing weak ice conditions and potential navigation lanes at the outer edge of the fast ice as they do in the Kara and the Laptev Seas. In summer the winds shift to northerly and the ocean currents favour the influx of ice from the north resulting in the permanence of the Ayon massif. Winter freeze-up begins in the north in September and is usually complete by mid-October.

The *Chukchi Sea* is almost ice covered from early December to mid-May. The seasonal variations in the ice conditions are large resulting in loosing about 80 % of its maximum winter extent in the summer season. Important factors influencing the variability is the bathymetry, wind, currents, air temperature and the presence of Wrangel Island. Ocean currents and wind tends to transport old ice from the Arctic to the Longa Strait under great pressure, which sometimes can present the greatest obstacle on the route. Breakup of the ice cover initiates in the eastern part and progresses westward due to influx of warm water from the Bering Sea.

Table 3.1 Environmental conditions of the Arctic Seas along the NSR (Mulherin et al., 1994).

	West Kara Sea	East Kara Sea	Laptev Sea	E. Siberian Sea	Chuckchi Sea
Mean fast ice thicknesses (cm)	120-200	200	200-250	170-200	130-180
Average date of minimum ice cover	24 Sept	14 Sept	17 Sept	13 Sept	12 Sept
Average date of complete freeze-up	Mid-late Nov	Mid Nov	___	Mid Oct	Mid-late Nov
Mean air temperature in winter	-15 to -20	-25 to -30	-30	-30	-20 to -30

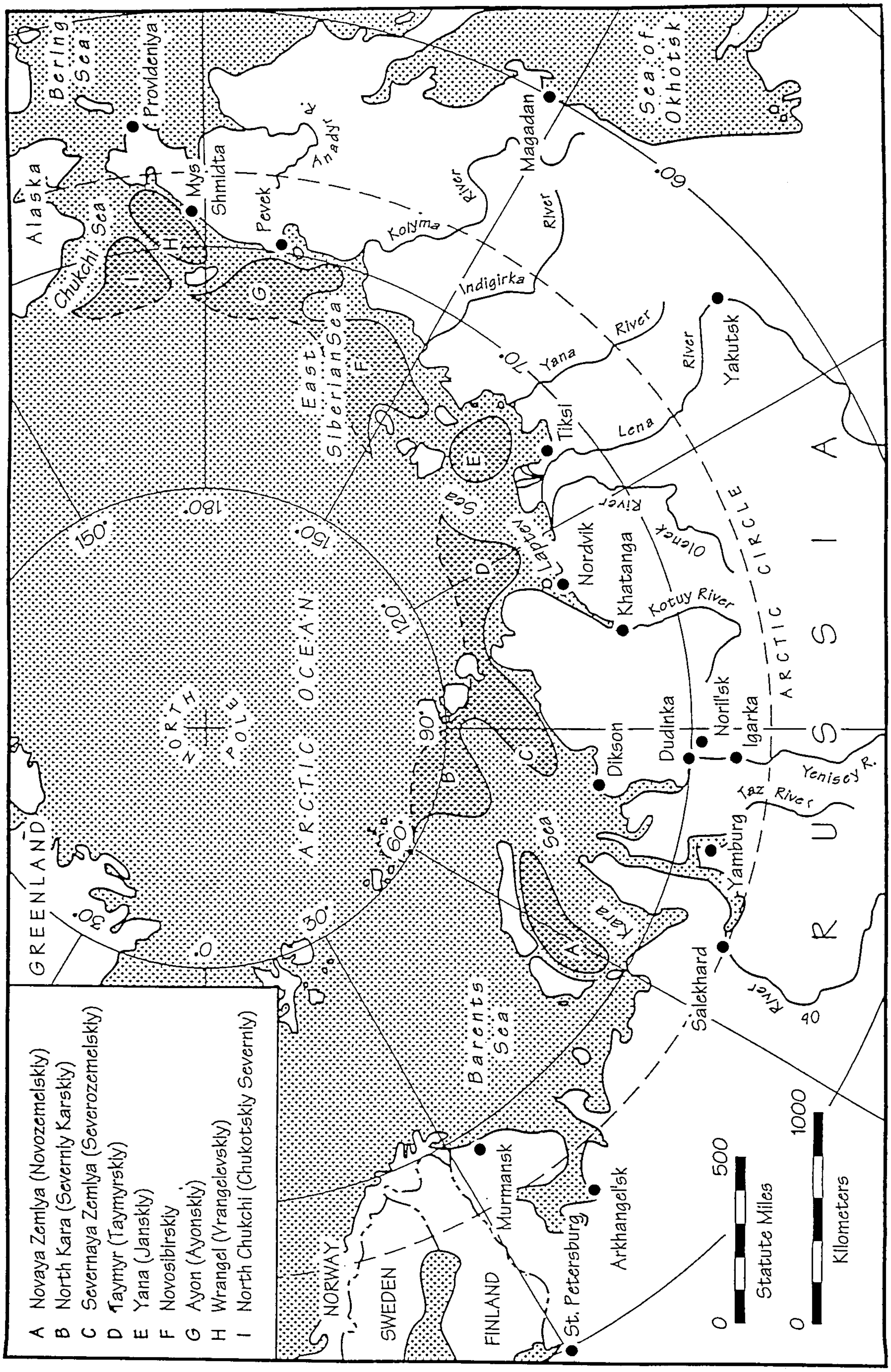

Figure 3.1 Main ice massifs of the Russian Arctic (Mulherin et al., 1994).

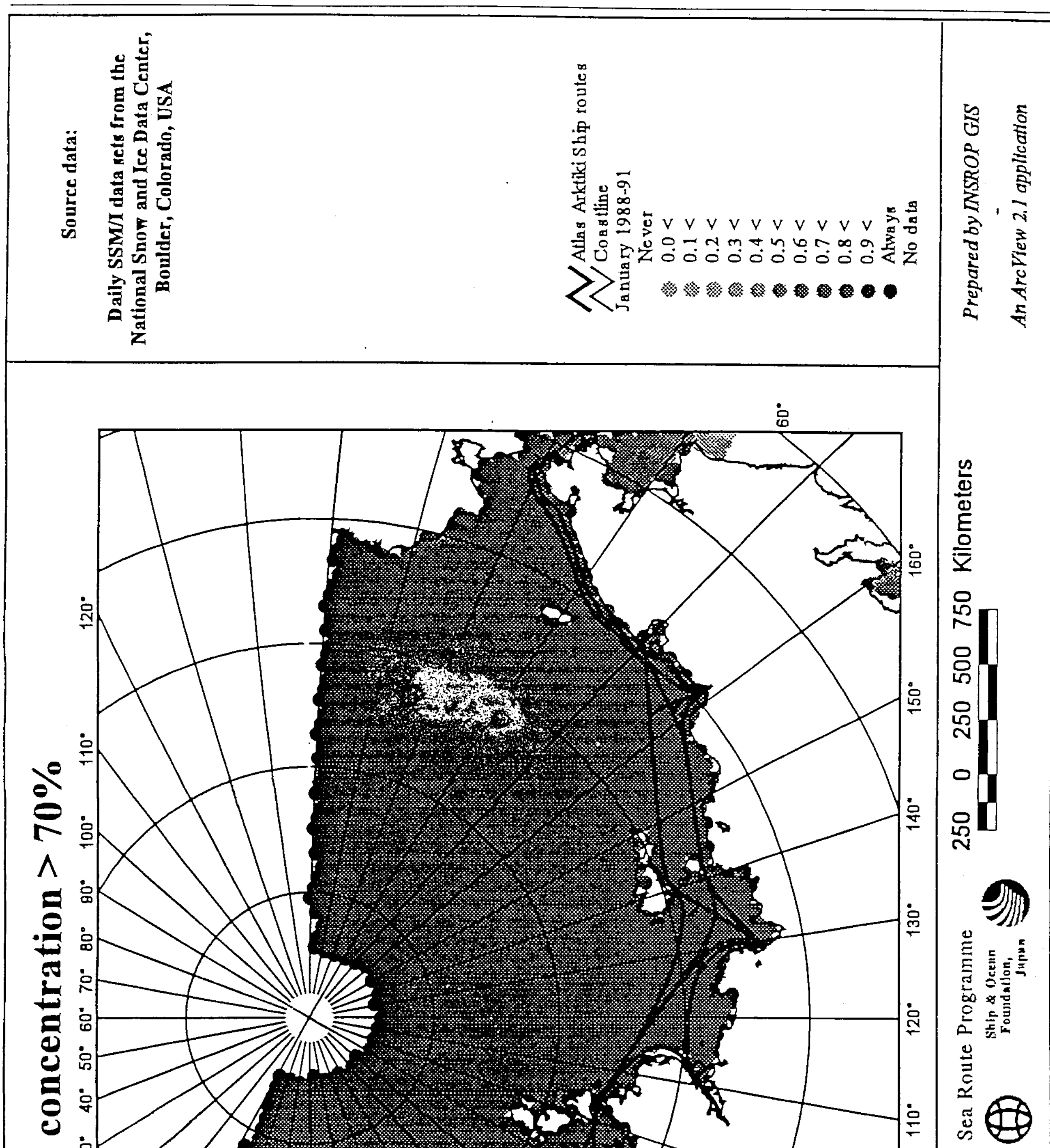

Figure 3.2 Probability of ice concentration greater than 70 % in January

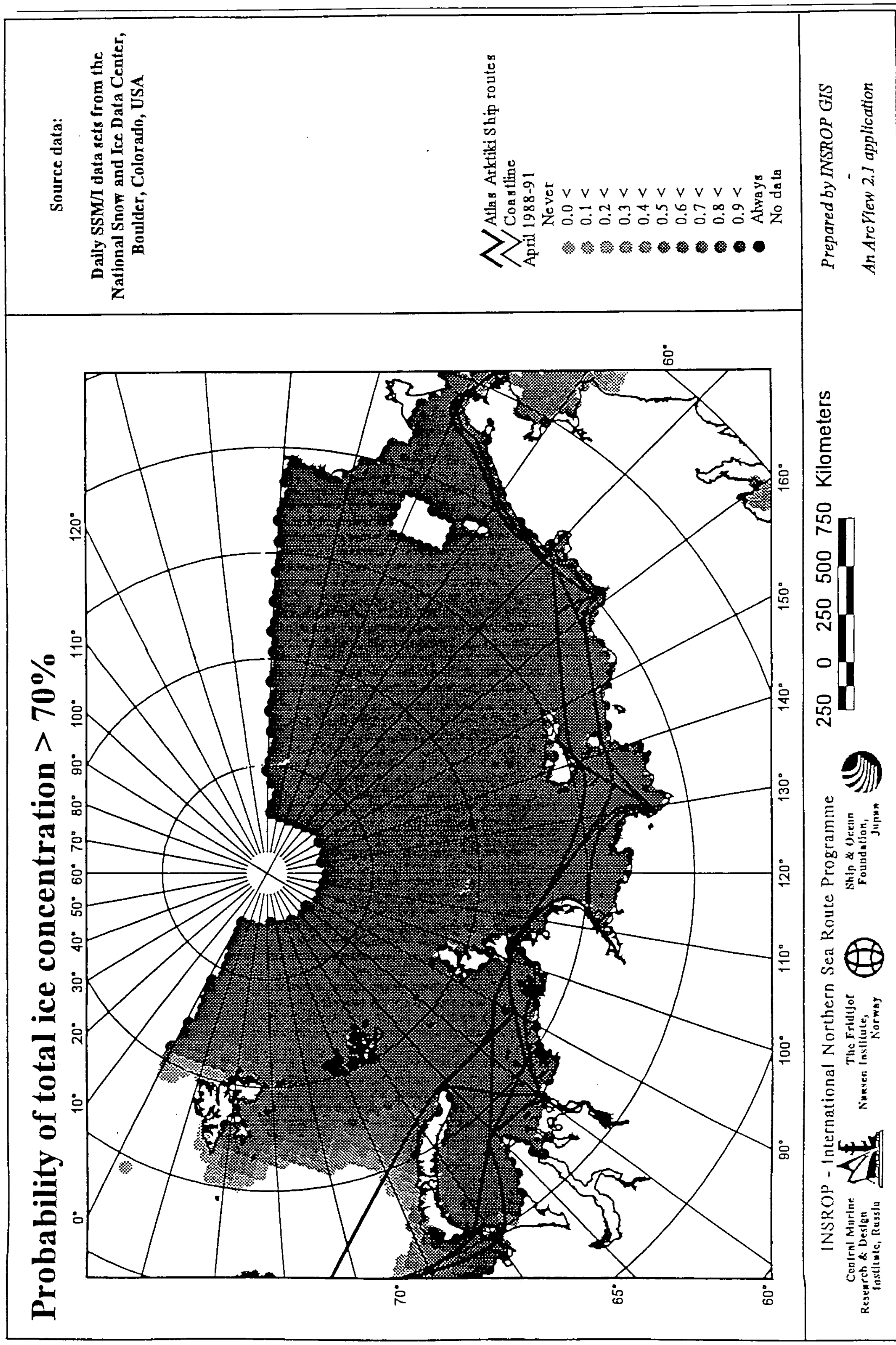

Figure 3.3 Probability of ice concentration greater than 70 % in April.

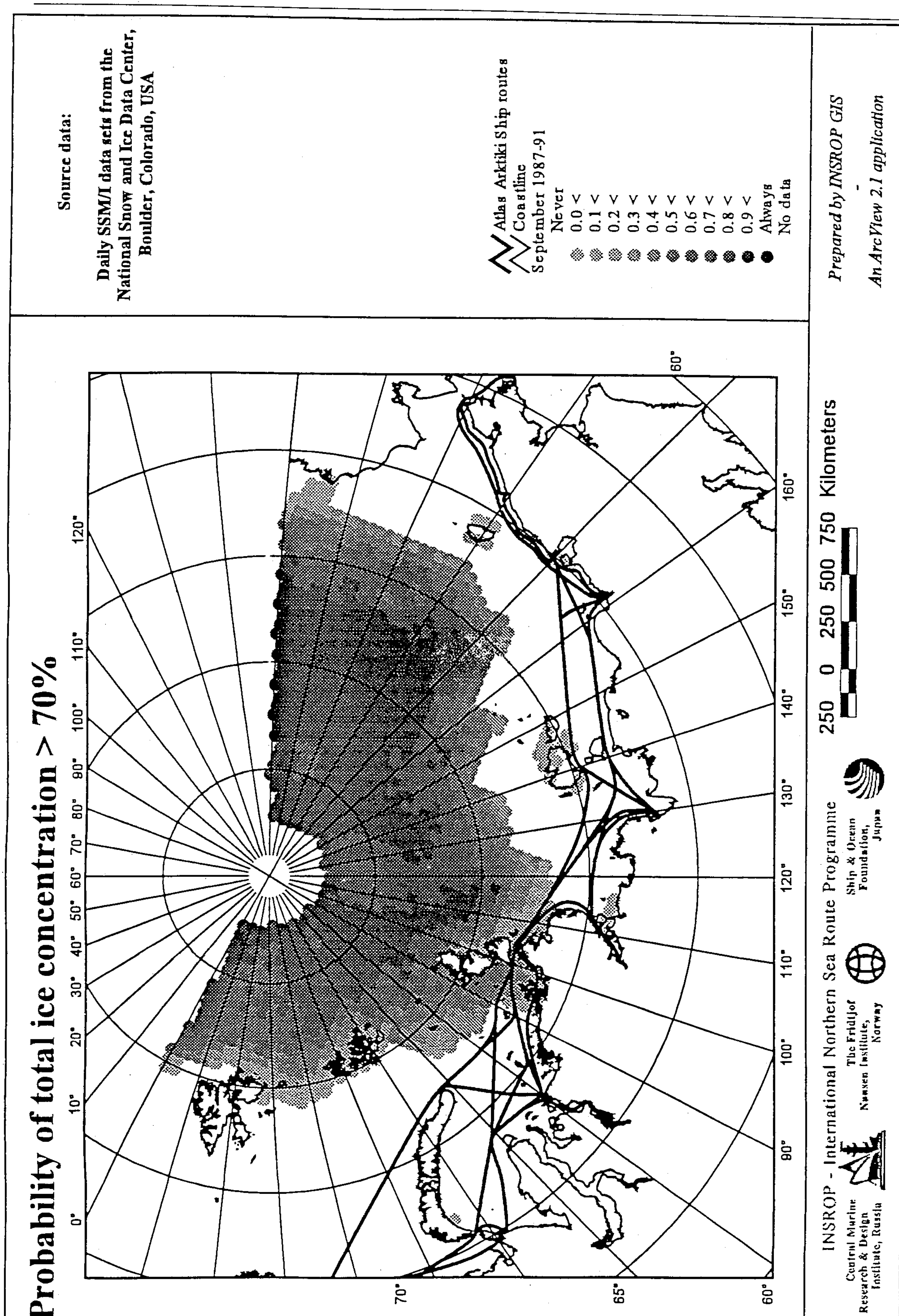

Figure 3.4 Probability of ice concentration greater than 70 % in September.

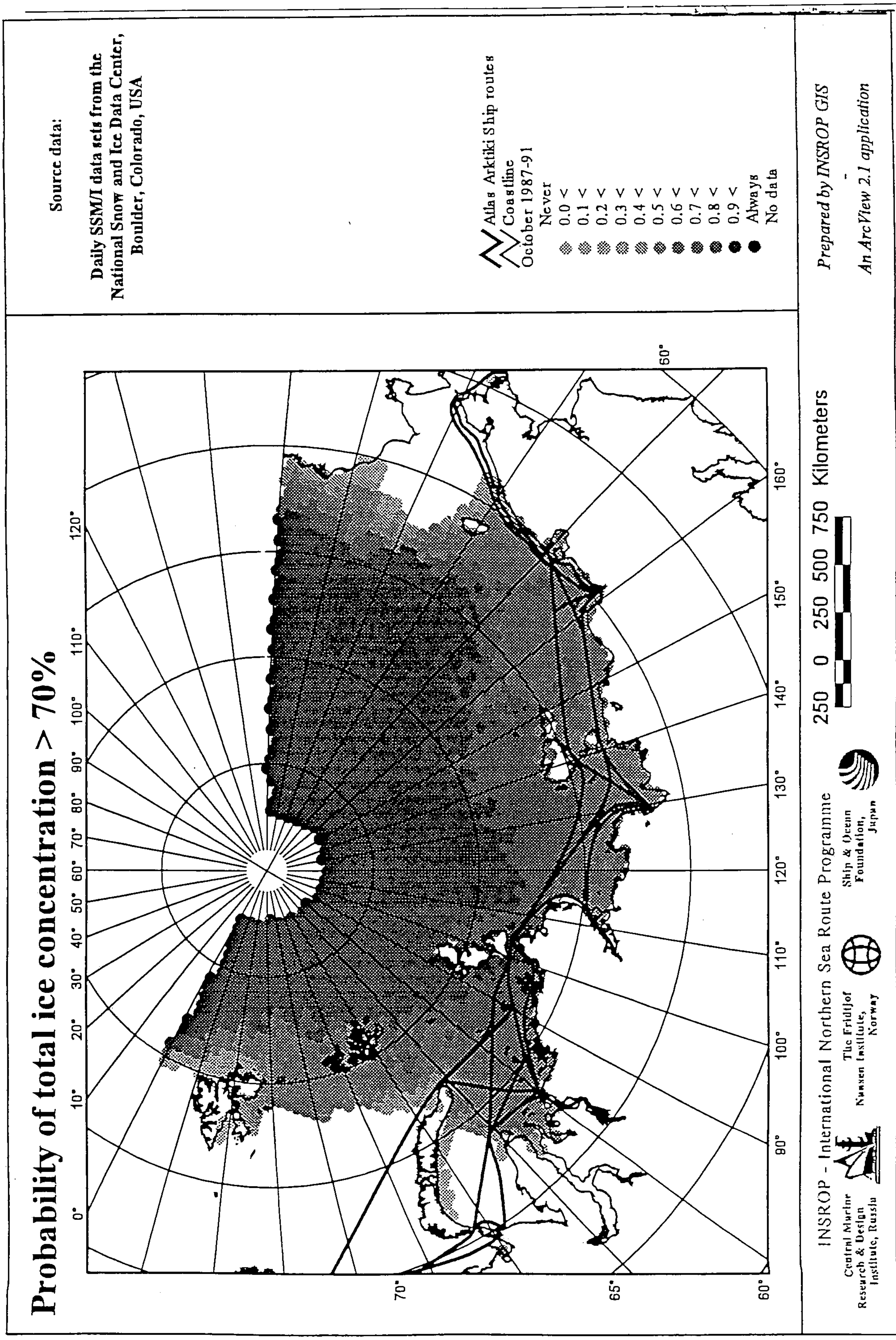

Figure 3.5 Probability of ice concentration greater than 70 % in October.

3.4 Conclusions and recommendations

As a first dataset on physical environmental data in the INSROP GIS, daily SSM/I data with a spatial resolution of 25 km for the period July 1987 to December 1992 has been analyzed. All source data have been converted to ARC/ INFO readable format and the analyzed results are implemented into INSROP GIS. Maps showing probability distribution of different ice concentration classes are presented for each month of the year. Since the time period covered by SSM/I ice data are very limited, the variability analysis will most probably not be representative for the region in a longterm perspective. Due to high temporal resolution of the dataset, it may, however, serve as a "reference" dataset when evaluating the quality of other datasets for ice concentration to be implemented into INSROP GIS.

The AARI Sea Ice Database covering the period 1972-90 with a temporal resolution of 10 days will be implemented into INSROP GIS during the 1995 project work. The analysis of the two datasets should be compared in order to evaluate the representativeness of the short period 1987-91 compared to the period 1972-90. A trend analysis of the AARI Sea Ice Database should also be performed in order to study the possibility to extend the navigation season. For the eastern sector (105-130 °W) the AARI Sea Ice Database covers the time period 1967-90. It is desirable to extend the time period also for the western sector in order to have time series as long as possible for the trend analysis. A trend analysis of the Barents Sea ice cover showed a principal cycle of about 10-12 years for changes in the ice conditions. Sinyurin (1992) reported that the ice conditions along the NSR in 1991 was very easy unless for the Kara Sea and the Vilkitskii Strait. The ice conditions along the NSR was very heavy in 1983 and caused a lot of problem with transit sailings.

The summer season for the region occurs roughly from June to September, when the ice cover melts significantly, diminishing in both extent and strength. The greatest seasonal fluctuation occurs at the east and west ends of the route. This is due to the influence of ocean currents moving northward from warmer Atlantic Ocean in the west and the Bering Sea in the east, which accelerate the ice decay in the spring and retard the freeze-up in the fall.

4. STATISTICAL OIL DRIFT DATA

In order to assess how pollution from NSR shipping will impact the environment, it is necessary with a statistical model to provide drift tracks of the pollutants. The original activity in this project concentrated on operational oil drift models for a local area with a very high spatial resolution. Due to the sparse resolution of the meteorological and oceanographic parameters for the region, efforts should not be made to local models. In order to quantify the assessment of possible conflict between pollutants and vulnerable resources, statistical drift data are needed to give a measure of the potential impacted area. Therefore, the activity has been modified to include a statistical oil drift model instead of a local oil drift model. The statistical oil drift model developed for the seasonal covered ice region in the Barents Sea (Johansen et al., 1994) is recommended to act as the statistical model producing oil drift data for the EIA study for the NSR region.

4.1 Statistical oil drift model

Most statistical models for open waters are based on the trajectory concept which means that the models simulate the drift and the weathering of the oil as individual points of mass released at different times within the available historical time series of wind data. Advection and loss of oil due to evaporation and natural dispersion as well as oil stranding are the main physical processes accounted for in such models.

The oil drift statistics is obtained by repeating the simulations of oil drift from chosen spill sites for a large number of spill scenarios, each based on monthly mean climatological surface currents fields and historical records of ice coverage and wind speeds. The oil drift mapping is to be performed for different seasons of the year in order to reflect the seasonal variations in wind climate and ice conditions.

Both natural dispersion and evaporation rates will be influenced by the presence of sea ice. Natural evaporation depends mainly on the wave conditions which in the open sea may be related to the wind speed. Waves propagating into the ice field (during on-ice wind) will be damped by the presence of ice floes. The evaporation rate will also be influenced by the presence of sea ice. Based on the experimental oil spill carried out in the Barents Sea (Sørstrøm et al., 1994) the evaporation was only about 20 %. During the field experiment the ice concentration was relatively high, about 60 - 90 %, and the oil drifted with the ice. Oil spilled in ice will spread more slowly than in open water and the spreading depends strongly on the ice conditions. Since spreading processes will not be explicitly represented in the model, the local ice concentration may be used to parametrize this difference in evaporation rates.

The statistical oil drift model applied for the Barents Sea North Region (Johansen et al., 1994) is based on a trajectory concept, i.e. the model simulates drift and weathering of oil slicks, represented as individual points of mass released at different times within the available historical time series of wind speed and ice coverage data. The main physical processes accounted for in the model are:

- Advection, i.e. oil drift due to surface wind anc currents.
- Weathering processes, including loss of oil due to evaporation and natural dispersion.
- Effects of the presence of sea ice on the oil mass budget and oil drift.
- Stranding of oil, i.e. contact with coastlines.

The effects of the presence of sea ice on the weathering processes are modelled by the following assumptions:

- Oil trapped under ice will be preserved in a "fresh" condition until the ice eventually melts
- Oil on ice floes will be subjected to evaporation, but not to natural dispersion.
- Oil in open leads will be exposed to both evaporation and natural dispersion,

The anticipated effects of sea ice on oil drift will be as follows:

- Oil drift in open water will be sensitive to the presence of sea ice upwind of the oil.
- Oil in open ice ($c < 30$ %) will drift with the surface water, but with a reduced contribution from the Stokes drift both during on-ice and off-ice wind due to wave damping.
- Oil in denser ice ($c > 50$ %) will drift with a velocity determined by the drift of the surrounding ice.

The model concept assumes that oil in ice-infested regions "follows" the ice. Oil inside the ice edge will not escape the ice during off-ice wind, and not be "left behind" the ice during on-ice wind.

Since ice drift velocities is seldom available, historical data on surface wind and background current data will be used as basis for the estimates of ice drift. The ice drift is estimated from wind induced drift superimposed on a seasonal averaged background current. The wind induced drift is derived from the local surface wind by a wind drift factor concept. The wind drift factor is anticipated to depend on the local ice coverage, decreasing from the value of 3.5 % normally used for oil drift in open water, to e.g. 2 % in dense pack ice. The wind induced drift is in general found to deviate from the wind direction by a certain angle θ. In order to include such deviations, the wind drift factor may be conceived as a vector. In open water, the angular deviation is normally assumed to be in the order of 15°, while the deviation may be larger for ice drift in dense ice, e.g. about 30°.

During the oil spill experiment in the Barents Sea (Sørstrøm et al., 1994) the wind drift factor was analyzed and found to be about 2.5 % of the wind speed in a height of 10 m. The deviation between average ice drift and the wind direction is on average 24°. The ice concentration was relatively high, about 60-90 %, during the experiment.

In regions of the ice field where fast ice is prescribed by the ice data base, oil will not be allowed to enter. This will be accomplished by "arresting" oil particles that should "try" to enter such regions until the wind eventually turns at a later stage. In the winter season fast ice is present along the NSR coast and the thickness may reach 200 cm. The fast ice boundary will be an important barrier for the oil transport and important limitation of the oil spreading.

4.2 Data requirements

The statistical oil drift model is based on the assumption that the major contribution to the variability in the oil drift pattern comes from the wind induced current, while the background current only depending on the season. The statistical oil drift model simulations for the NSR region will be based on time series of the following data:

- Monthly averaged background current stored in a regular grid (about 20 km resolution)
- Surface wind stored in a regular grid (time series or monthly statistical analysis)
- Sea ice conditions (type and fraction of different ice types)
- Coastline (land boundaries)

Landfast ice will in the winter season be present along the NSR coast and will prevent oil stranding. Landfast ice should therefore be one of the ice categories within the historical database. Oil spilled in slush, grease ice or brash ice will have a higher equilibrium thickness than oil spilled on open water between ice floes. Therefore, different categories of ice should be available in the geographical information system and the following are recommended:

- new ice (frazil ice, grease ice, slush and shuga)
- first-year ice
- landfast ice
- multi-year ice

Based on the requirement of input data to the statistical oil drift model, appropriate Russian data sources are identified and should be provided by AARI. Due to Russian rules some data are not allowed to be transferred to foreign users. Time series of wind speed and direction are not allowed to be transferred and the analysis have to be based on monthly statistics. The Markov chain method has to be used to construct historical wind records. The monthly averaged background current are allowed to be transferred as well as the AARI Global Sea Ice Database. The sea ice database includes sea ice concentrations and stages of developments from integrated sea ice charts and covers the time period 1972-90 with a temporal resolution of about 10 days and fulfils the requirements of the sea ice conditions for the oil spill model. The Sea Ice Database is available via Internet from National Snow and Ice Data Center. Since the data are stored in a regular grid with a temporal resolution of 10 days, a linear interpolation in time is recommended since the oil drift model simulates the response of the ice to wind and current.

Due to delays with the data deliverables from AARI, neither the wind nor the current statistics are available. The required data for the statistical oil drift model will be parts of the data project in 1995. The modification of the input module of the statistical oil drift model is therefore delayed and efforts has been made to specify physical processes to be involved in the oil drift model as well as cooperation with the EIA study in Sub-programme II.

4.3 Oil-contaminated area

The objective of the statistical oil drift model is to provide oil drift data for environmental impact assessments in the region of concern. The oil drift data required in the first stage of the environmental impact assessment are mainly related to a regional mapping of critical parameters s.a.:

- minimum and average drift time to shore
- minimum and average drift time to the ice edge (oil spill outside the ice edge)
- maximum and average length of the ice edge covered with oil (oil spill outside the ice edge)
- maximum and average drift time in the ice
- probabilities for stranding within certain drift periods
- average amounts of oil stranding

The NSR is a very large area and mapping the whole area with a spatial resolution of 20 km will result in an enormous amount of simulations. Within regions with high risk for accidents and vulnerable resources, special attention should be made during the consequence study. It means that the mapping should be performed with a high spatial resolution for those areas and lower resolution for less risky areas. It is assumed that the vulnerable resources are mainly located in the vicinity of the ice edge or adjacent to the coastline. Therefore, essential information to the EIA study is amount of oil related to the ice edge as well as oil stranding. The statistical model will be able to handle several spill sites in one model run with the positions of the spill sites specified by the user. With e.g. a 20 x 20 km spacing of the spill sites, this implies that a model handling 50 spill sites will map a region covering 120 x 120 km in one run. When larger areas are considered, the spacing between the spill sites may be increased, or subsequent runs may be made for selected sub-sections of the region.

The statistical oil drift model can also be run for oil spills along a "standard" navigation route with a spacing of about 30-40 km. This method will map the concequences of oil spills from a ship on a regional scale. For regions with high navigation risk and vulnerable resources the oil spill model should be run with a higher resolution than for the regional analysis. The evaluation of the resolution of the oil drift simulations should be made based on the resolution of both the physical and biological data.

4.4 Conclusions and recommendations

In order to assess how pollution from NSR shipping will impact the environment, a statistical model will be applied to provide drift tracks of the pollutants. The statistical oil drift model recommneded is based on a trajectory concept, i.e. the model simulates drift and weathering of oil slicks, represented as individual points of mass released at different times within the available historical time series of wind speed and ice coverage data. The main physical processes accounted for in the model are:

- Advection, i.e. oil drift due to surface wind anc currents.
- Weathering processes, including loss of oil due to evaporation and natural dispersion.
- Effects of the presence of sea ice on the oil mass budget and oil drift.
- Stranding of oil, i.e. contact with coastlines.

Based on the requirement of input data to the statistical oil drift model, appropriate Russian data sources are identified and should be provided by AARI. Due to Russian rules some data are not allowed to be transferred to foreign users. Time series of wind speed and direction are not allowed to be transferred and the analysis have to be based on monthly statistics. The Markov chain method has to be used to construct historical wind records. The monthly averaged background current are allowed to be transferred as well as the AARI Global Sea Ice Database.

The statistical analysis will show the conflicts between oil versus shorelines and ice-covered areas for the region of concern. The statistical oil drift model should be run for oil spills along a "standard" navigation route with a spacing of about 30-40 km in order to map the concequences of oil spills from ships on a regional scale. The analysis should be run for different times of the year in order to reflect the seasonal variations.

In Phase II of INSROP the statistical oil drift model should be fitted to the physical input data for the NSR region. Statistical oil drift simulations are to be performed along the "standard" as well as for high navigation risk areas.

5. RISK ASSESSMENT OF SHIP IN ICE OPERATION

Sailing the NSR represents a potential hazard to the environment, personal safety and damage on vessels. A major concern is the possible impact on the environment from accidental oil spills either from cargo or bunker fuel. Shallow waters and areas with heavy ice conditions are potential navigation risk areas and can be pointed out based on information about bottom topography and ice conditions. Contact with the ice itself may cause damages to the ship hull, its propulsion equipment, steering devices etc., which are large enough to seriously limit the operational capability of the ship or even stop the operation totally.

Thick ice cover is able to transmit high horizontal forces and even slight ice compression strongly affects the transiting capability of commercial vessels and heavy compression stop them totally. Minor ship collisions happen frequently in ice-covered waters. The distance between the assisted cargo vessels and the icebreaker must be smaller the more difficult the ice conditions are, and the risk of getting the icebreaker bow bounced towards the least protected sides of the cargo vessel can not be ruled out. When a long cargo vessel follows an icebreaker in a crooked lead, there is always the possibility to get a sideways impact to the cargo vessel shoulders.

When ships are conducted by ice-breakers or sail alone, ice damages result mainly from shocks of ships against ice, from ice compression under strong wind conditions and wrong maneuvering. Unfavourable conditions for maneuvering are created during heavy snow-fall, when freezed hummocks and old ice field fragments are impossible to detect.

Experience of sailing in Arctic ice shows that most vessels are damaged; only the features of the damage are different. The most frequent type of ice damage is hull fracture. During the years 1986-89, incomplete figures give 298 such cases or 82.5 % of the total for ice damage. The remaining 17.5 % are mostly damages to propellers, shafts and steering gear (Ushakov et al., 1991).

For carrying cargoes in the Arctic regions ships must be of UL or ULA ice class. There are not more than 25 % of such ships working on the Arctic routes. The ships of ULA class are used predominantly in winter. In summer season the major part of goods transportation is carried out by ore or wood carriers at the age of 10-20 years. Technical conditions of some ships hulls are found in an unsatisfactory state for using them in the Arctic Seas.

5.1 Data requirement

In Norway a database containing information of ship accident data called DAMA has been developed in cooperation between the Norwegian Maritime Directorate, Coast Directorate and DNV. The purpose of the databank is to present systematized information about accident events and causes which further will be used to increase the safety on seas. The presentation part of the database is based on 4 main parameters:

- Historical overview of accidents divided on years
- Consequences divided into categories depending on the accident extent
- Causes of the accident
- Events with focus on the most important/severe event

All accidents are divided on ship data (type, age, tonnage), consequences, causes and geographical location. The consequences of an accident is divided into 3 categories: total loss, severe accident and less severe accidents and other accidents where personnel accidents are included.

In order to present systematized information about accident events, detailed data about accident extent, the main event, the causes and concequences of the accidents are required. The main causes of accident can be divided into physical conditions, technical or human factors, cargo, procedures and routines. The ice conditions will be one of the physical conditions affecting the navigation risk. It is recommended to follow the strategy used in the DAMA databank in order to present the information about ship accidents along the NSR.

The accidental scenario within the EIA and the economic evaluation of the NSR will require a risk assessment of the operational scenarios to determine high risk areas. It is therefore important to know both the number of accidents and the total number of sailings for the different categories.

In the period 1957-89 the Rule about reporting of marine accidents acted in Russia. The purpose of this Rule was to recognize the circumstances, at which the emergency occured, its causes and concequences, investigation of staff guiltiness and preparing proposals for prevention of similar emergency cases. In 1989 a new Rule was introduced called "Rule about order of classification, investigations and record-keeping of emergency cases with vessels". The emergency case was defined as an event with the vessel caused by the effect of heavy hydrometeorological conditions, various damages of vessels hull, transported freight and/or change of its physical/chemical properties during marine shipping, stranding or grounding of vessel, hindering normal operation of vessels, the damage of coastal aids to navigation by the vessel, damages on other vessels, loss of towed object or deck freight.

Taking into account the state interests in the development of the NSR, legal status was given to the ice emergency cases. Masters of vessels and shipowners tried to treat any accident as ice emergency case, which automatically freed them from resposibility. The Ministry which was reporting to the communist party officials on total accidental losses, tried to treat any ice emergency case as master and crew mistakes case. All this background information which is taken from Baskin et al. (1994) must be taken into consideration when analyzing historical ship accident data.

5.2 Available ship accident data

Murmansk Shipping Company has performed an analysis of ship accident data for the time period 1954-90. Information from the Western and Eastern Arctic Marine Operation staffs as well as investigations of accidents events carried out by AARI and CNIIMF have been used in the analysis. More than 800 accident cases were considered and the analysis were grouped according to the ships ice class and to their ice-breakers assistance. In some cases ice damages of transport ships and ice-breakers result from several reasons simultaneously. Sometimes it is impossible to decide about the extent of each reason influence upon the damage.

For instance during 1965 navigation season in the Eastern Arctic Region more than 72 ships were subjected to ice damages and accidents, which comprise more than 40 % of total number of navigating ships. The 1983 summer Arctic navigation (as the heaviest) and the 1990 summer Arctic navigation (as the lightest) illustrate the dependence of accident rate on ice conditions. The data in the report should be implemented into INSROP GIS and presented in tables and on maps. Some of the statistical analysis in the report are presented in Tables 5.1-5.5. When comparing average number of accidents with the total number of navigating ships Table 5.1 shows that the eastern part of the NSR has a greater accidental risk than the western part. During the 1965 navigation season the eastern Arctic about 72 ships were subjected to ice damages and accidents, which represent more than 40 % of the total number of navigating ships. Table 5.2 shows that the most ship damages occur during heavy ice conditions and with ships of ULA and L1 classes. The majority of ice damages on ships of L1 class occur during assistance from ice-breakers. The ships of ULA class are most frequently situated to damages when sailing alone. In the Arctic seas about 40 % of the damages occur in the Kara Sea where the intensity of sailing is highest. About 20 % of the accidents occur in the Laptev Sea and the East Siberian Sea while only about 14 % occur in the Chukchi Sea. Table 5.3 shows the distribution of ice damages in different sections of the route (given in per cent of the total number of ships in the given sections). The following sections are most frequently subjected to ice damages: Bely island - Dickson island, Vilkitskiy strait, Tiksi - Indigirka river and Billings cape - Schmidta cape. Table 5.4 shows that most of the accidents occur at the end of the navigation period (August-September). Table 5.5 shows an increase in damages in 1983 during periods with favourable ice conditions. The main reasons may be the high number of ships with low ice class, high number of ships sailing alone or reduced attention of the navigators.

Table 5.1 Average number of ice damages on ships (relative to the number of navigating ships) during summer navigation under different ice conditions

Type of ice conditions	NSR Western (%)	NSR Eastern (%)
Heavy	7.5 - 8.0	14 - 16
Medium	3.5 - 5.0	8 - 10
Light	1.0 - 1.5	2 - 3

Table 5.2 Percentage distribution of ice accidents and damages during summer navigation in different ice concentrations

Ice class of ship	Ice conditions					Kind of movement	
	10	10	9-10	7-8	3-5	After ice-breaker	Without ice-breaker
Western Region (%)							
ULA	11	56	22	11	-	11	89
UL	5	35	50	8	2	60	40
L-1	3	7	55	20	15	95	5
Eastern Region (%)							
ULA	15	28	52	5	-	15	85
UL	5	20	65	8	2	70	30
L-1	-	7	22	56	15	90	10

Table 5.3 Distribution of ice damages and accidents in different sections of NSR (given in per cent of the total number of ships in the given sections).

Navigation route	Section of route	Ice damages (%)
Novaya Zemlya strait-Yenisey river port	Novaya Zemlya straits- Bely island meridian	28
	Bely island meridian- Dickson island	46
	Dickson Island- Sopochnaya Karga cape	17
	Sopochnaya Karga cape- Dudinka	9
Dickson Island-Tiksi	Dickson island- Vilkitskiy strait western	18
	Viskitskiy strait	38
	Viskitskiy strait eastern- Tiksi	52
Tiksi-Pevek	Tiksi- Indigirka river (through Dm. Laptev strait)	15
	Tiksi- Indigirka river (through Sannikov strait)	46
	Indigirka river- Pevek	39
Pevek- Bering strait	Pevek- Billings cape	30
	Billings cape-Schmidta cape	53
	Schmidta cape- Bering Strait	17

Table 5.4 Distribution of ice damages and accidents during summer navigation period (in per cent of total number of accidents during the whole summer navigation period).

Month	NSR Western (%)	NSR Eastern (%)
June	5	7
July	16	20
August	25	38
September	35	26
October	19	9

Table 5.5 Distribution of ice damages by months in 1983.

Month 1983	NSR Western	NSR Eastern	Total number
January	1	-	1
February	1	-	1
March	2	-	2
April	1	-	1
May	-	-	-
June	2	-	2
July	1	11	12
August	13	18	31
September	7	13	20
October	5	34	39
November	-	4	4
December	-	-	-
Total number	33	80	113

5.3 Identification of different accident scenarios

Kværner Masa-Yards has within Project I.5.1 performed a historical review of typical ship accidents in ice covered waters as well as identification of different accident scenarios. The study was performed as a collaboration between Sub-programmes I and II and is presented in the Discussion Paper "Environmental Safety of Navigation in Ice Covered Waters" by E. Ranki.

The identification of the basic scenarios are based on the general knowledge of the typical operation procedures in arctic environment. The two most evident scenarios based on the presented data are given below and Scenario A is assumed to have the greatest impact on the environment.

Scenario A. The vessel is trapped by heavy ice compression

Thick ice cover is able to transmit high horizontal forces. Even slight ice compression strongly affects the transition capability of commercial vessels, and heavy compression stops them totally. In the Baltic Sea even the highest category 1A Super ships suffer from minor hull damages and the level ice thickness is in those areas always below 1.0 meter. Among the arctic ice, consisting in the worst case of 3 - 4 meter thick multiyear ice floes, the compression may press the side structure inwards in large areas and even sink the ship. The damage cases of the Baltic 1A Super and 1A ships, "Stepan Razin", "Gotland II", "Nina Sagaidak" and "Kamensk Uralskiy" (the last two under the headline "Norilsk") represent this scenario.

Possible consequences to ship:

- Large area indentations are possible and leakages may be developed depending on the strengthening class of the vessel.
- As the worst case the vessel may even sink.

Possible consequences to environment:

- The outflow may be equal to the total amount of cargo.

Scenario B. Ship-ship collision

Minor collisions happen frequently in ice covered waters. In difficult ice conditions the commercial vessels must be assisted by icebreakers. Because the distance between the assisted cargo vessels and the icebreakers must be smaller the more difficult the ice conditions are, the risk of getting the icebreaker bow bounced towards the least protected sides of the cargo vessel can not be ruled out.

Possible consequences to ship:

- Very deep penetrations may be developed resulting in leakage.
- The cargo vessel is not able to proceed safely and may even sink.

Possible consequences to environment:

- The outflow may be a remarkable portion of the whole cargo, but probably not more than the contents of two consecutive cargo spaces. The case is similar to open water ship-ship collisions.

5.4 Conclusions and recommendations

Sailing the NSR represents a potential hazard to the environment, personal safety and damage on vessels. A major concern is the possible impact on the environment from accidental oil spills either from cargo or bunker fuel. Shallow waters and areas with heavy ice conditions are potential navigation risk areas. Contact with the ice itself may cause damages to the ship hull, its propulsion equipment, steering devices etc., which are large enough to seriously limit the operational capability of the ship or even stop the operation totally.

Murmansk Shipping Company has performed an analysis of ship accident data for the time period 1954-90. Information from the Western and Eastern Arctic Marine Operation staffs as well as investigations of accident events carried out by AARI and CNIIMF have been used in the analysis. More than 800 accident cases were considered and the analysis were grouped according to the ships ice class and to their ice-breakers assistance.

During 1965 navigation season in the Eastern Arctic Region more than 72 ships were subjected to ice damages and accidents, which comprise more than 40 % of of total number of navigating ships. Based on the analysis performed by Murmansk Shipping Company, the 1983 summer Arctic navigation (as the heaviest) and the 1990 summer Arctic navigation (as the lightest) illustrate the dependence of accident rate on ice conditions. The data in the report should be implemented into INSROP GIS and presented in tables and on maps.

Statistical analysis shows that the eastern part of the NSR has a greater accidental risk than the western part. The major ship damages occur during heavy ice conditions and with ships of ULA and L1 classes. The majority of ice damages on ships of L1 class occur during assistance from ice-breakers. The ships of ULA class are most frequently situated to damages when sailing alone. In the Arctic seas about 40 % of the damages occur in the Kara Sea where the intensity of sailing is highest. About 20 % of the accidents occur in the Laptev Sea and the East Siberian Sea while only about 14 % occur in the Chukchi Sea. The analyses also show that most of the accidents occur at the end of the navigation period (August-September). The analysis shows an increase in damages during periods with favourable ice conditions. The main reasons for that may be the high number of ships with low ice class, high number of ships sailing alone and reduced attention of the navigators.

6. REFERENCES

Barnett, D. (1991): “Sea ice distribution in the Soviet Arctic”. Polar Research Series, The Soviet Maritime Arctic, Ed. by Lawson W. Brigham, ISBN 1 85293 169 8.

Baskin, A., Samonenko, S. and Ushakov, A. (1994): “Ice accident rate, registration and analysis of ice accidents”. INSROP report.

Brestkin, S. et al. (1995): “Project I.4.1- Content of Database”. INSROP Discussion Paper.

Brovin, A. and Tsoy, L. (1995): “INSROP - discussion paper, Sub-programme I: Natural conditions and ice navigation, Planning and risk assessment. AARI, St. Petersburg.

Cavilieri, D. J.; P. Gloersen; and W.J. Campbell (1984): "Determination of sea ice parameters with the NIMBUS-7 SSMR". Journal of Geophysical Research, 89(D4), p. 5355-5369.

Coastal Directorate, Norwegian Maritime Directorate and Det norske Veritas (1992): “DAMA - Statistics for sea accidents, Annual Report 1992" (in Norwegian).

Comiso, J.C. (1986): "Characteristics of Arctic winter sea ice from multispectral microwave observations". Journal of Geophysical Research, 91(C1), p. 975-994.

Johansen, Ø., Martinsen, E. And Sunde, J. (1994): “Oil Spill in Ice Model Development- Phase III, Summary report on the statistical system”, OKN-report, ISSN 0332-9879.

Løset, S. and Vefsnmo, S. (1994): “Content of database, planning and risk assessment”. INSROP Working paper No. 5 - 1994, I.5.1, ISBN 82-7613-0801, ISSN 0805-2522.

Murmansk Shipping Company (1992): "Analysis of ice damages on ships during 1954-90".

Mulherin, N., Sodhi, D. and Smallidge, E. (1994): “Northern Sea Route and icebreaking technology, an overview of current conditions”. US Army Corps of Engineers, June 1994.

North, R. N. (1991): “The Siberian Rivers as a transport system”. The Soviet Maritime Arctic. Ed. by Lawson W. Brigham, ISBN 1 85293 169 8.

Pavlov, V.K., Kulakov, M. and Stanovoy, V.V. (1993): “Oceanographical description of the Kara and Barents Seas”. AARI, St. Petersburg.

Ranki, E. (1994): “Environmental Safety of Navigation in Ice Covered Waters - Part I”, INSROP Discussion Paper, December 1994.

Sinyurin, Y.N. (1992): "Hydrometeorological and ice conditions in the Arctic seas of the USSR during 1990-1991". Soviet Meteorology and Hydrology, No. 1, pp. 93-96, 1992.

Ushakov, A.P. (1991): “A historical Introduction”. The Northern Sea Route Project- Pilot Studies Report. The Fridtjof Nansen Institute, R:013-1991, ISBN: 82-7613-018-6, ISBN: 0801-2431.

Vefsnmo, S., Løvås, S.M., Mathiesen, M. and Kjelaas, A. (1992): "Trend analysis of the Barents Sea ice cover", Paper at Third International Conference on Ice Technology, (ITC-92), August 1992.

APPENDIX A

SHIPBASED GIS AND ANALYSIS
by Anders Backlund, Kværner Masa-Yards

1. General

As an important part of Subprogram I within the INSROP program a GIS of the Northern Sea Route is being designed. This study aims at defining the parameters defining the environment related to ice that should be included. The need is looked upon from the point of designing vessels for operation in the area and from the decision making process onboard a vessel operating in the environmental conditions of the NSR. Other parameters more related to general weather conditions are included only to the extent that they influence the behaviour of the ice cover.

The ice conditions in an area as the NSR are a mixture of a large number of separately identified types of ice features. In some studies only level ice thickness and ice coverage have been taken into account. This is a great simplification of the actual environment. Level ice, for example, is in very few seas a condition of any importance to the performance of a ship. The coverage of ice in areas along the NSR is for a large part of the year close to 100%, why this information is of less importance.

When describing the environmental conditions along such a vast area as the NSR, one should bare in mind the variety of conditions created by the change of location, season, type of year, etc. This variation leads to a great number of parameters, especially when the number of data users is large. Already the data required by a ship designer and a fixed structure designer differs from each other. In this study I have tried to group the data in a way that would make it easier for the GIS designers to build up the GIS in a user-friendly way.

As earlier mentioned, the amount of data needed varies depending on the user. Among designers, basically two main groups can be identified: those who need maximum existing aerial features and those who also need item dependant variations in the existence of the different features. The second main group of users included in this study, besides designers, is the ship operators. Their needs are more fixed on the aerial distribution of conditions and the predictability of coming ice conditions. These needs still enlarge the need of different parameters in a GIS and also emphasise the importance of combining different types of environmental data to a larger view of the prevailing conditions.

This study will in the following be concentrating on the parameters needed for

- designing of icebreaking / ice strengthened vessels for operation along the NSR
- evaluation of transit speed of a vessel / required power to achieve a certain speed
- route planning / speed evaluation onboard a vessel in the NSR

2. The strength of a ship and its components

The dimensioning of ships, regarding strength of parts influenced by ice, is today in many cases governed by the rules of different classification societies. In this extent they are similar to any open water vessel. However, the degree of knowledge in dimensioning of vessels operating in ice covered waters is not at the same level as it is for open water vessels. This fact leads to an increased need of case-by-case dimensioning of vessels operating along routes like the NSR.
The two main tasks in the dimensioning sense are the hull and the propulsion shaft line, including the propeller (rotatable propulsion units are to be included into this group). Other components to be specially designed are rudders, nozzles, bilge keels.

The main environmental features affecting the dimensioning of above mentioned components are

- multi-year ice (both sea ice and glacial ice)
- ridges (multi-year / first year)
- grounded features
- compressive ice

Within the NSR, all these features exist. On routes where none of these features exist (this might theoretically be possible) will level ice be the measuring feature.

The dimensioning philosophy mainly in use today is based on maximum existing features rather than a probability based approach, where a known risk is included. This is mainly because of the limited amount of data about the existence of dimensioning features.

In the following each feature and the parameters related to them are presented

1. Multi-year ice

Multi-year ice is, where it exists, the main feature for dimensioning of all mentioned ship components. The parameters describing the properties of multi-year ice are

- thickness (multi-year sea ice)
- mass of free floating block
- compressive strength
- flexural strength

In some areas of the NSR, the existence of multi-year sea ice is strongly dependent on the movements of the polar pack. To describe this event, the extent of the polar pack should be recorded to give an evaluation of the risk of meeting multi-year sea ice..

Glacial ice is often found close to Severnaya Zemlja and Frans Josef Land. As the existence of glacial has the greatest effect of ship design, registration of its existence is utmost important.

2. Ridges

Ridges are in many areas the main features regarding to dimensioning of ships. Parameters required to describe the ridges for dimensioning purposes are

- maximum keel depth
- thickness of consolidated layer inside the ridge
- strength of consolidated layer
- total mass of ridge
- ridge porosity, total and separately for different parts of the ridge
- internal friction
- is the ridge bottom founded or not

3. Grounded features

In some areas, shallow waters and close to structures, ice may be built up into grounded features. These can create loads governing the dimensioning of vessels. When dimensioning, the only parameter needed is the possibility of meeting such a feature.

4. Compressive ice

In some areas along the NSR, one of the most problematic ice features is compressive ice. Not only does it cause ships to stop because of increased resistance, it also causes considerable loads on vessels.
The only parameter needed to describe compressive ice is the force (or pressure) with which it compresses a ship moving through the ice field. With the knowledge of today, no data is available on the pressure inside an ice field. Within INSROP a project has been started to examine the phenomenon of compressive ice where one of the goals is to determine the parameters that should be recorded so that the compressive force can be calculated.

The values of some of the parameters can be calculated on the basis of other parameters. This is the case for the strength values, which can be determined as a function of salinity and temperature of ice. Because of this, these parameters should be recorded at least in cases where measured strength values are not known.

3. Transit speed of a vessel

The need for speed determination of a ship in the design phase is mainly concentrated to two different tasks:

- Determination of required propulsion power for a ship operating in specified maximum ice conditions (including comparison of different hull forms)
- Determination of the speed of a ship, with a certain propulsion power and hull form, in varying ice conditions along a selected route as part of transportation cost calculations

The practice in modern ship design, regarding icegoing vessels, is to specify the ship's capabilities in the form of ship speed in level ice of a certain thickness. The ice thickness specified is supposed to take into account the sum of features creating the maximum ice resistance. This determination of level ice thickness is based on experiences from other vessels. This way the required ice breaking capability is determined, based on which the required propulsive power is determined.
However, when designing new types of vessels no or very limited experience is available regarding the vessels in question. This emphasises the need for a calculation method of ship performance in varying ice conditions based on measurable physical parameters. Today such calculation methods are available, even though they are not public. The existence of such calculation methods and the inevitable fact that the resistance of a ship in ice must be describable in physical terms, justifies a need for more detailed information on existing environmental conditions, specified in measurable physical parameters.

The environmental parameters needed when determining the transit speed of a vessel in varying ice conditions are:

- level ice
  - thickness
  - flexural strength
  - thickness of snow cover
  - coverage
  - size of floes
- ridges
  - number of ridges/km
  - total height
  - porosity
  -
- compression
  - compressive force (pressure)

- channels
    - channel thickness
    - strength of ice in channel
- general
    - aerial variation (extent of different ice conditions)
    - seasonal variation
    - existence of leads

When determining the required propulsion power, only the maximum condition is required. When selecting the propulsion machinery configuration also other dominant conditions should be known
In the process of economic evaluation there is a larger need of data about the aerial and seasonal variations in ice conditions.

The parameters listed above have different influence on the transit speed of a vessel. The parameters having the greatest influence on the transit speed are:

- level ice thickness
- ridge size and frequency
- ice compression

Especially when larger vessels, with long parallel midbodies, are considered, the level of compression in the ice has a drastic effect on the transit speed.
The importance of the other parameters is smaller, partly because their values are more predictable and the variation smaller.

4. Onboard evaluation

Environmental data is mainly needed onboard ice going vessels for planning purposes: route planning, time consumption estimation, fuel consumption prediction. In all these plans, ship's safety has to be taken into account.

The environmental data needed for route planning purposes differs from the data required for ship design purposes by the need for exact local ice conditions. When planning the route of a ship, different levels of information is used: information received about the actual conditions (satellite images, observations from other ships, etc.), weather forecasts, statistical information about conditions in the area (level ice thickness, ridge number, ice strength, etc.) observations of your own. The statistical information needed should be stored in the GIS. From there the user can pick the data required.

An example of the actual routing process can be :

> A picture of the prevailing ice conditions can be based on satellite images of the operating area. These images can be scaled on the basis of own observations. Data gathered in this way is ice coverage, leads, ridge number, possibly ridge size. Data picked from the GIS would then be, for instance, ice strength, risk for compressive ice, risk for multi-year ice.

Because of the varying nature of ice conditions, predictability is important. In a stage with up-to-date satellite images of all areas, frequent observations from ships and other types of ongoing surveillance, route planning and transit time calculation can be made without larger amount of statistical data. However, this is not the situation in a predictable future, why statistical data is of great importance.

Data needed onboard a ship is:

- for safety aspects: parameters governing strength calculations
- for ship speed calculations: parameters mentioned above for transit speed calculations

Onboard the vessel one should additionally be able to predict changes in ice conditions, which requires knowledge about relations between general weather conditions and ice conditions.

5. General meteorological data

General meteorological data is required onboard an ice-going vessel in the same extent as in an open water vessel. The importance of temperature data is perhaps accentuated in ice going vessels, especially in areas of open water and cold air.

The following general meteorological data should be recorded:

- air temperature
- wind speed
- wind direction
- wave height
- drift speed

6. Summary table

The following table summarises the need of data in different tasks. The parameters are grouped according to the different features. The data needed from a GIS is indicated by an x, data gathered onboard a ship in operation is indicated by •.

	Ship strength	Transit speed	Onboard evaluation
Level ice			
Ice age (First year/Multi-year)	x	x	•
Thickness	x	x	•
Compressive strength	x		x
Flexural strength	x	x	x
Coverage		x	•
Size of floes	x	x	•
Thickness of snow cover		x	•
			•
Ridges			•
Maximum keel depth / sail height	x	x	•
Thickness of consolidated layer	x		x
Strength of consolidated layer	x		x
Total mass	x		x
Porosity	x	x	x
Internal friction	x		x
Is the ridge bottom founded	x		•
Number of ridges / km		x	•
Compressive ice			
Compressive pressure	x	x	•
Channels			
Channel thickness		x	•
Coverage		x	•
Strength of ice in channel		x	x
General			
Air temperature			•
Wind speed			•
Wind direction			•
Wave height			•
Drift speed			•
Aerial variation		x	•
Seasonal variation		x	x
Existence of leads		x	•
Glacial ice			
Mass of feature	x		

7. Analyses

As a part of the GIS, also an analyses of the recorded data should be included. The type of analyses needed varies depending on the user.

The main types of analyses of the environmental data needed for the tasks included in this study are:

- listing of maximum features
- seasonal and aerial variation
- cross-dependencies between different parameters (mainly for predicting)

When determining transit speed of a ship, an analyses tool is required combining the environmental data and ship data. The speed determination procedure can be a combination of an analytical formula and an experience-based scaling. The environmental input data required in the transit speed estimation analyses will be based on the environmental data analyses results. Calculation processes that are based on automatic analyses of the environmental data and direct transformation of input data to the transit speed analyses is not recommended, at least not before the basis for the statistical analyses is large. In the first stage, it is necessary to have a evaluation of input data by the user.

8. Conclusions and recommendations

For the design of icegoing vessels and for onboard evaluation of the safe operation of ships in ice covered waters a wide range of data is required. Some of the data is fairly stable and can be based on general knowledge of ice while others are very much site specific and varying by the season. Increased knowledge in these subjects is essential for the design of cost-effective icegoing vessels and for safe operation along routes like the NSR.

This study concentrates on the data needed for the design of vessels operating in ice. Other objects, such as harbours and offshore terminals, are not included. A separate study covering these topics is recommended.

APPENDIX B

REQUIREMENTS OF PHYSICAL ENVIRONMENT DATA PR NOVEMBER 1994

PHYSICAL ENVIRONMENTAL DATA NECESSARY FOR INSROP.

The main objective of Sub-programme I is to provide the essential supporting information on climatic variability and navigability which is needed for the assessment of the feasibility of opening the NSR to international shipping with an extended navigation season.

The length of the season and the average speed through the NSR are key factors to the NSR profitability. Transit of the NSR is today limited to the period July-October mainly due to severe ice conditions. To make the NSR really an international sea route the length of the operational season must be substantially prolonged with sustained average speed times. New ice breaker and ship technology, together with improved navigational systems, will give possibilities for extending the navigational period. Regularity is another key factor to NSR profitability. Irregularity might occur due to rapid changes in the ice and weather conditions as well as to inefficient coordination of convoys and ice-breaker support.

The purpose of the Environmental Impact Assessment (EIA), which is a part of Sub-programme II, is to evaluate the possible environmental impacts of increased use of the NSR as a shipping route. The EIA will focus on selected set of scenarios for NSR activities and their concequences. The scenarios for NSR activities will include geographical and temporal limitations of the activities as well as the type of NSR activity and the important environmental factors to be considered. The overall picture of the NSR will be mapped within the four sub-programmes, but will be of a general character and have a relatively low resolution due to the enormous NSR area. Based on an initial evaluation a set of focal EIA areas is suggested in the EIA Discussion Paper by Thomassen et al. (1994). In the focal areas more detailed analysis and mapping must be done with a higher resolution. The accidental scenario is closely related to the operational scenario as the sailing route and the physical environmental conditions are the same. The accidental scenarios will involve a risk assessment of the operational scenarios to determine high risk areas and seasons.

The physical environmental parameters important for transit sailings were selected at the workshop arranged in Trondheim (November 1993) and presented in Løset and Vefsnmo (1994). However, the spatial and temporal resolution of the different parameters were not discussed. The temporal and spatial requirement of the parameters are mainly based on the requirements from Sub-programmes II and III. However, the requirements are preliminary since the final selection of the EIA scenarios is not finished.

The purpose of INSROP GIS is not only to store, retrieve and display spatial data, but mainly to simplify the analyses of the spatial data as well as to provide extended analysis capabilities. Therefore all data should be in **digital form**, preferably TAB-delimited ASCII, ARC/INFO, HDF, Excel/Lotus 123 Spreadsheet or DBASE III/IV files. Together with all data sets a description of data sources, accuracy and resolution should be delivered.

METEOROLOGICAL DATA:

The meteorological data are mainly from meteorological stations along the route and the positions and operational period of the stations should be part of the data deliverables.

As general meteorological information for the area the following data are required as a minimum:

- Regional map showing monthly (or 10 days periods) minimum, maximum and average:
    * sea level atmospheric temperature
    * wind speed
    * wind direction (monthly mean within 16 sectors)
    * sea level atmospheric pressure
    * precipitation (snow, rain) or visibility

Since wind is the main driving force for the ice and the transport of the potential pollutants, gridded wind velocites for the whole region should be available during a time period covering 1962-91 (the same period as for sea ice concentration) with a daily or weekly resolution.

OCEANOGRAPHIC DATA:

As general oceanographic information regional maps showing monthly (or 10 days periods) minimum, maximum and average information of the following parameters are required:

* sea surface temperature
* sea surface salinity
* background current

Several buoys and hydrological stations are placed along the NSR and data with better temporal resolution than monthly mean will be neccessary information for the focal EIA areas and the scenario specifications.

Buoys and hydrological stations within the focal EIA areas should be parts of the deliverables including position and operational periods as well as data of the following parameters:

* wave height (swell data from 1967-91)
* sea surface temperature (hydrological stations, 1967-91)
* sea surface salinity (hydrological stations, 1967-91)
* sea surface elevation (hydrological stations, 1967-91)
* tidal current (1967-91)

MAIN RIVER DYNAMICS

For transportation evaluations the following data about the main rivers Ob', Yenisey and Lena should be delivered:

- Width and minimum depth in sections
- Drainage area
- Navigation season
- Discharge (monthly average volume)
- Temperature
- Ice coverage

SHIPS MOVEMENT IN ICE

Data about historical transit sailings are essential information when evaluating the commercial potential of the NSR as well as for the specification of the EIA scenarios. The main limiting factors for transit sailing are the ice conditions and the water depth. The sailing length in ice of 7-10/10 concentration serves as criteria of the complicated ice navigation conditions. In winter the success of the voyages will mainly depend on the polynyas and the discontinuities in the drifting ice.

The existing theoretical and empirical statistical methods for the assessment of the ice cover effect on the success of the ship navigation use a limited number of ice characteristics. These are ice and snow thickness, ice concentration, prevailing ice floe dimensions, amount of hummocking, degree of destruction and ice compression. The "QAD" model concept should be implemented into INSROP GIS to simulate ships speed in different ice conditions. Therefore, we need a very detailed description of the model and the different parameters involved.

The historical sailing routes should be devided into segments where the following information are described:

- Type of vessel
- In convoy or alone
- Icebreaker assistance or not
- Positions and times
- Vessel speed
- Total ice concentration along the sailing segments
- Ice thickness along the sailing segments
- Snow thickness along the sailing segments
- Amount of hummocking along the sailing segments
- Degree of ice destruction along the sailing segments
- Degree of ice compression along the sailing segments

The variability analysis of the ice and snow data will enable prediction of transit time for any existing class of ship through the NSR for any month of the year. Since the QAD model is only based on historical data the model will not be useful for new ship designs.

For general purposes it is desirable to have regional maps showing minimum, maximum and averaged speed for different ship/icebreaker categories (for instance icebreaker of "Arktika" type, etc)

ICE AND SNOW DATA:

The ice conditions along the NSR are extremely dynamic, leading to large annual, seasonal and regional variations. The Taimyrsky, Ayonsky and Vranghelevsky massifs are known to exert the most unfavourable influence on navigation due to high ice concentration and presence of multi-year ice, high ice stress and lower degree of seasonal melting.

In order to evaluate the potential for extending the navigation season, information about ice type, ice coverage and thickness with high temporal resolution are required. Therefore the databases containing the following weekly data should be delivered:

- Time series with gridded total ice concentration (weekly 1962-91, 15 nautical miles resolution)
- Partial ice concentration (FYI and MYI, weekly 1962-91, 15 nautical miles resolution)
- Time series with gridded ice thickness (weekly 1962-91, 15 nautical miles resolution)

Fast ice along the shore will prevent a potential oil spill to reach the shore. In winter the success of the voyages will mainly depend on the polynyas and the discontinuities in the drifting ice. Therefore the databases containing the following data should be delivered:

- Monthly mean fast ice boundaries (1960-90)
- Polynyas (monthly mean, 1960-90)

The success of navigation also depends on other parameters as stated above and regional information of the following parameters are required when evaluating the potential for extending the navigation season:

- Thickness of snow cover on level ice (regional maps showing monthly mean, minimum and maximum)

- Degree of ice destruction (1960-1980, charts)
- Map showing average date of maximum puddle development on ice

- Degree of hummocking (1960-1980, charts)
- Degree of ice compression (1960-1980, charts)

- Prevailing floe size (radar ice surveys, 1972-92)
- Ice drift velocities (drifting buoys)

- Iceberg concentration (monthly average, 100 km resolution)
- Iceberg height and width (monthly average, 100 km resolution)
- Ridge concentration (monthly average, 100 km resolution)
- Ridge height and width (monthly average, 100 km resolution)

DAMAGES ON SHIPS

The potential risks involved in sailing through the NSR will be assessed by investigating accidents and damages related to NSR transit navigation. Sailing the NSR represents a potential hazard to the environment, personal safety and damage on vessels. A major concern is the possible impact on the environment from accidental oil spills either from cargo or bunker fuel. Most of the hull ice damages are related to convoying.

The accidental scenario within the EIA and the economic evaluation of the NSR will require a risk assessment of the operational scenarios to determine high risk areas. For all the ship damages it is also desirable to identify the causes of the damages as well as the concequences for the ship, for the cargo and for the personnel.

For all the ship damages, the following data are required to give a relationship between the risk of hull damages and physical conditions:

- Position and time
- Type of ship
- Age of ship
- In convoy or alone
- Water depth
- Ship speed
- Causes of damages
    * Ice concentration
    * Ice thickness
    * Snow thickness
    * Amount of hummocking
    * Degree of ice destruction
    * Degree of ice compression
    * Visibility
    * Wind speed
    * Degree of icing

GENERAL BASIC DATA

- bottom topography (for the whole area, but especially important for the shallow straits)
- position and operational period of meteorological stations
- positions and operational period of oceanographic stations

APPENDIX C

MINUTES OF INSROP MEETING AT AARI DURING 3-6 APRIL 1995

Minutes of INSROP meeting in St.Petersburg, 3-6 April 1995

Participants:

From Russia:

Dr. A. Buzuyev, AARI (Coordinator Russian Sub-programme I)
Dr. V. Grishchenko, AARI (Supervisor Project I.3.4)
Dr V. Smirnov, AARI (Project I.3.4)
Dr. V. Stepanov (?), AARI, (Project I.3.4)
Dr. S. Brestkin (Supervisor Project I.4.1)
Dr. A. Brovin, AARI (Supervisor project I.5.5)
Gennady Semanov, CNIIMF (Coordinator Russian Sub-programme II); partly
V. Peresypkin, CNIIMF (Russian INSROP Coordinator), partly
Dr. V. Borodachev, AARI (Project I.4.1); 6 April

From Norway:

Stig Magnar Løvås, SINTEF NHL (Supervisor Project I.3.1)
Sylvi Vefsnmo, SINTEF NHL (Supervisor Project I.5.1)
Kjell A. Moe, DNVI (Coordinator Norwegian Sub-programme II); partly
Jørn Thomassen, NINA • NIKU, (Projects II.5); partly

Purpose of meeting

1. To exchange status of Russian and Norwegian projects within INSROP Sub-programme I.
2. To discuss GIS cooperation between I.3.1 and I.3.4.
3. To agree upon which ice and hydrometeorological data, needed by Norwegian INSROP projects, AARI can provide, when they can be provided, and whether there are any special terms connected with making the data available to INSROP.
4. To discuss scientific cooperation in 1995-projects and towards IST'95 in Tokyo.

Achievements

1. Project I.4.1 (Dr. Brestkin) has prepared a note on the opinions and possibilities for providing AARI data to foreign INSROP projects. The Norwegian partners had studied this description and expressed an understanding of several viewpoints in this note, but expressed also that some of these viewpoints was not in compliance with the basis for the INSROP cooperative agreement. See Item 3 for further information on this issue.

Project I.3.4 presented the growing GIS center at AARI, and their plans for using ARC/INFO to prepare ice charts. Project I.3.1 demonstrated the present version of INSROP GIS using Arcview 2.0 , and how the online INSROP documentation is available from INSROP GIS (ArcView), and also as a standalone product under Microsoft Windows. The preliminary version of the INSROP GIS online documentation module was installed on a PC at AARI, and an installation diskette was provided to AARI.

2. The Joint Project Plan prepared for the JRC meeting in October 1994, is still valid. The further progress for fulfilling the project plan is closely connected with the work on preparation of data sets.

3. In November 1994 a complete list of physical environment data necessary for INSROP was prepared by the Norwegian parties. The requirements of the data was based upon an agreement at the workshop in Trondheim in November 1993 on parameters important for transit sailing as well as requirements from the EIA and the economical evaluations in Subprogrammes II and III. As described in the note by Dr. Brestkin, few of the primary (original) data bases of these parameters are allowed for transfer to foreign partners.

INSROP GIS is a tool for building up the knowledgebase and for transferring information to the decision makers. Due to Russian rules some of the desired data are restricted. The Norwegian informed that if there are data important for INSROP which are not covered by the specifications in the umbrella contract, it is possible to give special restrictions to these data.

Due to Russian laws, the access to data can be divided into 5 categories as described in the note by Dr. Sergey Brestkin. For data that are not permitted for transfer to foreign parties, secondary data bases (i.e. statistics) must be prepared. Several discussions on the status of the content of the AARI data bases, the INSROP agreement, and amount of work to provide needed data to Norwegian INSROP projects took place during the meeting. Due to the present status of the data bases at AARI, and the personell and financial resources required to prepare statistics and data bases for access to INSROP, it seems unrealistic to populate INSROP GIS with all necessary data during 1995. A priority list (Part I) including the most important data allowed for transfer to foreign parties, and serving as a first part of the transfer of Russian data, was worked out during the meeting (see Enclosure I). This list will be negotiated further, possibly leading to some changes in the priorities of Project I.4.1.

On 6 April Dr.Borodachev presented color plots showing ice thickness distribution and ridging frequency in April. AARI is working to prepare such statistics for any month, and also for 10-day periods, during the year. The Norwegian side expressed that such information was very useful to INSROP, but AARI did not consider it possible to prepare this information within the temporal/financial frames of INSROP Phase I.

Parts of the Global Sea Ice Data Base (1972-91) was delivered to SINTEF on diskettes at the end of the meeting and the rest will be send by courier to Norway within 1 May 1995.

"Atlas Arktiki" (Paper format), was given as a present from AARI to SINTEF NHL and DNVI. This atlas from 1985 comprises a wide range of general information about Arctic conditions. The information is often presented as winter and summer values/contours on maps at scales 1:20 mill. to 1:60 mill.

4. In order to present cooperation within INSROP, it was agreed upon giving joint presentations at IST'95. Existing Norwegian abstracts will be reviewed. The Norwegian side will also try to arrange a workshop in Norway with selected participants from Russian INSROP projects.

Enclosure I AARI data sets to be made accessible to INSROP

Data set/type	**Amount of data**	**Extra aggrement**	**Additional cost**	**Time of delivery**	**Responsible**
WDC Ice chart data base	1972-1991, 10-day periods	No	No	1 May 1995	Dr. V.Smolianitsky
Degree of ice decay	Min, average, max; June, July	Yes	Ca. USD 7000	1 July 1995	Dr. Borodachev
Amount of hummocking	Min, average, max; June, July	Yes	Ca. USD 7000	1 July 1995	Dr. Borodachev
Degree of compression	*Methodology*	No	No	1 May 1996	Dr. S.Brestkin
Cracks, leads fractures	Parts of the route, May, June, October	No	No	1 may 1996	Dr. S.Brestkin
Fast ice boundaries		No	No	1 May 1995	Dr. V.Smolianitsky
Ice drift		Yes	?	?	Prof. Gordunov
Ice thickness	*Formula, not data*	No	No	1 May 1996	Dr. S.Brestkin
Sea surface temperature		Yes	Ca. USD 7500	1 July 1995	Dr. V.Sokolov
Average current		Yes	Ca. USD 7500	1 July 1995	Dr.V.Volkov
Wind (speed, direction)		Yes (?)	?	?	?
Atmospheric pressure		Yes (?)	?	?	?
Air temperature		Yes (?)	?	?	?

This table will be negotiated further, and the terms for making the data available to INSROP may be improved.

APPENDIX D

PROJECT REVIEW

National Research Council Canada | Conseil national de recherches Canada

DOCUFAX

NRC·CNRC

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DATE: November 23, 1995

 # OF PAGES (INC. COVER): 8

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RE: Review of Project I.5.1 Report on 1994 Work

Following is my review of the report on the above noted project. Also several pages with typographical corrections are attached.

In spite of my many comments it is a good and useful report.

Please note that I now have a different fax number and am with a different part of the National Research Council.

Regards,

[signature]

INSROP I.5.1 Content of database, planning and risk assessment

Review by R. Frederking

The report covers work accomplished during 1994 on the project. It covered the following four activities:

1) Identification of data sources on the physical environmental
2) Implementation of a basic data set on ice cover into INSROP GIS
3) Selection of statistical oil drift model
4) Evaluation of risk assessment of ship in ice operation.

In Chapter 2 the physical environmental data requirements for both ship safety and transit speed have been spelled out in terms of characteristics, frequency, region and time of year. The emphasis was on conditions affecting design of vessels operation in the NSR area. One of the key points of this chapter was the identification and acquisition of Russian data. A complete listing of pertinent Russian data was established, however it was learned that not all the data was available to INSROP. In some cases the data were not in a suitable form for inclusion in the database. In other cases the data are not available for release. Other data sources have also been identified. These are mostly in national or international data centres. I should point out that CANATEC Consultants in Calgary have prepared atlases and databases of ice conditons in the Russian Arctic. For example, they have atlases of Barents, Pechora and Kara Seas ice concentrations based on 18 years of data from US Navy and NOAA sources. They also have an "Environmental Atlas of the Pechora Sea" which includes iceberg, ice cover, hydrology, climatology, chemistry, etc information obtained from AARI. Reference to these atlases should be included in Table 2.3.

There is duplication between the contents of Appendix A and Chapter 2. It is noted that Appendix A makes a very important contribution to Chapter 2, however it would be better for the reader if Chapter 2 just summarized the contents of Appendix A, rather that repeating parts of it word for word. The table on page 8 of Appendix A is virtually identical to Table 2.1 on page 5 of the main report. In regard to Table 2.1 I would suggest that density of the ice in a ridge keel is also an important factor in defining ridge properties.

Some specific comments on Appendix A:
page 2, last sentence of second paragraph; something is missing, meaning unclear.
page 4, Section 4, second paragraph; there is reference to an INSROP project on the phenomenum of compressive ice, there should be specific reference to the project; i.e. project number.

A specific question on Appendix C:
page 3, half-way down the page there is reference to the "QAD" model. What is it?

Chapter 3 discusses the application of the INSROP GIS program to sea ice concentration data obtained from the National Snow and Ice Data Centre in Colorado for the period 1987 to 1991. Statistical characteristics of ice concentration have been determined and average concentrations by month plotted. The variability of ice conditions is discussed in a qualitative fashion. The short time span of the data preclude any extensive analysis.

Chapter 4 explains the redirection of an oil drift model from a local operational one to a statistical one more suited to general assessments of pollution impacts. Again there is repetition. In Section 4.1 the same idea is repeated almost word for word in the first paragraph and the fourth paragraph. In the third paragraph of Section 4.1 there is reference to evaporation of 20 %, 20 % of what? On page 25, about half way down the page there is discussion of drift velocities. It is stated that oil drift is normally taken as 3.5% of wind speed and that in the presence of ice a value of 1% will be assumed. For ice it is normally assumed that drift velocity is 2 % of wind speed. Could it be explained how oil could drift at 1% of wind speed in an ice field which is drifting at 2 % of wind speed. Again on page 27 there is word for word repetition of part of the second paragraph from the top of the page and the second paragraph from the bottom of the page.

Chapter 5 does a risk assessment of ship operation in ice and is supported by Appendix B which is actually a report carried out for sub-program II "Environmental Factors". Extensive quantitative data on accidents and damage in ice along the NSR were carried out by Murmansk Shipping Company and included in this chapter. Ice class of ships, ice concentration, area and operation are the factors considered. This is a valuable contribution.

Some specific comments on Chapter 5:
page 28, third paragraph, second sentence; meaning not at all clear.
page 30, the caption of Table 5.1 refers to number of ice damages, but the heading of the columns of the columns gives percentages, % of what?
page 30, Table 5.2, The second and third columns of the table are labelled ice concentration 10. What is the difference between the two columns.
page 30, sentence starting in fifth line from the top of the page, "About 20 % of the accidents ...." how does the content of this sentence relate to the results presented in Table 5.3.
The repetition in the description of scenarios in pages 32-35 of Chapter 5 and pages 27-30 of Appendix B should be avoided.

In spite of my specific criticisms, the report is well laid out with an abstract and summary as well as conclusions and recommendations for each chapter. It is a good demonstration of the progress made on the project over 1994.

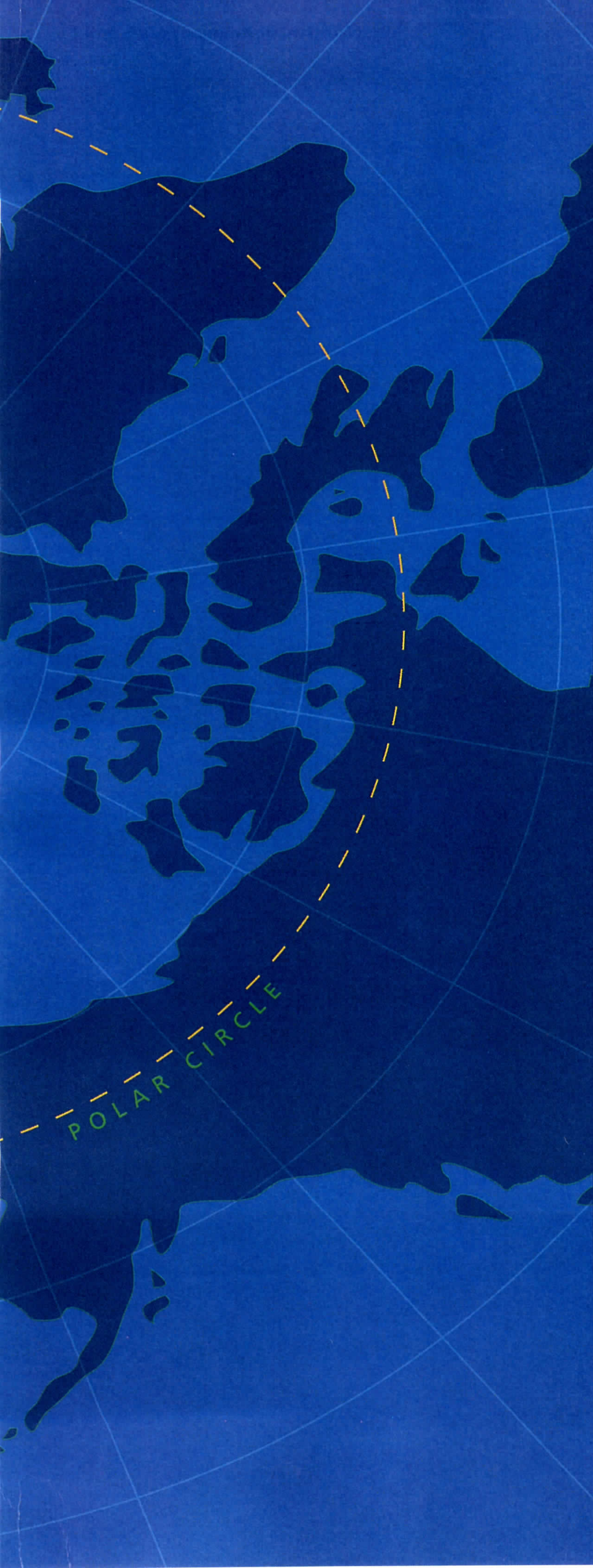
Comments to the project review:

Chapter 2:
CANATEC Concultants was contacted early in 1993 by the project team and through an oversight the databases produced was not referred. The environmental atlas has been included into Table 2.1. The duplication between Appendix A and Chapter 2 has been removed.

Appendix C:
The QAD model is a model for quantitative assessment of the difficulty of ice navigation.

Chapter 4:
The evaporation is given in percent of volume
During the field experiment in 1993, the wind drift factor of the ice was analyzed and found to depend on the ice concentration and on average 2.5 % of the wind speed in the height of 10 m above sea level. The oil drift depends on the ice concentration and when the ice concentration is above 30 % the oil is assumed to drift with the ice.

Chapter 5:
The number of ice damages in Table 5.1 is relative to the number of navigating ships.
Table 5.3 gives distribution og ice damages in percent of the total number of ships in the given sections.



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.