Integrated Weather, Sea Ice and Ocean Service System (IWICOS)

System design and user requirements study

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Executive SUMMARY

The overall objective of IWICOS is to develop a prototype marine information system that will provide a single-entry access to integrated meteorological, sea ice and oceanographic (met-ice-ocean) products in electronic form, and to demonstrate this prototype for a group of users working in fisheries, sea transport, exploitation of marine resources in Northern European waters, or whose work is related to sea ice monitoring on a scientific or pre-operational basis. As a first part of this RTD project, a user requirements and design study has been undertaken, in the period from January to August 2000.

For IWICOS to succeed, it is essential to know the requirements from the main users of meteorological, sea ice and oceanographic information, especially those operating in the marine environment in the targeted areas. In previous projects, the user requirements for sea ice information have been studied in the Baltic Sea, in Greenland Waters and in the Northern Sea Route, involving a selection of representative users from public sector and commercial enterprises. In this project, a dedicated survey of user requirements has been carried out in Iceland in the first half of 2000, and a group of users invited to a design workshop held in April 2000 has provided additional input for the IWICOS prototype. Even if the ice, ocean and weather conditions can be very different from one area to another, and different user groups focus on somewhat different information needs, there are some basic requirements that can be used as guidelines throughout the project.

Based on the previous user requirements studies and user involvement during the first phase of this project, the following recommendations have been proposed:

- IWICOS should recognise that the marine user community may have different needs for information, may work in different regions and have different educational background.

- The IWICOS system must be able to combine information from different sources in a flexible way. Consequently, it should be possible to construct user defined displays and combinations of information.

- IWICOS should provide an integrated system enabling users to access and display all information with one system. It is important that users do not have to worry about sources of a given information layer and formats . Today, much of the information already exists, but must be collected from different sources and may exist in different forms that obstruct easy combination of information layers from different sources.

- It is important that the IWICOS system has a user friendly interface so difficulties with understanding and using the system will not obstruct the application and dissemination of the system. Therefore the user interface must be developed by means of known industry standards or public domain tools.

- IWICOS should aim at adopting existing standards for data presentation, e.g. standard colour coding of ice charts and standard symbols for presentation of meteorological information and ensure source independence and seamless display of data from different sources.

- IWICOS must disseminate products using standard technologies and standard data exchange formats.

- IWICOS must acknowledge the limitations of marine communication systems and the cost of using them and must adopt methods to effectively handle these problems.

- IWICOS should provide a range of products with different levels of information, aimed at different user groups. In both demonstration periods a representative set of free products should be prepared and advertised through the IWICOS web site, to raise awareness of the service and allow for a wide audience to give feedback on the products and IWICOS prototypes developed.

- The cost of the met-ice-ocean products is another important aspect in the end-users' evaluation of IWICOS. Some products will require high-priced input data and/or a significant amount of processing and therefore be expensive to generate, while others may be produced by means of low-cost input data and simple, automated processing tools. Whether or not a product is to be delivered in near real-time will also have a large impact on its cost. As information needs will differ between various user groups, and also depend on the type of activity carried out, the user should be able to select and change the level of service requested to best match the current situation.

In this context of IWICOS, products means both met-ice-ocean data at various processing levels (meteorological fields, satellite data, ice data, etc.) and the presentation techniques used to show the data (images, graphical products, etc.). During the first phase of the project, the partners have reviewed their existing products and suggested a plan for new development of products that integrate or display data from several sources, and that combine meteorological, oceanographical and sea ice data. Some data products will be tailored to the geographical regions and the specific user requirements in these regions, while other products will be more or less similar in all regions. The products can be divided into three main groups: daily, near-real time products which are used for monitoring, forecasting of weather and ice conditions using numerical prediction models, and archived products giving statistical information about mean and extreme conditions as well as snapshots of interesting events.

One type of planned product is SAR quick look images from a database, which will give many examples of detailed ice images in different parts of the Arctic Ocean. Other archived products can be ice charts, AVHRR and SSM/I data and meteorological statistics. Improvements in operational ice monitoring is expected by the introduction of SAR images and ice classification from SAR images, providing better resolution in the ice maps. During IWICOS the digital GIS information about ice properties in the routine ice chart will be combined with SAR image classification algorithm. Daily and archived SSM/I ice maps, combined with AVHRR, SAR and other data products, are developed for presentation on Internet. Ice drift and wave forecast visualisations are planned to be improved in the Baltic Sea and in Icelandic waters. Improved visualisation of the data will be tested in all study regions, Access to the products will be possible in several ways. In the Baltic Sea, products will be sent out to icebreakers and some ships using communication satellites and cellular telephone system. In Icelandic and other waters ice and weather information will be sent to fishing vessels via the Inmarsat communication system.

In general, the products will be developed to serve two types of users: ship based users using thick clients who want to download different types of data for own processing and presentation, and land based users using thin clients who only want ready-made products that can be easily downloaded and viewed without further processing.

The design study established the need for three major subsystems in the IWICOS processing chain: production, brokering and presentation. The production subsystem will be responsible for all processing required to generate the defined products using various types of remote sensing, in situ and model data as input and incorporating a suite of tools ranging from simple, automated algorithms to complex computational or human-computer interaction software. The production subsystem will also hold a repository of all generated products and make these available to the broker subsystem or directly to thin/thick clients, which implement the presentation subsystem for selected end-user groups.

The main task of the broker is to establish contact between the producers and users of met-ice-ocean products. Several broker interaction models were investigated to find the most suitable solution for the IWICOS prototype. It was found that a hybrid of the basic-service-model and the diminished-broker will best serve the needs for both thin and thick clients, which are needed by different user groups. In the basic-service-model, a broker will receive a request from a (thick) client, use its internal metadata repository to find the closest supplier and collect all needed data from a number of production systems, distributed across countries and networks. Then, it will bundle these data for optimal transfer rates and send the bundled data to its client. This is suitable for connections via a low-bandwidth communication network, such as cellular phones and satellite communication. In the diminished-broker model, the broker will also receive requests from its (thin) client, but instead of obtaining and passing on all products to the client, it will simply provide a reference to them. Then it will be the client's responsibility to connect to the relevant production system using the provided references and to retrieve the desired products by means of standard protocols such as HTTP or FTP. This type of distribution mechanism is suitable for high-bandwidth networks, which are typically land based.

As outlined above, two types of presentation systems are foreseen for different user groups in IWICOS. Some partners will develop thick clients with sophisticated manipulation and customisation capabilities, which will download products for further processing, analysis and display. Other partners will focus on thin clients, which will download products that have already been prepared for display, and which therefore will need only limited facilities for further processing. The flexibility in the defined 3-tiered system architecture and the hybrid brokering models, will enable development of tailored end-user systems (thin/thick clients) for different areas and user groups - within a common framework of shared services for product storage and dissemination.

A key issue in this first phase of IWICOS has been to define a common format, to enable exchange of products between the different suppliers in the consortium and the thin/thick clients to be developed. The IWICOS format has to capture both metadata (i.e. description of the data) and data (i.e. measured, estimated and predicted environmental parameters), and must be extensible to support new product types that are planned for the second demonstration period.

To enable easy exchange and use of baseline products between IWICOS partners, a limited set of standard exchange formats was identified: BSQ, Shapefile, GRIB and ASCII. These formats facilitate exchange of raster, vector, grid and plain text data and are all open and well documented. In addition, it has been decided to use XML to represent metadata. During the past two years this W3C standard has been accepted world-wide and used in a wide range of applications, including systems for geographic and time dependant data. Both large industrial companies as well as public domain software organisations have committed to development of the XML standard and derived technologies, and as a result numerous powerful tools have been released and more will follow in months and years to come. This will ensure that IWICOS will have a solid foundation on which to base its metadata representation. The physical separation of metadata and data will also enable easy extension of the data representation, simply by adding another standard data format when a new product that cannot be stored in any of the baseline data formats is defined. Relations between metadata and data will still be maintained through references to the respective data files and by adhering to a prescribed naming convention for data formats. The production, brokering and end-user system can share the extensions needed to handle the new formats, and thereby reduce overall development costs. Conforming to standard formats for both metadata and data will make the IWICOS products more versatile and robust, and allow for easy integration into future commercial services for integrated met-ice-ocean monitoring and forecasting.

After the initial phase of the IWICOS project reported on here, work will continue with baseline product and prototype development for the selected areas and end-user groups. The baseline version of the IWICOS system, including sample met-ice-ocean products and associated analysis and presentation facilities, is planned for demonstration in 2001. Then, there will be a evaluation and feedback period, before the development of enhanced and new products will be undertaken along with corresponding extensions of the IWICOS prototype systems, ending with a final demonstration of all products around in 2002.

Further information about the IWICOS project, including product examples, can be found on the project web site:

http://www.nrsc.no/IWICOS/

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CONTENTS

1. Introduction

1.1 Background

The objective of IWICOS is to develop a prototype marine information system which will provide a single-entry access to meteorological, sea-ice and oceanographic (met-ice-ocean) data and products in electronic form provided by weather forecasting, ice and research centres. It is stated that IWICOS will put emphasis on forecasts for safe and cost-effective operations and it is also intended that IWICOS will play an important role in early warning and as part of a decision support system for navigation. If these goals are to be reached the marine weather sevices offered within the IWICOS framework must necessarily follow the standards given by WMO for marine weather services.

The requirements from selected end users have been analyzed to identify their needs for integrated met-ice-ocean information and how to present this information with state-of-the-art computer equipment. User requirements for ice information have also been investigated in previous studies (EC funded projects IMSI and OSIMS). These studies have been supplemented with additional requirements for integrated met-ice-ocean products, which address a wider range of users than only the ice community. E.g. the Icelandic user requirements has investigated the needs of representatives from the fishing fleet. The user requirements provide input to the design of the IWICOS system. The requirements for functionalities and the developed design are documented so that the main concepts can be easily understood by both end users and the partners. The system design was discussed at a dedicated workshop where selected users participated. Figure 1 shows the main modules of the IWICOS system, as seen from the user's perspective. First, the system must consist of a set of user interface elements that provides access to data/products and related functionality (ordering, displaying, etc.). This includes also a retrieval system on the provider side. Secondly, modules for communication between the service provider and the user must be developed and adapted to the infrastructure in the respective study area. When the baseline system has been developed and tested, the system design will be modified, if needed, before the extended system is implemented in the latter half of the project period.

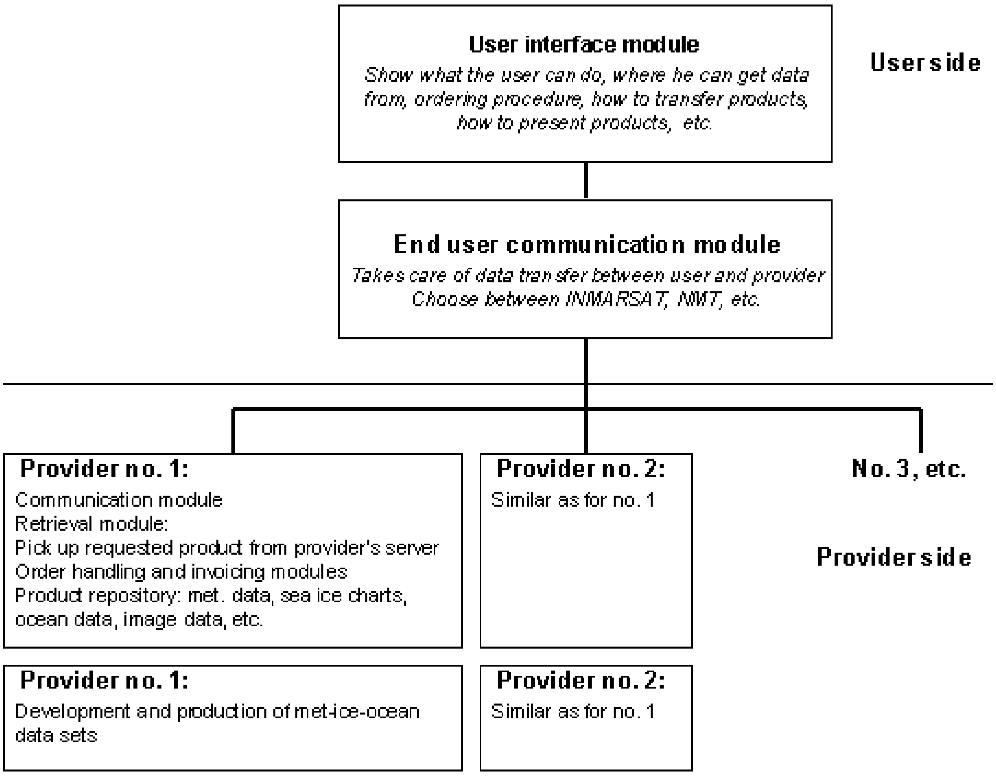


Figure 1. Graphical presentation of the IWICOS system.

1.2 Relation to existing meteorological services

The following text is taken from the preface of Handbook on Marine Meteorological Services, WMO/TD-No. 348, 1991 edition:

"… Broadly speaking, marine meteorological services may be classified as:

Basic marine meteorological services provided in support of the safety of life and property at sea, in accordance with the International Convention for the Safety of Life at Sea (SOLAS);
Specialized marine meteorological services in support of an increasing number of ocean-based economic and commercial activities. These latter are often specifically tailored to an individual user's requirements and may be provided on a fee-for-service basis."

The basic marine meteorological services are regulated by WMO standards which shall be followed by all national weather forecasting centres. The main documents describing these standards are Manual on Marine Meteorological Services, WMO No. 558 and Guide to Marine Meteorological Services, WMO No. 471. In these documents the content and format of warnings, synopses and forecasts is described. F.ex. it is stated explicitly in the Manual on Marine Meteorological Services (Services for the high seas, 2.2.3.8 and Services for coastal and off-shore areas, 2.2.2.4) that warnings, synopses and forecasts shall be given in plain language.

The WMO Marine Programme co-ordinates the dissemination of warnings and weather and sea bulletins according to a broadcast schedule, in conformity with procedures laid down under the Global Maritime Distress and Safety System (GMDSS) protocols within SOLAS (Safety of Life at Sea). For broadcast purposes, the world's oceans are divided into a number of areas of responsibility called Metareas (Figure 2).

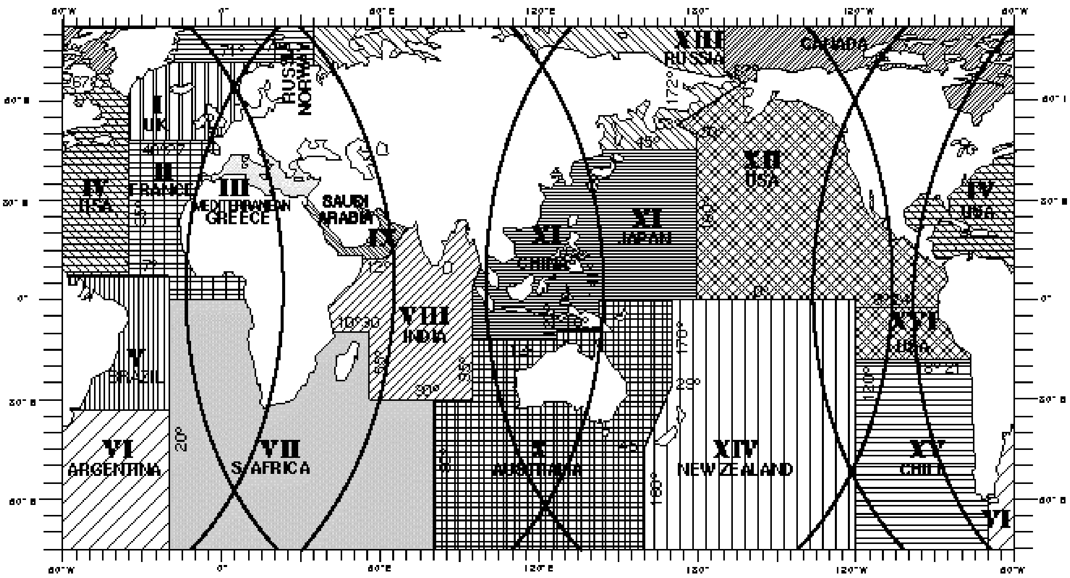


Figure 2. Division of the world's oceans into Metareas.

For specialized weather services and as additional information many kinds of graphical products may be developed. Such background information may:

- Clarify the meteorological situation by use of maps, images, observations etc. and thus make it easier to understand the situation.
- Give ideas to alternatives, possibly by using probabilistic forecasts based on EPS (Ensamble Prediction System).
- Include additional information which might be useful for planning purposes.

A single-entry access to met-ice-ocean data and products can not focus entirely on additional products for specialized services but must put the basic marine meteorological services at the front and harmonize with well established systems, such as GMDSS (Global Maritime Distress and Safety System) of the International Maritime Organisation.

1.3 Organisation of this report

This report describes the results of the first phase in the project: user requirement analysis and system design. It will form the basis for the development of the baseline version of the IWICOS prototype, and be used together with the user evaluation of the first test period to develop a revised design and subsequent implementation of the final IWICOS prototype.

In this first phase, the requirements from selected end users have been analysed to identify their needs for integrated met-ice-ocean information and how to present this information with state-of-the-art computer equipment. User requirements for ice information have been investigated in previous studies carried out in the EU funded IMSI project from 1997 – 1999 (ENV4-CT96-0361) and OSIMS project from 1997-1998 (ENV4-CT96-0329). The results from these studies have been supplemented with additional requirements for integrated met-ice-ocean products, which have addressed a wider range of users than only the ice community. E.g. the Icelandic user requirements survey has investigated the needs of representatives from, among others, the fishing fleet, tourist ships and harbour authorities. Also, some input to the user requirements study was given at the Design Workshop, by the invited users. The total set of user requirements established in WP240 are reported in Section 2, and has been used as input to the design of the IWICOS system.

Products for the selected user groups have been defined in WP210, and will be demonstrated in the baseline period. Section 3 describes these products, and ends with a summary of the product types that will come out of the project, and that the respective data providers will co-operate on.

Another important aspect of the IWICOS project, is the development of a common format for the selected products, which has been addressed in WP220. This format must include both metadata and data, i.e. both a description of the data/product as well as the measured, estimated or predicted met-ice-ocean parameters. The consortium has defined such a format on which all exchange of data and products between that partners will be based in Section 4.

A major effort in the design phase has been to develop a common system architecture for the baseline end-user and retrieval system (WP230). A layered architecture has been proposed, with a Production, Broker and Presentation modules as its main blocks. Section 5 reports on the defined architecture, and how each partner plans to implement this architecture in the baseline demonstrator.

Finally, conclusions from the design and user requirements study are presented in Section 6.

Product and parameter description is included in appendix A for all partner.

Cost and technical facts regarding different means of communication are presented in appendix B.

Some existing Internet services which may be related to IWICOS are listed in appendix C.

In appendix D the header structure of a file format used operationally when transferring image data to the icebreakers, is described. This header serves as an example of image metadata.

In appendix E, XML has been used to define the data produced by the Parametric wave model at FIMR predicting the wave parameters at some points in the Baltic Sea area. This serves as an example of using XML to describe model output data.

2. User requirements study

2.1 Background

In order to design a system for integration of meteorological, sea ice and ocean data, it is essential to know the requirements from the main users of this information, especially those operating in the marine environment. In previous projects the user requirements for sea ice information have been studied in the Baltic Sea, in Greenland Waters and the Northern Sea Route. A selection of representative users were contacted (Table 1), and they provided information about their current/potential needs for ice data, which areas are relevant, demands for near-real time delivery, etc. (Sandven et al., 1998a). The requirements for better ice information also implies that the meteorological and oceanographic data are better integrated with the ice data. The requirement for the IWICOS prototype can therefore be based on recommendations from IMSI and OSIMS projects, supplemented with information requirements for ice-free oceans. The first IWICOS Workshop, held at DMI 6-7 April 2000, also provided valuable recommendations for the IWICOS system.

The partners in the IWICOS project communicate regularly with end users. The conclusion of IMSI and OSIMS, where NERSC, FIMR, DMI and DTU participated, are used to define the user requirements in the IWICOS project. The Icelandic partners have conducted a specific user requirements survey in Iceland and the results of this survey are presented in this report. The requirements can be very different from area to area and may change when new products become available. However there are some basic requirements which can work as guidelines throughout the project. The idea of presenting ice information digitally including images and distribution of this information via Internet have been demonstrated with success in the IMSI project. This idea is the background for the IWICOS project.

2.2 Results from IMSI and OSIMS

Both IMSI and OSIMS explored the end users' requirements for ice information based on questionnaires, workshop discussions, analysis of technical capabilities and assessment of economic and safety aspects of marine operations. OSIMS was investigating the possibilities for introducing more satellite data in the European ice services for improving the general information level and quality of the products. IMSI was focused on exploitation of new microwave satellites and was developing and applying new and improved ice products to the benefit of the users.

One of the conclusions was that the most useful satellite data are SAR data and in particular Radarsat ScanSAR because of the good coverage and high spatial resolution. The cost of SAR data is a factor which limits the use of these data. However, IMSI was instrumental in developing operational use of SAR data for ice monitoring in the Baltic Sea and in Greenland waters.

Satellite imagery was during the operational tests in the IMSI project and is today relayed directly to end users. The work clearly showed what was possible with modern communication systems and the current satellite systems for ice monitoring to relay both charts, imagettes etc. to the navigators in action. These are very important issues to consider together with the user requirements (demands) because there may simply be a technical gap between what is requested and what can be delivered even with the best data available.

The actual quality of the ice information is also important for the users. Ice charts which are used by the majority of the users describe the ice situation with symbols, positioning the ice edges, ice types, ice concentration and ice features like bergs, strings, growlers, leads, cracks, ridges etc. on a map. In Greenland waters, for example, two types of ice charts are made, one type which the navigator will use navigating the ship with smallest possible impact of ice. For this type of charts the ice edge and features like strings and bergs are very important and must be positioned with greater precision than the ship radar range (4 nautical miles), while the classification of the ice covered areas can be done as an overview. The other type of charts are those used for entering the ice and navigating within the ice covered areas. In this type of chart the ice areas and the concentration must be positioned and classified with at least the precision of the ship radar range. Concentration and type must be classified with great accuracy. When the ice chart does not describe the actual situation with sufficient precision it is outdated. The time for a chart to be outdated depend on the area, weather and ice conditions.

The Baltic Sea, the Greenland/Icelandic waters and the Northern Sea Route are very different, both from environmental point of view and with respect to the type of traffic and marine operations. Some user requirements may be specifically related to a region while other requirements are general for the entire user community. The Baltic Sea has a seasonal ice cover lasting from weeks to half a year. For example, Finland has more than 20000 port calls per winter. The sea transportation represents normally 70-90% of the total transportation in the region, where 40% of that is during the winter and potentially in ice infested waters. Finland and Sweden are operating an ice breaker fleet in the ice season. This is done by actual ice piloting and by maintaining open leads along the most important ship routes. The Greenland ice is present throughout the year more or less, and the characteristics of this ice is such that navigation should be avoided even by ice enforced vessels. On the west coast there is a seasonal ice cover mixed with glacier ice represented by ice bergs, growlers and bergy bits. The east coast is dominated by an all year ice cover of multi year ice with origin in the arctic. The east coast ice is a mix of multi year ice glacier ice and seasonal ice drifting along the coast to the southern point Cape Farewell. There are no icebreakers in Greenland Waters and the conditions change rapidly. The ice in the Northern Sea Route is multi year and first year ice, which can be present year round. The ice cover is severe with ridging and thick multi year ice. Cargo vessels are piloted by ice breakers to maintain the traffic to and from the important mining and oil ports on the Siberian coast.

The users of sea ice information can be divided into three main types according to their different roles, responsibilities and problems to be solved.

User type 1 are people in direct contact with ice in their daily work and need ice information to operate ships safely and cost effectively in ice covered seas. Typical users are icebreaker captains, cargo ships captains or skippers on fishing vessels or oil platform managers, managers of coast guard vessels.

User type 2 are people who are responsible for planning and implementation of sea transportation, icebreaker convoys, offshore operations and other marine operations in ice covered areas. These people often work at land, but have responsibilities and give directions to the people working at sea.

User type 3 are national institutions responsible for collection of ice data and production of ice charts, ice forecasts and other ice products to be delivered to user type 1 and 2. They are customers of satellite ice data, but they are providers of final ice products to user type1 and 2.

Table 1. Users who have contributed to the requirements study.

Category	**User**	**Type**
National Ice Service	FIMR, DMI, Ice central in Greenland, German Ice Service	Public
National Weather Services	DMI, FMI	Public
Shipping Companies	MSC (Russia), RAL (Greenland), TF (Finland),	Commercial
Oil Companies	Nunaoil (Greenland/Denmark), Statoil (Norway) Neste (Finland)	Commercial
Offshore Industries	Kvaerner Masa Yard	Commercial
Other National Institutes	FMA (Finland), Danish Coast Guard, Greenland	Public
Other	Fishing vessels, Russian Oil Companies	Commercial

Topics that were discussed with the users included:

- Use of new satellite data
- Data collection
- Data integration and analysis
- Distribution to users
- Cost-benefit considerations

2.3 Baltic Sea

The Baltic Sea is a semi-closed brackish water basin located in the northern Europe between approximately 53° 50' - 64° 50' N and 09° 20' - 30° 20' E and connected to the Northern Sea through the Kattegat and Skagerrak. The countries surrounding the Baltic Sea are Finland, Russia, Estonia, Latvia, Lithuania, Poland, Germany, Denmark and Sweden. Some 85 million people live at the draining area of the Baltic Sea.

In the Baltic Sea some 80-90% of the foreign trade is marine transported. The total amount of cargo turnover in the Baltic Sea is more than 500 million tons, some 40% of which occurs during the winter. This makes the Baltic Sea the most heavily marine operated area in the world, where seasonal sea ice plays an important role in navigation. Number two is the Gulf of St. Lawrence in Canada with about 180 million tons transported annually. E.g. in Finland 90% of foreign trade is marine transported with annual turnover of over 80 million tons. During the winter months there are over 25,000 port-calls at the Finnish harbours and more than 30 million tons of goods are transported.

The transportation chain has become more effective and schedules have been tightened rapidly: goods must be transported in minimum time from producers to consumers. Schedules in marine transportation have also tightened. This means that customers are expected their goods transported very fast regardless of weather or ice conditions. Delays in marine transportation effect negatively to the whole transportation chain.

The ships need weather, sea ice and ocean information and forecasts for 1) effective time table planning, b) effective route planning, c) secure navigation conditions for ships and cargo and d) minimising for transporting costs.

The ships require a year around weather information and forecasts. This includes wind speed and direction, air temperature, precipitation, visibility and icing. The meteorological authorities are producing data and forecasts every 3-6 hours for next 24-48 h, which seems to fill in user requirements. Mostly users are receiving information at sea via Navtex, fax and occasionally by e-mail. Various kinds of weather forecasts in many scales are published in the Internet. Quality of these forecasts is varying and they are not normally capable to fill in the user requirements. Typical user in the Baltic Sea needs weather forecasts along the route for next 12-48 h. At the moment effective, integrated digital weather data analysis and route planning and display system for ships is rare or non-existing. There seems to be a common requirement towards tailored solutions integrating ship's data with weather and ocean data and forecasts.

The Baltic Sea weather is sensitive against the Northern Atlantic Oscilation. Especially the mildness and severity of ice season have a strong correlation to large scale atmospheric circulation. The Baltic Sea freezes annually and the maximum annual ice cover ranges from 12 to 100% of 420,00 km² being on average 218,000 km². The ice season begins in October - November and end in early June. Thus depending on the sea area and severity of ice season last from a few weeks (in the south) to six months (in the north). During mild winters, the sea ice causes navigation difficulties in Finland, Sweden, Russian and Estonia. In average and severe winters, ice affects all the Baltic Sea countries.

All the Baltic Sea countries have national ice services, which provide sea ice information emphasising their own territorial waters. Input data consists of ground truth (stations, harbours, ships, icebreakers), visual and/or digital air-born data (aeroplanes and helicopters) and satellite data (NOAA AVHRR, ERS SAR and RADARSAT SAR). Ice charts issued on daily basis are the most important and widely used output products of the ice services. Other output products are at least ice reports. Some services provide wider range of output products. E.g. in Finland ice drift forecasts, satellite images and SAR image classifications are delivered to a limited number of users at sea.

The output products are mainly delivered to users at sea via Navtex and fax. In Finland and Sweden also a joint network connects ice services, maritime administrations and icebreakers making possible to deliver e.g. digital ice charts and satellite images. In Finland also the ViewIce application on board ships is making possible digital product delivery from the ice service to ships.

If the shipping could be made more efficient, the shipping companies would achieve cost savings which could result in reduced price for transported goods. This would furthermore be beneficial for the national economy. The users in the Baltic Sea require very detailed and up to date information about the ice conditions. The users at sea need reliable, fast delivered sea ice information, which could used in ship's scale for route planning. Experts, like icebreaker captains, would like to have as much as possible the original data like satellite images in original resolutions. Ship captains on the other hand would like to have interpreted information, like classificated SAR data, digital ice charts, ice drift forecasts, etc.

The sea ice users in the Baltic Sea could be divided into tree classes. The first category of users consists of navigators operating in sea ice. This group requires detailed tactical information for the optimisation of the route. Category 2 is typically maritime administrations on land requiring strategic and to some extent also tactical information. Forecasts are an important issue especially for this group. Category 3 is the administrations at shipping companies making plans for the cargo ships. These plans are made weeks ahead but may of course be adjusted on shorter time scales according to the present ice conditions.

Table 2. Requirements for each user category in the Baltic Sea.

	User category 1: Ice navigation	User category 2: Planning and administration of ship traffic	User category 3: Export and import companies and producers and manufactures
Users	Vessels	Vessels, NMA, coast guard, navy	NMA, Companies
Coverage	Local	Regional	Regional
Spatial Resolution	100-1000m	1-10 km	>10 km
Time Delay	<2 h	2-24 h	>24 h
Type of Data	In Situ/forecasts	In Situ/forecasts/statistical	Forecasts/statistical
Ice Products	Charts, satellite images, forecasts	Charts, satellite images, forecasts. Statistical analysis	Charts, forecasts, statistical analysis
Delivery	fax, net	Fax, net	Fax, telephone
Satellite Data	AVHRR, SAR	AVHRR, SAR/no need	No need
Ice Drift	Forecasts +5 h Hindcasts -12 h	Forecasts +5 d -14 d	Forecasts +5 d - 14 d

Ocean data marine user requirements in the Baltic Sea consist of wave and water level data, products and forecasts. At the moment this data and products are mainly delivered to users at sea by Naxtex and fax. Digital information is rare. The users require hindcasts, in situ data and forecasts in digital format along the ship's route to be used in route planning. Resolution should be sufficient with the ship's scale and time steps suitable for next 24-48 h. Water level data is important near coast areas and fairways when entering harbours. Wave and swell information optimally should be integrated with ship's own navigation information and tailored for each ship individually.

2.4 Greenland Waters

In most Greenland waters surrounding sea ice is present all year round. The ice regime is characterised by predominately old multi-year ice along the east coast and the southern part of the West coast, and by predominately first year ice which forms in the Baffin Bay, off the West coast of Greenland.

Most of the ice in the Arctic Sea is several years old with an average thickness of 3.5-5 m. This ice flows through the Fram Strait and covers the entire east coast of Greenland most of the year. As the multi-year ice drifts southwards, the floes break into smaller pieces and are mixed with ice which is formed locally. During the melting season the thickness of the multi-year ice decreases from about 4-5 m in the Fram Strait to about 2 meters in the Cape Farewell area. In most years, old and small ice floes are present in the Cape Farewell area. At the seasonal maximum in March-June, the ice may reach 700 km up along the West coast. While most of the ice along the east coast originates from the Arctic basin, nearly all ice present in the Baffin Bay has been formed locally during the winter and is a considerably less threat to navigation. The thickness of this winter ice usually increases to a maximum of about 70 - 100 cm in April, when the ice covers the entire Baffin Bay leaving only the south-west coast of Greenland ice free in most years. Even more dangerous to navigation than the sea ice is the occurrence of icebergs and calved ice from the inland ice. Ice bergs may be found in all Greenland waters.

In Greenland waters the users have been categorised into 4 groups. 1) The ship traffic needing tactical and strategic information for navigation in this particular ice situation, 2) The exploration of natural resources will need almost the same information as the ship traffic only the exploration group will also require archived data considering cost and operation planning. Today both tactical and strategic planning involve ice and weather information but often as separate information layers. Consequently, users are interested in combining weather information and ice charts in a much more user friendly way. 3) The Offshore activities are particularly concerned about the threat of icebergs this will require very special and detailed information which will not only consists of ice bergs positions for a give time but also on drift forecasts. In general ice and ice berg forecasts will depend heavily on accurate ocean currents and wind forecasts. 4) Weather services require data with very large coverage like the entire Arctic but the spatial resolution may be coarse

The users are primarily commercial vessels passing Cape Farewell and local traffic, especially in West Greenland south of 69°N. Since no inter urban roads exist in Greenland, all traffic has to go by air or sea. Consequently, the local freight traffic carried out by ships is large compared to the relatively low number of inhabitants. (The ship traffic has been reduced from 500 to 300 port calls per year due to user of larger vessels.) In addition, fishing vessels are also using the ice information, in particular information about the ice edge position. In recent years information from the Ice Service is requested by a wide range of new users such as the increasing number of sea cruise ships and companies working with exploration of oil, gas and mineral resources. Ships navigating the Greenland waters may be divided into two groups with respect to ice information requirements, i.e. ships that need to go through the ice and ships which only need to circumnavigate the ice. It is also important to note that icebreaker assistance is not available anywhere in the Greenland waters.

The Cape Farewell area is the most important sea ice area since all ships to the major cities on the West coast need to pass this area. This region is often characterised by high seas, strong winds and low visibility, which together with the dynamically nature of the sea ice distribution, makes navigation very dangerous and difficult. Users therefore require timely weather and ice charts of this area. The ice charts must in particular contain timely information about the position of the ice edge. This means that in most cases the information should not be older than 6 to 8 hours. Information about the ice edge is often sufficient because ships will often only need to circumnavigate the ice. To meet this requirement 3-5 Cape Farewell ice charts must be issued every week throughout the year. This information is especially acquired by RAL cargo ships, but also fishing vessels and tourist ships use this information regularly. Detailed information about ice type and concentration in the Cape Farewell area is also important especially during the spring and summer month where ice may complicate or hinder approach to harbours along the southern part of the West coast.

During the summer information about the ice type and concentration is needed to approach harbours on the Eastern part of the Greenland coast. Since there is a limited number of port calls within a narrow time frame, the ice monitoring of especially these areas must be co-ordinated with the ships sailing plans. In these areas a ship will navigate using a combination of ice chart information and helicopter reconnaissance. The ice chart should therefore be as timely as possible to assist in navigation and planning of helicopter flights. In comparison to the Cape Farewell area, the ice information must indicate more than only the ice edge position, since the ship have to pass through the ice and detailed information about ice concentration and leads can be important. The information should be updated regularly while the ship is sailing within the ice edge. The calling of harbours on the North Western part of the coast is limited to the ice free period. Identification of the time of sea ice break up and closing is therefore important.

Navigating the Greenland waters without any ice information is dangerous and can cause much larger sailing times. If the ships are caught within the ice for days or weeks, the result may be damages to the ship and in the worst case loss of ship. RAL indicated, that without any information about the ice conditions the travel time may increase up to 24 hours, which is equivalent to approximately 15.000 ECU of extra costs. Furthermore, it can be anticipated that repair of damages to the ship will add to this figure. For passenger ships, cancellations due to lack of ice information may lead to additional costs because passengers are entitled to alternative transportation, i.e. by air. Furthermore, lack of inshore ice information could easily mean that a passenger ship could be locked in the ice for a period of days to weeks, leading to severe economic losses and potential damage of the ship. Offshore operations, such as seismic measurements are carried out by specially equipped vessels. They may work within or near the ice edge. During seismic surveys it is very important to have access to actual and accurate ice information for selection of potential areas of operation. Accurate ice information may therefore lead to significant cost reductions.

It is unquestionable that improved ice information accessible for the users will reduce the risk of accidents and economic losses. In particular, accurate and timely ice information is a prerequisite for safe operations of oil platforms, tankers and other vessels.

Table 3. Summary of users in Greenland Waters and their requirements for met-ice-ocean information.

Ice problem	User	Requirement for information
Ice edge position	RAL and other ships (e.g. tourist vessels) passing Cape Farewell while circumnavigating the ice. Fishing boats working outside the ice.	An ice chart (1:2.000.000) with the ice edge position indicated combined with wind and ocean currents. Information on Ice drift would be desirable. The chart should not be older than 6-8 hours.
Ice type and concentration	RAL and passenger ships which need to pass through the ice. Offshore operations performed near or within the sea ice.	An ice chart (1:2.000.000) where the ice type and concentration is estimated combined with wind and ocean currents. Information on ice drift would be desirable.
Free passage	Inshore route passenger ships.	A ship will need to contact the ice service (e.g. by telephone) to update information about present route conditions.
Ice extent	National weather service.	A daily map covering Greenland waters (1:10.000.000) showing where sea ice is present.
Ice concentration	Shipping companies and other users who want a general picture of the ice conditions around Greenland, e.g. for planning purposes.	A weekly updated overview map (1:10.000.000) covering Greenland waters.

2.5 Northern Sea Route

The Northern Sea Route (NSR) is the world’s longest sailing route in ice-covered waters (Figure 3), extending from the Barents Sea in the west to the Bering Strait in the east. The sailing route is of vital importance for the national Russian transport system, because it includes many rivers and inland waterways connected to the Arctic Ocean. The ice conditions restrict sea transportation which requires ice class vessels as well as icebreaker assistance throughout the year. In summer there is traffic in the whole Northern Sea Route, whereas in winter it is limited to the western part between Murmansk and the Yenisei river.

An extensive ice monitoring and forecasting service has been built up in Russia over the last 50 years with a main objective to serve the icebreaker fleet and the cargo transport in the Northern Sea Route (Smirnov et al., 1998). Use of space-borne SAR has not yet been part of this service until the start of the ICEWATCH programme (Johannessen et al., 1996, 1997a, 1997b). The users of ice information are primarily the shipping companies responsible for the cargo transport as well as the supporting icebreakers. In addition, oil companies, and their supporting consulting companies need ice information to plan offshore operations. Research expeditions have temporary needs for near real-time sea ice information in order to facilitate and optimise their research field programs.

Three Russian shipping companies are responsible for most of the transportation in various parts of the Russia Arctic. The largest is Murmansk Shipping Company, which is responsible for the governmental icebreaker fleet, operating mainly along the western parts of the Siberian coast and in its rivers. The fleet consists of about 10 icebreakers and several ice-strenghtened cargo vessels. The Northern Shipping Company and the White Sea - Onega Shipping Company are operating in the White Sea and on the lakes and rivers between the White Sea and the Baltic Sea.

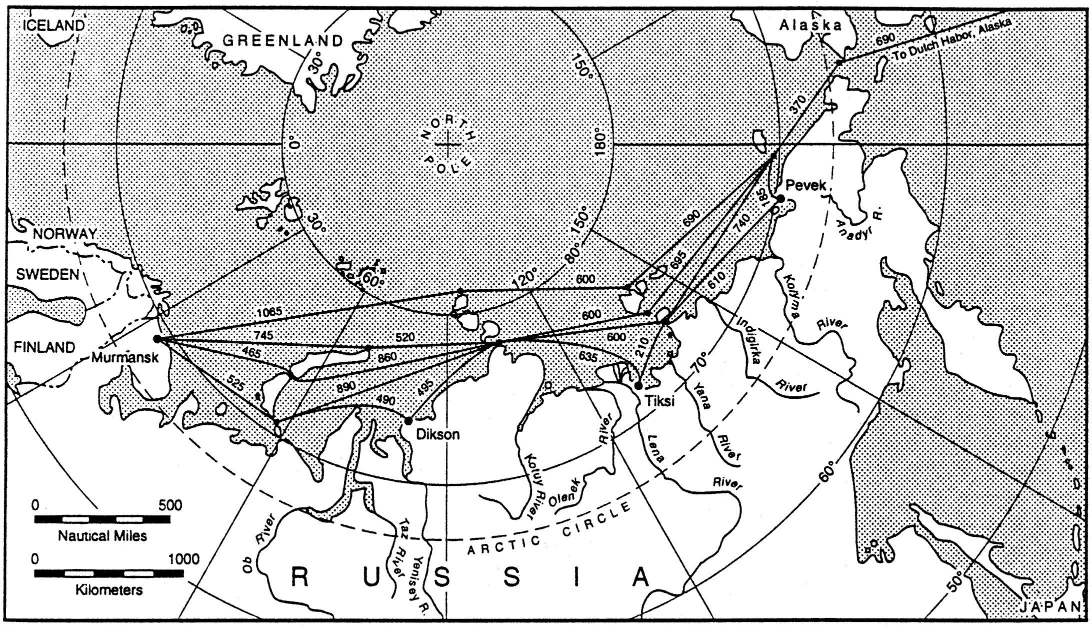


Figure 3. Approximate distances, in nautical miles, of the various route segments between Murmansk and Dutch harbour (Mulherin 1996).

Sea ice information is required in all seasons, because of the raise in transport operation in parts of the Northern Sea Route throughout the year. The purpose of ice monitoring and forecasting is to optimise the ship operations, as well as to obtain the best sailing routes and minimise the risk for damage on icebreakers and escorted vessels. This requires detailed information on many sea ice parameters: ice edge location, ice type (or ice age) classification, ice movement, coastal polynyes, fast ice, shear zones, leads and ice roughness.

The most important ice information produced is the comprehensive ice maps (CIM) generated by the Russian ice service (Smirnov et al., 1998). These maps are based on several types of satellite data (NOAA AVHRR, Okean SLR, Meteor, etc.), ship observations, meteorological and oceanographic data. Use of aircraft surveillance with SLAR and SAR was the most important source of data for many years, but now this monitoring has been cancelled due to the difficult financial situation. Use of satellite SAR (ERS-1 and ERS-2) in ice monitoring of the Northern Sea Route has been tested in several demonstration projects since 1991 (Johannessen et al., 1997a). The use of SAR data will clearly be beneficial to improve these maps and provide more details of the ice cover. The most promising technique is direct use of SAR data onboard icebreakers in tactical ice navigation where images are transmitted to the icebreakers in near real-time.

Low Resolution Images (LRI) contain information, not included in ordinary ice maps, needed by the ice pilots onboard the ships. In this respect there is a need for education and training of the ice pilots in order to perform the correct onboard interpretation of the ice information in SAR images. For practical use the ERS SAR coverage is very limited with respect to the ice monitoring, although when available the data are efficient and optimal for planning of the tactical navigation.

The mapping of sea ice in the Northern Sea Route is defined at three different levels: (1) strategic ice reconnaissance; (large scale), (2) operative ice reconnaissance; (regional scale), and (3) tactical ice reconnaissance; (local scale), which serve different objectives and tasks for the users.

Ice data for support of navigation in the Northern Sea Route must be obtained at strategic, operative and tactical levels, defined by different spatial and temporal scales as shown in Table 4.

The data must satisfy strategic, operative and tactical ice charting, which means that data must be available at different spatial and temporal scales. The most challenging requirement is to provide tactical ice information from satellites 2 -3 times per day for each convoy working somewhere in the Northern Sea Route. This would require 3 - 4 satellites, and the resolution of the data should be 100 m or better. Direct downlink to ships will be necessary to avoid time delays.

Table 4. Summary of requirements for sea ice information for ice navigation in the Northern Sea Route.

	Strategic	Operative	Tactical
Users	User category 1: NSRA, User category 2: MOH	User category 2: MOH, icebreaker captains	User category 2: icebreaker captains
Coverage	Global (the whole NSR including the Eurasian sector of the Arctic Ocean	Regional (Murmansk - Dikson)	Local
Spatial resolution	~ 10 km	< 1 - 2 km	< 100 m
Required repeat period	10 days	2 - 3 days	< 100 m
Products	ice charts with scales 1 : 7 000 000 1 : 5 000 000 1 : 2 000 000	ice charts with scales 1 : 7 000 000 1 : 5 000 000 1 : 2 000 000	ice charts with scales 1 : 500 000 1 : 200 000
Requirement for archived data	very important for statistics	important for interpretation of satellite images	not required
Requirement for real-time data	not required	important within one day	important within 2 - 3 hours
Requirement for ice forecast	long term forecast: monthly and seasonal forecast	forecasts up to 7 days	short term forecast

2.6 Synthesis of met-ice-ocean information requirements

For tactical operations which includes ship navigation users, offshore activities etc. Radarsat ScanSAR data is the data type at the moment that will meet the requirements in term of resolution and coverage (by early 2002 ENVISAT will provide data with similar or better qualities). Ice features like ridges, leads, cracks, floes, growlers and ice bergs must be resolved and either marked on the ice chart or communicated to the navigator with image information. NOAA-AVHRR data whenever cloud free qualify for producing tactical ice charts. Aerial reconnaissance is also a method for acquiring tactical ice information. Tactical information should provide the navigator with detailed up to date information about the ice conditions in a local target area. The navigator onboard the ship have a ship radar with a range of maximum 4 nautical miles (concerning sea ice cover) and will be able to navigate according to the radar within this radius. The tactical ice information have to provide the navigator with ice information with sufficient accuracy and overview for him to navigate smartly and safely.

The data requirements for strategic ice information are less strict in terms of spatial resolution but ought to have a broader coverage. The data type which is suitable for strategic ice information is Radarsat ScanSAR, NOAA-AVHRR (and satellites with similar qualities) and to some extent SSM/I. Strategic information should provide the navigator onboard the ship or the ship route planning administration with an overview type of information that will enable the navigator to chose the fastest and least troublesome route trough or around the ice. The navigator must be able to recognise ice features like ice edges ice type boundaries read from the information within the ship radar range.

Ice information for weather prediction models, and climate research needs global coverage (or Arctic). The data type that will meet the user requirements for this type of ice information is DMSP-SSM/I and ERS Scatterometer data or similar data types.

The focus in IMSI and OSIMS was on user requirements for ice information, and especially what new information could be extracted from satellite data. However, users operating in the three selected regions, i.e. the Baltic Sea, the Greenland Waters and the Northern Sea Route, also need meteorological and ocean parameters, both in the ice free period and during harsh winter conditions. Some of these could also be derived from satellite data, or their accuracy improved by assimilating satellite data into an ocean or weather forecasting model. Table 5 summarises the role of satellite data in the process of obtaining met-ice-ocean parameters.

Table 5. The role of satellite data to retrieve met-ice-ocean parameters.

Main ice parameters	Role of satellite data
Ice area and ice edge position	SAR detects different ice types with high spatial resolution, cloud and light independence. Passive microwave radiometers distinguish between open water, first year ice and multi year ice, with lower resolution. The ice edge position can be marked with a precision of 100-1000m
Ice type development New ice Young ice First year ice Multi year ice Ice edge	SAR parameters with impact on ice classification: incidence angle, frequency, and polarisation. Backscatter values from open water is highly dependent on the current sea state. Rough sea state gives a higher backscatter than calm sea state. SAR backscatter from grease ice is very weak because of damping from surface waves. The edges of the pancakes has high backscatter. Ice edge can be determined by all sensors The ice type area can be located with 100-10000 m accuracy and a concentration accuracy of 1/10.
Ice forms and features Floe size Deformation Leads and Polynyas Ice bergs / Growlers Snow cover on ice	SAR is the most useful instrument. It is sensitive to surface roughness. High spatial resolution. Penetrates the snow cover, except in the summer season when the snow is wet. Ice features can be located with an accuracy of 100-1000 m.
Ice dynamics	AVHRR and SAR are used to identify fast and drifting ice. SAR has the best capability to estimate ice velocities, because ice features can be recognised. The main problem with SAR is to get large enough coverage at regular time intervals to get representative data sets.
Ice dynamics	AVHRR and SAR are used to identify fast and drifting ice. SAR has the best capability to estimate ice velocities, because ice features can be recognised. The main problem with SAR is to get large enough coverage at regular time intervals to get representative data sets.
Weather forecasts Wind (10 m) Air Temperature (2 m) Pressure (mean sea level) Waves	Satellite data such as AVHRR (SST), scatterometer (wind) and altimeter (wave height) are already used as input to operational weather forecasting models.
Ocean winds Wind (surface)	Scatterometer, altimeter, SAR and SSM/I can be used to derive wind at the sea surface, at different levels of spatial and temporal resolution. SAR can give the best spatial resolution, but has lowest temporal revisit frequency. The other instruments listed above give a better temporal coverage, but at a much coarser spatial resolution.
Ocean temperatures Sea surface temperature	AVHRR and ATSR can be used to derived SST, provided that cloud conditions are favourable. NOAA's AVHRR spatial resolution is about 1km (or coarser), but these satellites provide daily coverage (or better) of the areas of interest.
Ocean waves Significant wave height Wave data	The altimeter can be used to obtain significant wave height, with a resolution of about 20 km. The temporal frequency will vary with the orbital patterns of the satellites. The ERS-2 satellite provides wave data from SAR wave mode data (imagettes) for every 200 km whenever the satellite is over an ocean.
Ocean current Depth integrated current	The altimeter provides an estimate for average ocean circulation through sea surface level anomalies.
Ocean salinity Surface salinity	The are currently no satellites that provides this parameter, but ESA is planning a satellite called SMOS, which will use a passive microwave instrument to obtain sea surface salinity. The SMOS satellite is planned launched in 2004.

The processing of SAR data is at the moment the major technical drawback for fulfilling the user requirements for tactical information. The users require information which is maximum 2 hours old. For example the RADARSAT processing takes approximately 2-4 hours plus the data transfer time from the receiving station to the ice analysts. The ice analysts need approximately 1-2 hours for analysing the situation. It is possible to use satellite data for production of ice information that largely satisfies the user requests, even if the requirements for time delay cannot be met with the current operational satellites. The IWICOS project will need digital and very flexible met-ice-ocean data combined from various sources. Satellite data will play a major role in product generation, as will operational numerical models.

Table 6. Summary of user requirements for the Barent Sea, Greenland Waters and the Northern Sea Route.

	Tactical	Strategic	Planning/Research/Weather
Users	Ships, offshore, construction, ice breakers, exploration	shipping planning administrations, ships, offshore activities, ice breakers, exploration	Research, offshore, exploration, operational numerical weather forecast models
Coverage	Local-regional	Regional	Global (Arctic)
Spatial resolution	100-1000m	1-10 km	>10 km
Time delay	2- hours	2-24 hours	2 - >24 hours
Data type	SAR data NOAA-AVHRR and similar Aerial reconnaissance	SAR data NOAA-AVHRR and similar Aerial reconnaissance DMSP-SSM/I and similar	DMSP-SSM/I and similar
Communication	Satellite communication, radio, fax, mobile phone, Internet	Satellite communication, radio, fax, mobile phone, Internet	Internet
Satellite data	SAR data NOAA-AVHRR and similar	SAR data NOAA-AVHRR and similar DMSP-SSM/I and similar ERS-Scatterometer and similar Altimeter	DMSP-SSM/I and similar ERS-Scatterometer and similar Altimeter
Ice products	Ice analysis/ice chart Imagettes Automatically generated classification product	Ice analysis/ice chart Images Automatically generated classification product	Gridded data Automatically generated classification product
Ice forecast	Short term forecast	Short to long term forecast	Long term for climate prediction. Short term filling gaps between an already regular coverage.
Weather products	Wind, SST and/or wave height measured by buoy networks or obtained from satellite data	Wind, SST and/or wave height measured by buoy networks or obtained from satellite data Daily and weekly means, standard variation and extrema	Gridded data Climatological data
Weather forecast	Short term forecast	Short to long term forecast	Long term for climate prediction. Short term filling gaps between an already regular coverage.
Ocean products	Instantaneous wind, SST and wave height measured by buoy networks or obtained from satellite data Sea level from buoy networks and/or numerical models	Instantaneous wind, SST and wave height Sea level measurements and predictions Daily and weekly means, standard variation and extrema	Gridded data Long term statistics
Ocean forecast	Short term forecast	Short to long term forecast	Long term for climate prediction. Short term filling gaps between an already regular coverage.

2.7 User requirements study in Iceland

The user requirements, which are presented in this section, are based on IMO's knowledge of the Icelandic market through year-long experience and co-operation with users of weather, ocean and sea-ice information. These requirements are in many respects different from the other study areas.

The user groups in Icelandic waters:

- fishing fleet
- cargo vessels
- research vessels
- tourist ships
- yachts and pleasure boats
- harbour authorities

For simplification, one can divide the users into two main categories that have slightly different needs for sea ice information.

The first category consists of ships that are not ice-strengthened and wish to avoid all contact with ice if possible. They can experience difficulties when there is even a very little amount of ice near the coast. This category will only need sea ice information when the ice is close to the coast, and then the information must be detailed enough for them to decide whether the sailing route off Horn (NW Iceland), the most critical area for navigating around Iceland concerning sea ice, is navigable.

The second category consists mainly of fishing vessels in the Denmark Strait and the Iceland Sea that primarily operate in open water but do also tend to fish near the ice edge or in-between ice bands in the marginal ice zone. This category needs a great amount of data and on a more regular basis, preferably every day, for the fishing grounds off North and West Iceland.

User opinion:
During a computer seminar (MaxSea) at Radiomiðun in January 2000 a few captains were interviewed. The captains came from a trawler and long liners. After giving them an introduction of the IWICOS project the weather information package, which is included in Radiomiðun’s Service Bank, was discussed.

The captains all expressed their interest in having this type of information transmitted to their vessels wherever they are. It was mentioned that ice information service had improved after the IMO started to send information over the Navtex broadcasting system. None of the participants had seen the weather forecast as it is presented in MaxSea, but they were impressed. Five days weather forecast showing wind, pressure and sea temperature was presented.

The captains have a basic knowledge of the Internet and they could clearly see the benefits of sending packed vector data to the ships, instead of raster charts. Their ships all have NMT mobile telephones and the trawler has an Inmarsat C terminal.

The captains did not have a strong opinion on how weather, ocean or ice forecast could be presented in detail, but they were impressed with the way the weather forecast was presented in MaxSea and were interested in using it.

On June 13th, two meetings were held at the Icelandic Meteorological Office (IMO) with representatives from the National Association of Small Boat Owners (NASBO) and from the Federation of Icelandic Fishing Vessel Owners (FIFO). Both groups are active users of weather, sea-ice and ocean data but, as it turned out, their requirements for information and media are very different.

An extensive user survey is planned during the design period where representatives from the different user groups above will be interviewed.

Both meetings started with a thorough presentation of the IWICOS project, its background, methods and objectives. Subsequently the attendees discussed future possibilities and needs as regards environmental information and broadcast options.

The main results of the user study so far can be summarised as follows:

- NASBO uses mainly Text TV and IMO's Automatic Phone Service in the morning to get weather related information, before deciding whether to go out to sea or not.
- FIFO uses MaxSea and/or the Navtex system to get weather, sea-ice and ocean information, depending on the equipment on board. FIFO also gets weather maps transmitted from Northwood by radio-facimile.
- The new Automatic Reporting System for Icelandic Vessels was discussed at the meetings. Both NASBO and FIFO members are pleased with the system and think it has improved safety at sea greatly. The possibility of using this system to send weather information to land was discussed at the meeting, but this topic needs further research.
- Both NASBO and FIFO representatives encouraged the IWICOS group to carry out an extensive user requirement study amongst seafarers, and they offered to be of assistance throughout the study.

2.8 User requirements from the design workshop

Participants from the user community:
Fritz Ploug is the Captain onboard the supply vessel Kista Arctica from the Royal Arctic Line. The ship is enforced to ice class 1 and has icebreaking capabilities. Each summer Kista Arctica sails along the Greenland East Coast where it needs specialised ice information. DTU and DMI have earlier participated in projects providing information to Kista Arctica.

Palle Eriksen is currently positioned at DMI where he is a sea ice specialist and point of contact for the marine users. He is still serving part time in the Greenland Ice Patrol and is First Mate on board the Arctic Umiaq Line passenger ships sailing along the West Coast of Greenland.

Jesper Theilgaard, senior forecaster and responsible for DMI's worldwide weather routing service for ships.

Gudmundur Hafsteinsson, responsible for Icelandic Meteorological Office's weather forecast

Kristjan Gislason, director of Radiomidun and developer of MAXSEA, which is an information system for fishing vessels which includes met-ice-ocean information. Radiomidun's MAXSEA system is a main distribution channel for digital data to fishing vessels.

Hans Valeur, retired dircetor of DMI's ice service. He has 40 years experience in building up the operational ice monitoring service in Greenland.

Statements from the users:
Fritz Ploug: Combined weather chart and ice chart would be attractive. The current information is not digital and can not be combined directly. Subscription to data is a good idea and is basically what has already been tested at Kista Arctica.

When sailing in the heavily ice infested waters along the Greenland east coast SAR imagery and digital ice charts have been very valuable for the navigation of Kista, the last couple of years fog and bad weather has often made it impossible to use the reconnaissance helicopter onboard.

The transfer of data is done via Inmarsat B even above 70°N at rates of 60kbyte/min (~28Dkr). Communication at elevation 0 is possible with Inmarsat from Qaarnaq and Danmarkshavn (~77°N).

For actual ship routing, why give more information than just the text message? It is basically all the captain needs to know.

Palle Eriksen: Concerning the communication cost. Navigating a ship is extremely expensive, saving half an hour by an optimised route could easily cover the expenses of both communication and first class meteorological and oceanographic information. However when a ship is operating many interests want to gain a piece of the cake. The owners of the ship have to be very tough when negotiating all expenses to make their business profitable. Even though the cost of communication may seem like peanuts it is after all an expense.

Jesper Theilgaard: All new data which can contribute to a better routing model will be useful, especially the inclusion of ocean models will be important. Wind, wave and current forecasts are the main elements in the routing model which calculates recommended speed and sailing route. The distribution of information to ships in graphical form instead of plain text messages is planned, and the efforts in IWICOS to develop cost-effective techniques for transmission of graphical information to ships is most welcome.

Gudmundur Hafsteinsson: Improvements in weather service requires primarily more accurate forecasts, but also better presentation methods which are dedicated for the specific users. It is hoped that IWICOS can contribute to better presentation techniques for weather and ice forecasts as well as to improve the quality of the forecasts by facilitate more use of satellite data.

Kristjan Gislason: The philosophy of MAXSEA is to give fishermen access to all relevant data through a single system which is easy to operate on a fishing boat. The integration of met-ice -ocean data, planned in IWICOS is therefore very much appreciated. New data products in compact, digital form, developed in IWICOS, can be distributed to ships via MAXSEA which is used by 3500 fishing boats (close to 500 in Iceland).

2.9 Recommendations for IWICOS

Based on previous user requirements studies and user involvement during the first phase of the IWICOS project the following recommendations have been identified:

- IWICOS should recognise that the marine user community may have different needs for information, may work in different regions and have different educational background.

- The IWICOS system must be able to combine information from different sources in a flexible way. Consequently, it should be possible to construct user defined displays and combinations of information.

- IWICOS should provide an integrated system enabling users to access and display all information with one system. It is important that users do not have to worry about sources of a given information layer and formats . Today, much of the information already exists, but must be collected from different sources and may exist in different forms that obstruct easy combination of information layers from different sources.

- It is important that the IWICOS system has a user friendly interface so difficulties with understanding and using the system will not obstruct the application and dissemination of the system. Therefore the user interface must be developed by means of known industry standards or public domain tools.

- IWICOS should aim at adopting existing standards for data presentation, e.g. standard colour coding of ice charts and standard symbols for presentation of meteorological information and ensure source independence and seamless display of data from different sources.

- IWICOS must disseminate products using standard technologies and standard data exchange formats.

- IWICOS must acknowledge the limitations of marine communication systems and the cost of using them and must adopt methods to effectively handle these problems.

- IWICOS should provide a range of products with different levels of information, aimed at different user groups. In both demonstration periods a representative set of free products should be prepared and advertised through the IWICOS web site, to raise awareness of the service and allow for a wide audience to give feedback on the products and IWICOS prototypes developed.

- The cost of the met-ice-ocean products is another important aspect in the end-users' evaluation of IWICOS. Some products will require high-priced input data and/or a significant amount of processing and therefore be expensive to generate, while others may be produced by means of low-cost input data and simple, automated processing tools. Whether or not a product is to be delivered in near real-time will also have a large impact on its cost. As information needs will differ between various user groups, and also depend on the type of activity carried out, the user should be able to select and change the level of service requested to best match the current situation.

3. Product plan

The term ***product*** means that input data (e.g. a satellite image) undergoes a processing phase (e.g. radiometric and geometric corrections, followed by ice type classification) and a presentation phase (plots, visualisations, etc.) before the data are delivered to the users. Hence, a product may be both the actual dataset (measured, analysed or forecasted) delivered to the end-user, as well as the facilities for presenting it in the IWICOS End-User System.

3.1 NERSC

3.1.1 General products to be developed

The following products will be developed by NERSC for demonstration in the baseline version of the IWICOS system:

1. Near Real Time products:
    - SSM/I ice concentration contours (*)
    - Met model simulations (*)
    - Sea ice motion from satellite data (*) and by combining satellite and model data
2. Archive products:
    - SAR quicklook images
    - SAR quicklook images combined with ice concentration from SSM/I
    - Interpreted SAR images (o)
    - SAR ice classification maps (o)
3. Forecasting products:
    - Ice forecasting using a coupled ice-ocean model

Products marked with (*) have been partially tested during the Arctic Ocean 2000 demonstration on Internet, but will need some customisation in order to be included in an IWICOS presentation system.

Products marked with (o) are "optional", i.e. a small number of examples will be prepared from historical data. During the baseline period, the forecasting products will be tested using historical data. In the extended phase, the aim is to demonstrate these products in near real time.

Required input from the other IWICOS partners:

- Met.data from DMI for an area in the Arctic Ocean.
- Ice motion algorithms from DTU.

Required input from other NERSC projects:

- Ice-ocean model data from the Modelling and Data Assimilation group.

The clients will be Java-based thin clients for users with medium/high speed network connection. All products will be embedded in HTML to ensure that they can be read by standard web browsers like Internet Explorer and Netscape.

Sample products (including meta-data) will also be made available through a prototype broker for exchange with other IWICOS partners. These products will be in stored in the IWICOS format, which is described in Section 5.

During the extended phase, NERSC plan to develop the following products:

- Offline database of monthly oceanographic data from climate models for the Arctic Ocean, the Nordic Sea and the Barents Sea. Model output will be made available from other NERSC projects.
- Ice dynamic data sets from time series of SAR images in combination with meteorological forcing fields. These datasets will be important for the validation of the ice forecasting model.
- Further enhancement of the ice forecasting products, which will be initially tested in the baseline version (last baseline product listed above).
- Examples of new met-ice-ocean products developed in cooperation with DTU.

Design of the content and presentation form of these, however, will not be undertaken until the start of extended phase. Then, end-users have provided feedback on the baseline products, including input on how they would like these products to be improved and what new products they would like to see demonstrated in the extended phase.

3.1.2 Data sources and parameters

Parameters (and products) that will be available for the IWICOS client system from NERSC are listed in Table 7. The given temporal frequency is assuming that the respective SAR sensors are always turned on for the area of interest.

Table 7. Overview of NERSC products and parameters.

Name	Parameter(s)	Units	Spatial resolution	Temporal frequency	Origin
Sea ice	Ice edge	None. (1)	Horizontal: 25 km from SSM/I; 100 m from SAR. Vertical: N/A	SSM/I: daily SAR: variable (depends on availability)	SSM/I or SAR
Sea ice	Ice concentration	Per cent	25 km	Daily	SSM/I
Sea ice	Ice type	WMO ice type code	100 m	SAR: variable (depends on availability)	SAR
Sea ice	Ice motion	Km	Horizontal: 25 km from SSM/I, 100 m from SAR, 1 km from AVHRR Vertical: N/A	SSM/I: daily SAR: variable (depends on availability) AVHRR: daily (provided cloudfree conditions)	SSM/I, SAR or AVHRR
Remote Sensing	SAR images	db	Horizontal: 100 m from SAR Vertical: N/A	SAR: variable (depends on availability)	SAR
Sea ice	Ice chart			Daily, weekly, biweekly, depending on user request	(2)
Sea ice	Combined SAR image and SSM/I ice concentration product		Horizontal: 25 km from SSM/I, 100 m from SAR Vertical: N/A	SAR: variable (depends on availability)	SSM/I and SAR
Sea ice	SSM/I data combined with coupled ice-ocean model		Approx. 25 km	Daily	SSM/I and a coupled ice-ocean model.
Sea ice	Ice dynamics data set from time series of SAR data	Km (ice motion)	Approx. 100-500m	Variable (depends on availability of SAR)	SAR
Ocean	SST	Deg.C	(3)	(4)	Oce. model
Ocean	Salinity	ppt	(3)	(4)	Oce. model
Ocean	Currents	m/s	(3)	(4)	Oce. model
Ocean	Wave heights	m	(3)	(4)	Oce. model
Meteorology	Wind speed Temperature Pressure	m/s Deg.C Pa	0.45 (G45) degrees or 0.15 (N15 or E15) degrees	6 hours up to +48 computed daily at 00 and 12	DMI HIRLAM

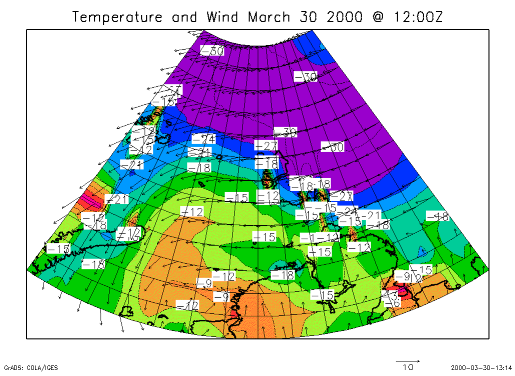
(1) The ice edge is usually defined as a certain percentage of ice concentration, e.g. 50%.
(2) All available sources of Satellite data and in situ observations.
(3) Resolution depends on model set up. Typical values range from 1 to 25 km.
(4) Varying from hours to weeks, depending on target user group.

3.1.3 Data presentation

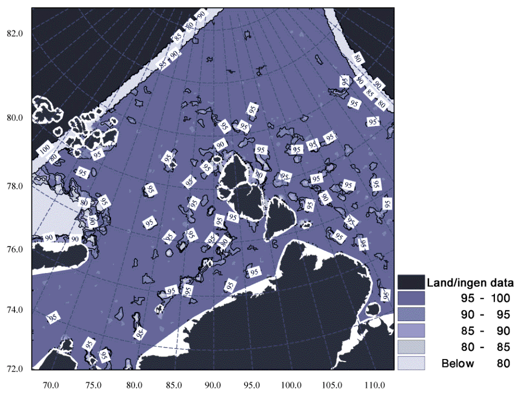
Table 8 describes how NERSC plan to present their met-ice-ocean parameters in their End-User System. Then, some of the current NERSC products are shown in Figure 4. These were demonstrated on Internet during the Arctic Ocean 2000 Expedition (see e.g. AO2000 web page at http://sofia.nrsc.no/ao2000/).

Table 8. NERSC data presentation.

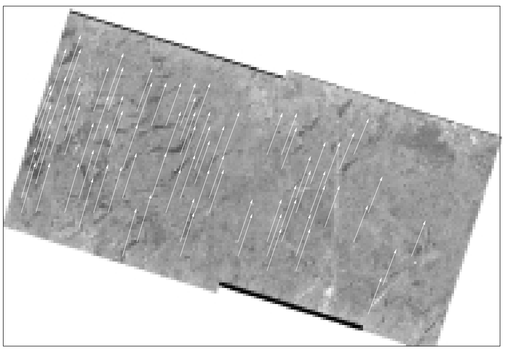
Category	Parameter	Presentation form
Meteorology	Wind (speed/direction) Temperature Pressure	Arrows Contour (colour coded) Contour
Ice	Ice edge Ice concentration Ice motion Ice type Ice chart SAR and SSM/I ice concentration SSM/I ice concentr. and ice-ocean model Ice dynamics	Contour (50% ice) Contour (colour coded or greyscale) Arrows Image (colour coded) WMO/Russian egg code Image with contours overlaid Contours Arrows
Ocean	Sea surface temperature Salinity Current Wave heights	Contours (colour coded) Contours (colour coded) Arrows / Contour Contours (colour coded)
Remote Sensing	SAR	Image (greyscale)



(a) NCEP weather forecast



(b) SSM/I ice concentration


(c) SAR 14 March 2000 with ice motion

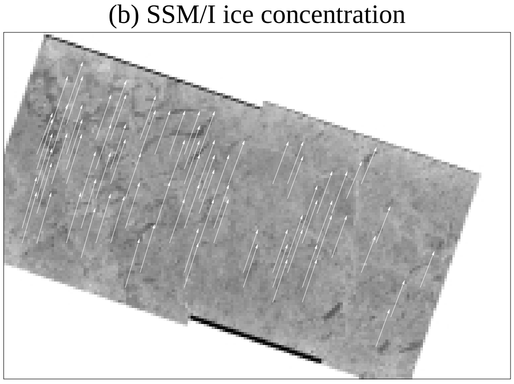

(d) SAR 17 March 2000 with ice motion

Figure 4. Examples of NERSC products demonstrated during AO2000.

3.2 FIMR & VTT

3.2.1 General products to be developed

General products to be developed under IWICOS, will be done in two phase: first baseline products and latter on extended products.

The following baseline products are planned to be developed in baseline version of IWICOS system in the Baltic Sea by the FIMR:
Real-time products:

- Ice charts over the Baltic Sea in WMO ice symbols. Normal coverage will be north of latitude 56° 45' N. When ice exists further south the whole Baltic Sea will be covered.
- Satellite images from NOAA AVHRR and RADARSAT SAR covering north of 57°. RADARSAT SAR images will be mainly delivered only to the use for Finnish icebreakers and only a small number of images will be delivered to merchant vessels. RADARSAT SAR images will be available only if annual negotiations between RADARSAT International and the FIMR are successful. Areas of interest will be cut out from the original images and send to users at sea.
- SAR image classifications for 100 screens a season will include open water, level ice and deformed ice.
- Water level data product showing data and trend at the Finnish coast for last 24-48 h will be developed by the end of year 2000. At the first stage this will be put into IWICOS web pages. Next stage will be to develop further the output format for the users at sea.
- Wave height and direction data for last 24h and forecasts for next 24h will at the first stage put into web pages (year 2001). During the next stage these will be to develop to fit the output format of users' applications for the users at sea.

Weather forecast products for the Baltic Sea will be in responsible of the DMI.

The following products are planned to be develop during the extended phase by the FIMR:

- Improved SAR image classifications by adding ice thickness into classificator, resolution will be improved down to ~100*100m, number ice classification classes will be reduced down to ~ 3
- Ice forecast presentation will be improvement by vector based digital charts
- Wave forecasts presentation will be improved by vector (?) based digital charts
- In situ and hind cast water level presentation output will be improved.
- ‘Forecasted satellite images’ will be implemented by applying ice drift forecast information to satellite images on the server side as well as on the client side. This will be implemented mainly by VTT.

VTT will work together with FIMR in product development.

3.2.2 Data sources and parameters

Parameters that will be available for the IWICOS client system from the FIMR are listed below. Parameters in details could be found in Table 9.

In situ ice conditions:

- Remote sensing data
    - NOAA AVHRR data, normally channels 2 and 4, 8-12 passes a day, resolution 1 km, covering the Baltic Sea
    - RADARSAT SAR, 100 ScanSAR Narrow images in a winter, coverage 300*300 km, resolution 100*100 m. Images are also classified by an algorithm into 5 classes in 500*500 m resolution: open water, thin ice, thick ice, deformed ice, fast ice
- Air-borne data
    - Fixed wing reconnaissance flights, every 10 days between October and February, coverage north of 59° N, visual observations
    - Reconnaissance flights by icebreaker based helicopters, when needed, typical coverage 300*300 km, visual observations, ice thickness measurements
- Ground truth

- Ice observation station reports and charts, once a week, ice boundaries, ice structure, ice and snow thickness, ice concentration, coverage 20*20 km – 100*100 km
- Icebreaker reports, along the route, several a day, ice boundaries, ice-edge, concentration, ice thickness, deformation, leads, ice pressure, ice drift

In situ SST:

- Ships' measurements, along the route in the Baltic Sea, >20 ships, normally measurement every half a degree latitude and longitude
- Stations, coastal stations and automatic light houses, daily measurements
- October-February reconnaissance flights by fixed wing plane, IR measurements along the track, normally north of 59 ° N
- NOAA AVHRR data, several passes a day, used when cloud free conditions and calibrated with ground truth data

In situ water level:

- 13 Finnish gauge stations along the Finnish coast, measurements 4 times an hour, operational accuracy <1cm, online recording at FIMR.

In situ wave height:

- 2-3 operational wave riders, data of wave direction and height, measured 2 times an hour, measurements are delivered via Argos to FIMR

Ice drift forecasts:

- Operational +72 h ice drift forecast, operational normally Dec.-May on daily basis, input data from Finnish ice charts (ice concentration and thickness) and ECMFC wind forecasts in 40*40 km grid. Standard outputs at the moment are ice drift direction (degrees), ice drift speed (in 10ths of knots), equivalent ice thickness in +0 h, +6h, +12h, +18h, +24h, +36h, +48h, +60h, +72h. At the moment forecasts are sent to users in text format: forecasted ice drift today, in the evening, tomorrow morning, tomorrow evening, day after tomorrow. Verification of results: icebreaker observations and SAR image data.

Wave forecasts:

- A year around operational wave forecasts covering the Baltic Sea on daily basis. Input data is taken from HIRLAM (at the present 22*22km grid, in a year 11*11km grid data), the model is a parametric wave-ride model thus it has no down limit in resolution, forecasts significant wave height, direction, in +0h, +6h, +12h, +18h, +24h.

Table 9. Overview of FIMR products and parameters.

Name	Parameter(s)	Units	Spatial resolution	Temporal frequency	Origin
Sea ice	In situ ice conditions		<1*1 km	Daily	Finnish ice service
Sea ice	+72 h ice drift forecast	Direction in degrees, speed in tens of knots	40*40 km	Daily	ECMWF winds/ ice conditions Finnish ice service
Sea ice	SAR image classifications	Classifies image information into 5 classes	500*500 m	When SAR data available	FIMR
SST	In situ SST charts	°C in one deg. intervals		Twice a week (Mondays & Thursdays	AVHRR, in situ measurements by ships and stations, IR air.borne measurements
Wave	In situ wave height	Wave direction, wave height, wave period, water temperature		Twice an hour	FIMR
Wave	+48 h wave forecast	Significant wave height, direction, period		Daily	HIRLAM / FIMR
Water level	In situ water level	Resolution1 mm, operational accuracy <1cm		Four measurements per hour	FIMR

3.2.3 Data presentation

The presentation forms for different FIMR parameters are given in Table 10, and an example of FIMR's present ice drift forecast product is shown in Figure 5.

Table 10. The planned presentation forms for the FIMR.

Category	Parameter	Presentation form
Meteorology		
Ice Ice forecasts	In situ ice charts Ice class Ice drift direction Ice drift speed Ice-edge and concentration Equivalent ice thickness due to deformation or divergence.	WMO ice symbols/ code In situ SAR image classifications in 3-5 ice classes, each class in individual colour Vectors Colour coded Also in text format.
Ocean	In situ wave direction In situ significant wave height In situ water level	
Wave forecasts	Significant wave height Wave direction	Colour coded Vectors
Remote Sensing	NOAA AVHRR RADARSAT SAR RADARSAT SAR	Images sent to icebreakers and ships (greyscale) Images sent to icebreakers and ships (greyscale) Classificated (colour code)

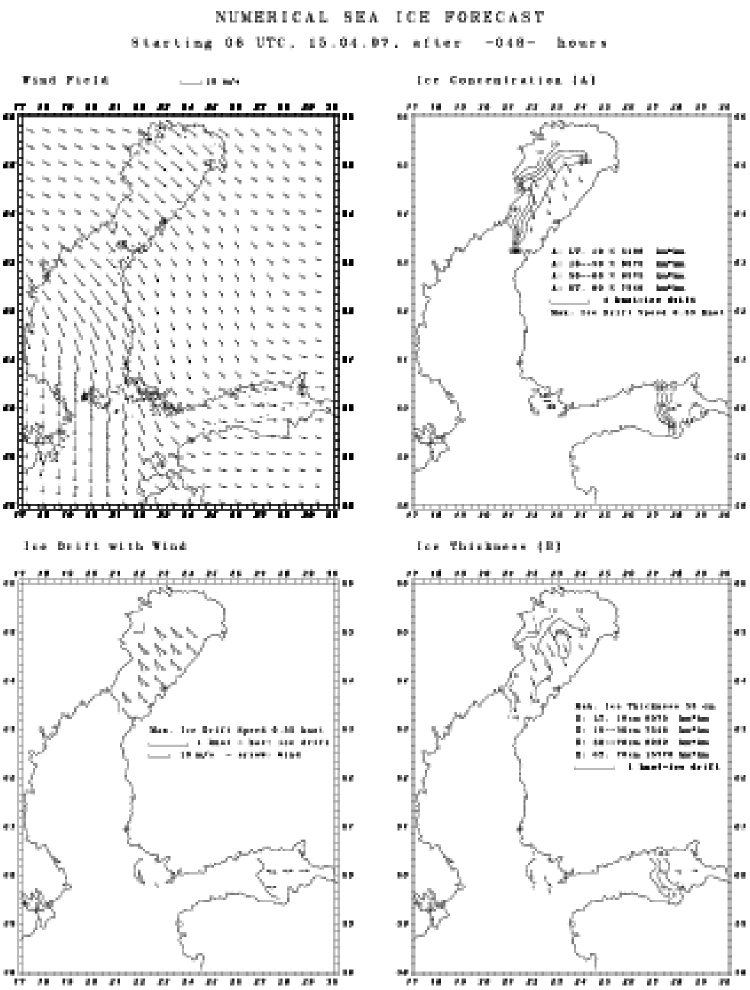


Figure 5. An example of FIMR's present ice drift forecast format. At present forecasts are sent to users only in text format.

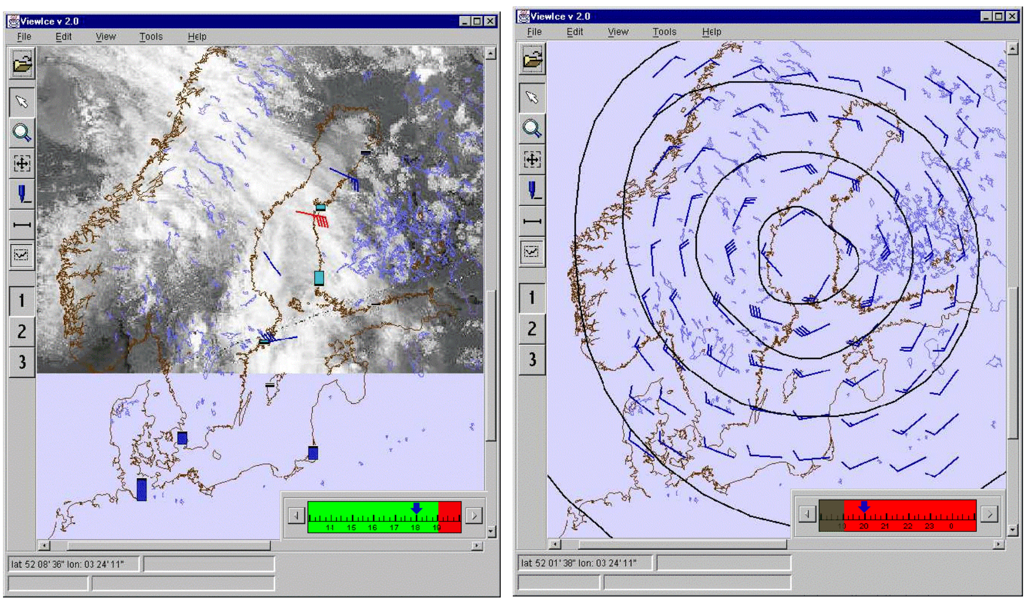


Figure 6. User interface examples showing observation data (satellite image, water levels and wind observations) to the left and forecast data (wind and atmospheric pressure) to the right. Note the time slider down right.

3.3 DMI

3.3.1 General products to be developed

DMI will provide a range of sea ice and weather related products both to the end users and to project partners. All standard products originate within the DMI operational production system, i.e. sea ice charts, model fields (e.g. pressure, winds, temperature) and satellite images but are subsequently processed to conform with IWICOS product content and format rules. These products may when entered into the IWICOS system constitute an information layer of its own or may, through combination with other standard products, form new (user defined) baseline or extended products, see Figure 7. A list of the DMI standard products is presented in Table 12. DMI will prepare an off line data set consisting of a range of standard products, e.g. information about weather, sea ice charts and satellite images which may be used by the partners to test the end user baseline system data during the development phase.

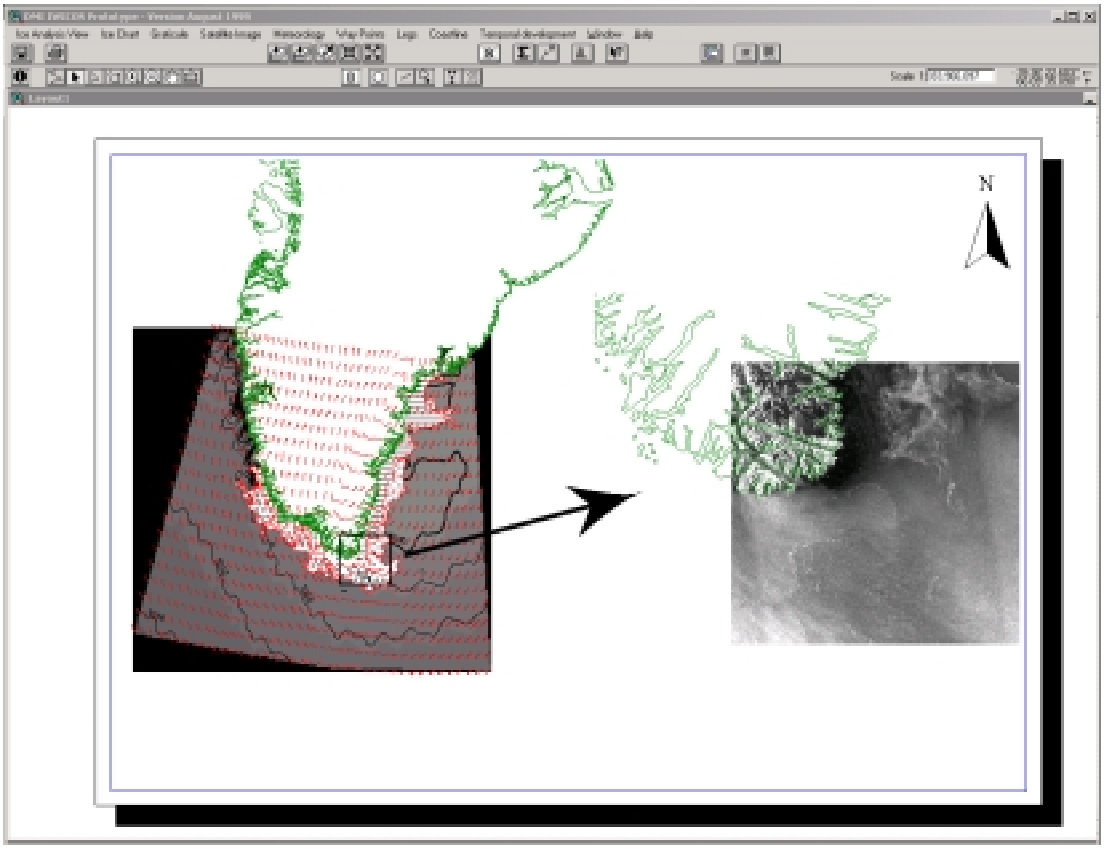


Figure 7. DMI prototype example.

3.3.2 Data sources and parameters

DMI will focus on data and information about weather parameters and sea ice. These features will be made available through a range of existing and new products which will be based on weather model fields, ice charts and satellite images.

Weather parameters will be extracted from the DMI-HIRLAM model fields. The operational system consists of four nested models called DMI-HIRLAM-G, DMI-HIRLAM-N, DMI-HIRLAM-E and DMI-HIRLAM-D (Figure 8). The models are identical except for horizontal resolution and integration domain. The model domains are shown in the above figure. Table 11 contains information for each model about vertical and horizontal resolution and the number of grid points along latitude (mlat) and longitude (mlon). It also contains specification of the applied time step, age and frequency of boundary files. The lateral boundary values for the "G" model are ECMWF forecasts, while those for "N" and "E" are "G" forecasts, and those for the "D" model are "E" forecasts.

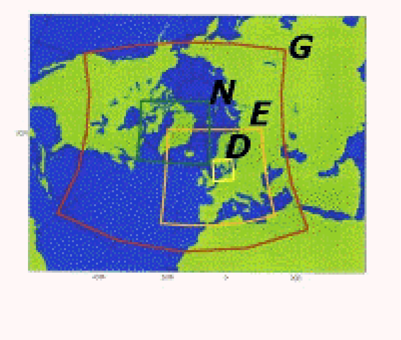


Figure 8. HIRLAM model areas.

Table 11. HIRLAM model definition.

Model	G	N	E	D
Gridpoints (mlon) Gridpoints (mlat)	202 190	194 210	272 282	182 170
Number of vertical levels	31	31	31	31
Horisontal resolution	0,45°	0,15°	0,15°	0,05°
Timestep	240s	90s	90s	30s
Boundary: age Boundary: frequency	12 h 1/(6 h)	0 h 1/(1 h)	0 h 1/(3 h)	0 h 1/(1 h)

Each run is identified by three characters followed by the forecast length in hours. The first character is the model identification, and the next two digits are the initial hour. As an exampleG00+48h means a model "G" analysis at 00 UTC followed by a 48 hours forecast. Improvements in the quality of the data-assimilation is achieved by performing a number of reruns of short range forecasts. The reruns introduce analysed boundaries in the data-assimilation. IWICOS will have access to output from model G,N and E and up to +48 hours forecasts. See also http://www.dmi.dk/eng/f+u/index.html.

Sea ice information will be extracted from ice analysis based on manual interpretation of satellite images. An ice analysis is in vector format and contains information (attributes) about sea ice concentration, sea ice type, floe size and (geometry) ice edge and boundary position. All ice information are coded using the SIGRID code that can be directly related to a WMO code but which are numeric. Positional information are originally in Lambert Conformal Conical coordinates.

Satellite data that are used by the Ice Service are potentially available to IWICOS. However, in praxis only a limited number of images will be used for dissemination. All satellite images (NOAA, RADARSAT and SSM/I) are georeferenced to the Lambert Conformal Conical projection. RADARSAT images may only be made available to a few well defined users but which users and how much data we are allowed to distribute have to be negotiated with RSI before we can start a near real time service during the test (demonstration) phase.

3.3.3 Data presentation

There are two standards that may be used for presenting sea ice and weather information. For sea ice it is the WMO Sea Ice Nomenclature, WMO No. 259 TP. 145 with supplements and for weather symbols it is the WMO Manual on the Global Data Processing System, WMO No. 485, Appendix II-4 Graphical Representation of Data, Analyses and Forecasts. These standards must be consulted to use the point, line and area symbols whenever possible and feasible. In many cases users are accustomed to a certain set of symbols, consequently, the readability of a given display may be related to the usage of well known symbols. However, it may not be easy or possible at all to implement a given symbol set and in some cases there may be no standard symbols to use. For instance a standard presentation of a meteorological observation may be a very complex matter. But as a general rule the user should have both options, i.e. a standard WMO presentation or a modified / new presentation method.

In general there are three basic types of vector information, i.e. point, line and polygon and two types of raster layers, i.e. an image and a grid. In some cases a given parameter can be illustrated using both a vector or a raster type, e.g. a surface temperature field may be presented as evenly distributed points where a colour or a text label communicates the temperature or as isolines or contour lines coloured and with labels or as polygons or as a raster grid which can hold attribute information which are related to the individual pixel values. This is definitely also true for many other parameters including information about sea ice. It is not always obvious which presentation method to choose and in many cases it will depend on the context, i.e. which other data types are displayed and which kind of operations do you wish to apply. The important thing is that we do not restrict ourselves by tying one given parameter to one given presentation method.

Table 12. Overview of DMI products and parameters.

Name	Parameter(s)	Units	Spatial resolution	Temporal frequency	Origin
Meteorology	Mean sea level pressure 10 m. wind (u,v) 2 m. air temperature 2 m. specific humidity Acc. Convective precipitation Acc. Stratiform precipitation High clouds Medium clouds Low clouds Fog Cloud	Pa m/s K g/g mm mm per cent per cent per cent per cent per cent	0.45 (G45) degrees or 0.15 (N15 or E15) degrees	6 hours up to +48 computed daily at 00 and 12	DMI HIRLAM
Sea ice	Ice concentration Ice type Floe size	SIGRID codes	Varying	Varying	DMI Ice navigational charts
Sea ice	Ice concentration Ice type Floe size	SIGRID codes	Varying	Weekly	DMI Ice strategic charts
Remote sensing	Radarsat Scansar wide	Intensity / PMR	Varying	As available	RSI
Remote sensing	NOAA AVHRR		Varying	As available	NOAA

Table 13. DMI data presentation.

Category	Parameter	Presentation form
Meteorology	Wind Pressure Temperature	Arrows, contours Contours, grid Contours, grid, points
Ice	Edge Boundaries Concentration Type Attributes	Line Line Area Area, symbols WMO standard, SIGRID
Ocean	TBD	
Remote Sensing	NOAA AVHRR RADARSAT ScanSAR	Greyscale image, pseudocolour image Greyscale image

3.4 DTU

3.4.1 General products to be developed

For the baseline system, DTU will focus on refining existing satellite ice data products, and on incorporating weather and sea-state forecast data from various sources on the internet. The aim is to use freely available weatherforecast data and sea state forecast data from either the National Center for Environmental Prediction (NCEP) or the Fleet Numerical Oceanography Center (FNOC).
A data mining system will be set up to gather the data from the Internet, and to process it and convert it to a format compatible with the visualization system.

3.4.2 Data sources and parameters

Various satellite image products (geocoded but not converted into a specific ice parameter). Examples are the 85 GHz polarization difference from SSM/I, single channel AVHRR, multichannel AVHRR, single channel SAR and scatterometer.
Freely available weather forecast data and sea state forecast data from either the National Center for Environmental Prediction (NCEP) or the Fleet Numerical Oceanography Center (FNOC).
In general products will be produced automatically without user intervention. Temporal resolution of these data range from 6-8 times per day to 1-2 times pr month. Geographical coverage range from Northern hemisphere to 100x100 kilometres or less. Units vary (and may not be meaningful) Origin are satellite receiving stations and product providers. This is our major product area for a number of users. First of all because these data can be very low cost, as they are easy to produce (being produced already in some automatic processing chain).

Table 14. Overview of DTU products and parameters.

Name	Parameter(s)	Units	Spatial resolution	Temporal frequency	Origin
Remote sensing	SSM/I 85 GHz polarization difference	K	10 Km	2-4 / day	NASA/ DTU
Remote sensing	Single and multi band AVHRR	arbitrary	1-10 Km	1-4 / day	TSS AWI DMI
Remote sensing	Scatterometer data	TBD	10-20 Km	1-2 / day	NASA
Remote sensing	SSM/I Ice concentration	Per cent	20 km	2-4 times / day	Satellite data provider

3.4.3 Data presentation

Images and vector graphics will all be made compatible with our Java based presentation system. The aim is to show how data from a number of differetn sources can be brought together in a unified way using standard tools including strong compression to enhance usability and reduce transmission costs.

Table 15. DTU data presentation.

Category	Parameter	Presentation form
Meteorology	Wind speed and direction (forecasts) Surface temp Upper air temp. Surface pressure	Vector graphics symbols Images/contours Images / contours Contours
Ice	Ice concentration Ice indexes Digital ice chart Ice motion vectors	GIF images and contours GIF or JPEG images Clickable polygons w. attributes Vector overlays (arrows)
Ocean	Wave height / direction Swell Ice Accretion Forecasts	Vector graphics symbols
Remote Sensing	Vis/IR images Microwave images	B&W and colour JPEG / GIF images

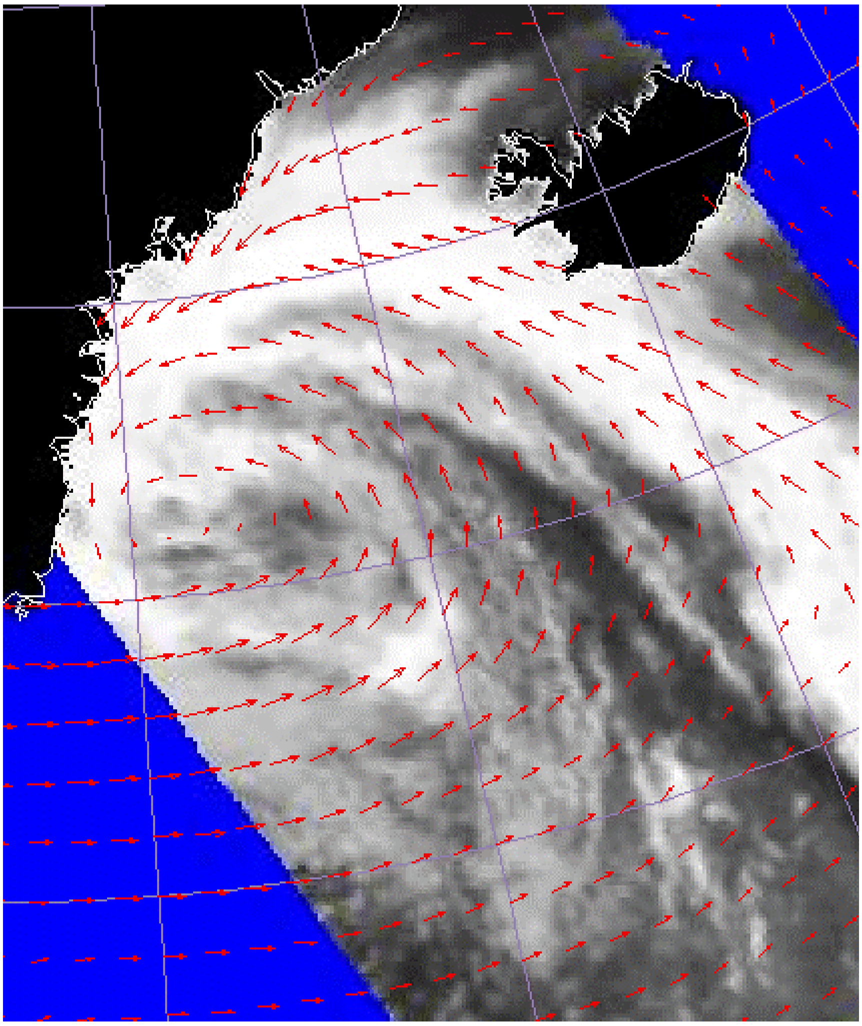


Figure 9: Example of an 85 GHz polarization difference image produced at DTU from SSM/I data (21:26 UTC) (from NASA's Marshal Space Flight Center) overlayed with red arrows of wind speed and direction forecasted by the National Center for Environmental Prediction (NCEP) (00:00 UTC + 24hours, e.g. a forecast for 24:00 UTC (2½ hours after the satellite pass).

3.5 IMO

3.5.1 Base line products

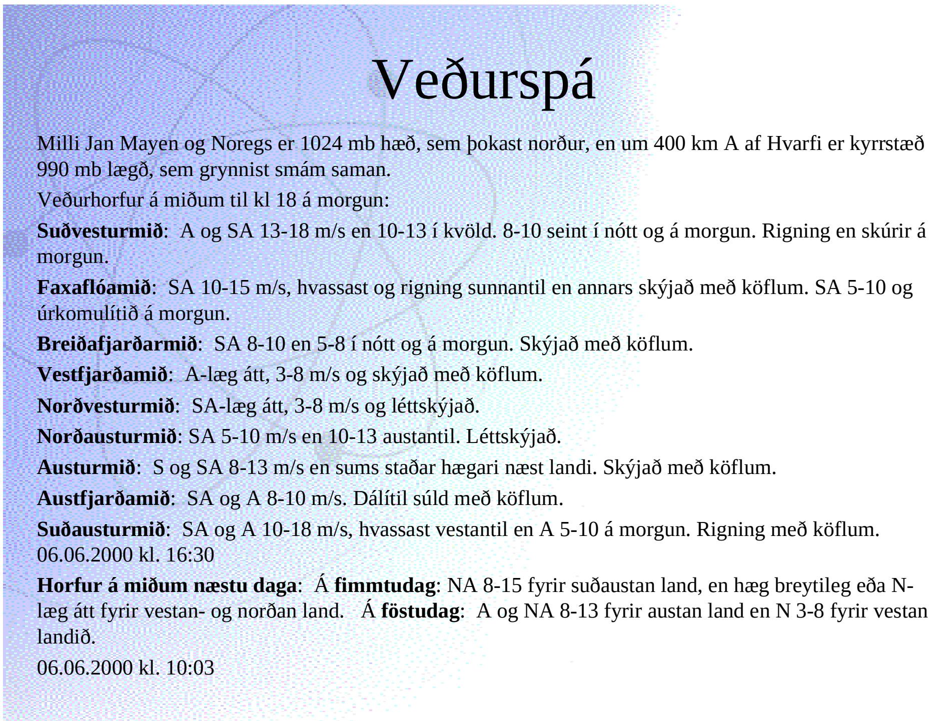
The main objective of the IWICOS system is to provide a user with a single entry access to met-ice-ocean products. Therefore it is natural to start with products which are defined to be the basic products in all met-ice-ocean services today. Some other products will be added as shown below. These products will be made available in IMO's contribution to the IWICOS baseline package.

IMO's workplan for baseline product development:

- Integrate existing weather products into the IWICOS system. They consist mainly of warnings and forecasts sent in plain language according to WMO standards
- Develop dangerous waves forecast, predicted from wave forecasts and risk assessments, based not only on the sea state but also on accident frequency and acceptable risk level
- Develop sea ice charts based on observations
- Improve the flexibility of MaxSea to make it capable of visualizing sea ice information

Examples:

- Marine weather forecast



Veðurspá

Milli Jan Mayen og Noregs er 1024 mb hæð, sem þokast norður, en um 400 km A af Hvarfi er kyrrstæð 990 mb lægð, sem grynnist smám saman.

Veðurhorfur á miðum til kl 18 á morgun:

Suðvesturmið: A og SA 13-18 m/s en 10-13 í kvöld. 8-10 seint í nótt og á morgun. Rigning en skúrir á morgun.

Faxaflóamið: SA 10-15 m/s, hvassast og rigning sunnantil en annars skýjað með köflum. SA 5-10 og úrkomulítið á morgun.

Breiðafjarðarmið: SA 8-10 en 5-8 í nótt og á morgun. Skýjað með köflum.

Vestfjarðamið: A-læg átt, 3-8 m/s og skýjað með köflum.

Norðvesturmið: SA-læg átt, 3-8 m/s og léttskýjað.

Norðausturmið: SA 5-10 m/s en 10-13 austantil. Léttskýjað.

Austurmið: S og SA 8-13 m/s en sums staðar hægari næst landi. Skýjað með köflum.

Austfjarðamið: SA og A 8-10 m/s. Dálítil súld með köflum.

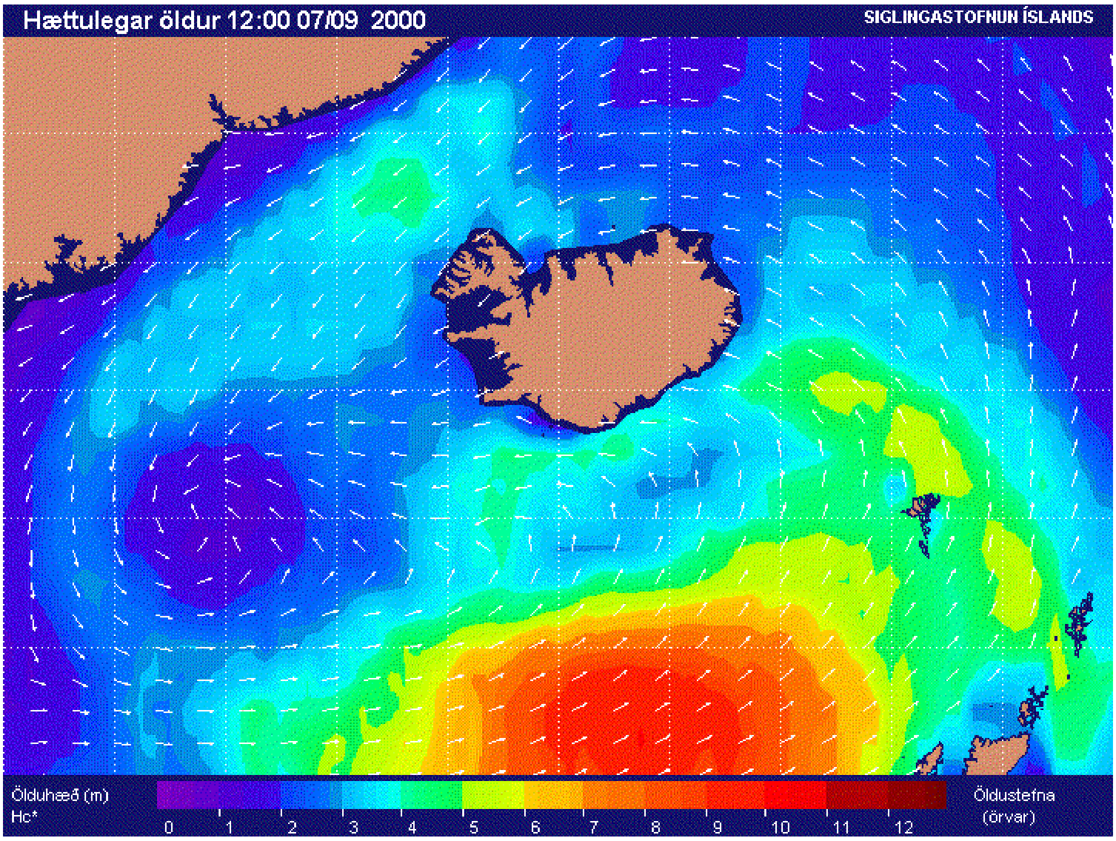
Suðausturmið: SA og A 10-18 m/s, hvassast vestantil en A 5-10 á morgun. Rigning með köflum.

06.06.2000 kl. 16:30

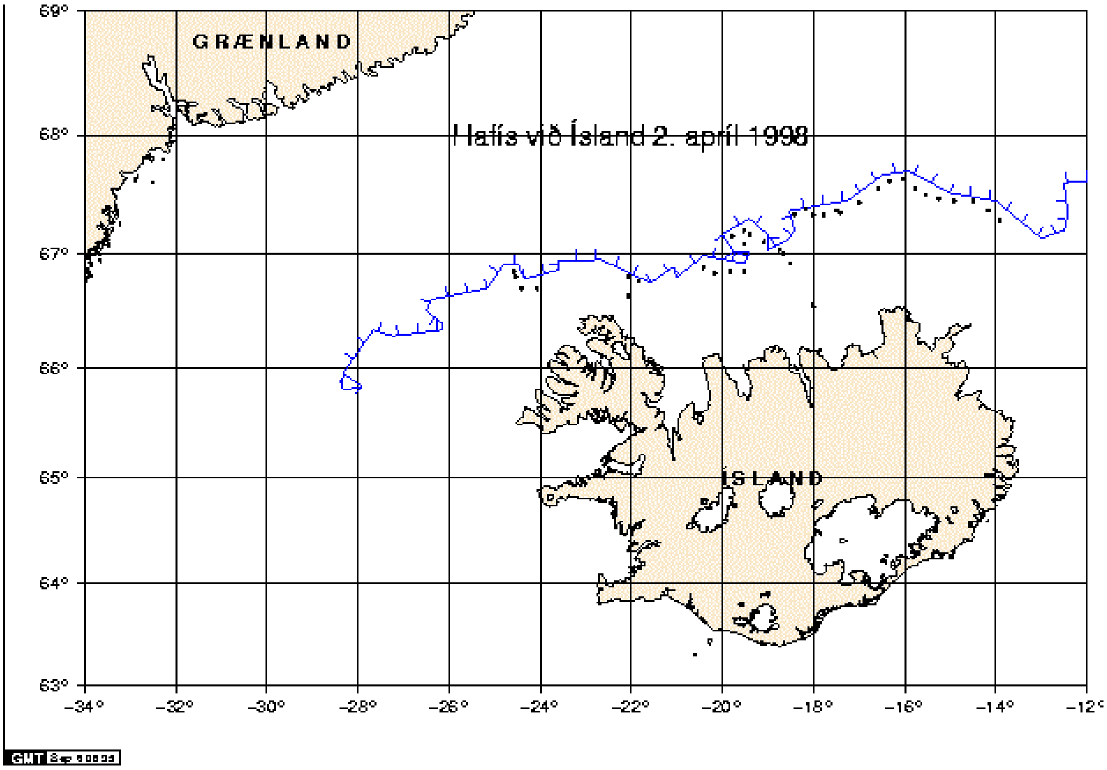
Horfur á miðum næstu daga: Á **fimmtudag**: NA 8-15 fyrir suðaustan land, en hæg breytileg eða N-læg átt fyrir vestan- og norðan land. Á **föstudag**: A og NA 8-13 fyrir austan land en N 3-8 fyrir vestan landið.

06.06.2000 kl. 10:03

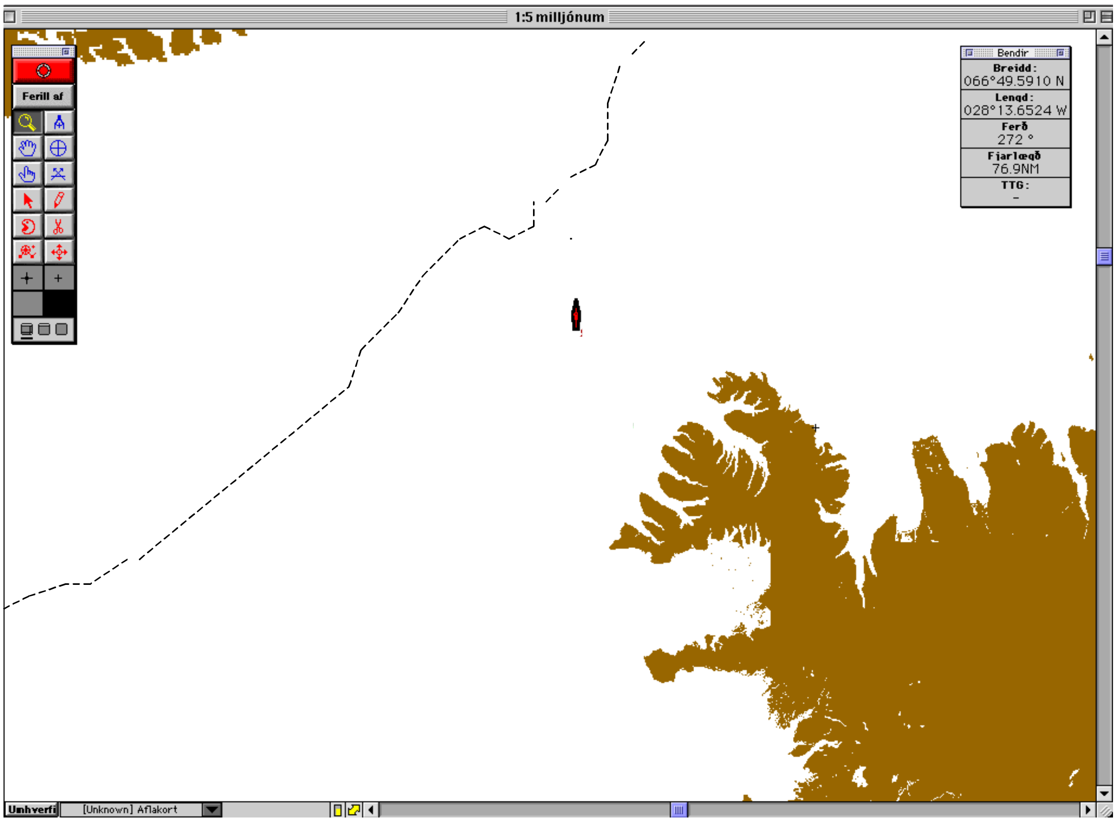
- Dangerous waves forecasts



- Sea ice chart



- Sea ice edge position in MaxSea



3.5.2 Planned products

Within metarea I (UK) in Figure 2 The Icelandic Met. Office issues weather forecasts and warnings for 17 sub-areas, shown on Figure 10. This service is according to the rules given in Manual on Marine Meteorological Services, WMO No. 558.

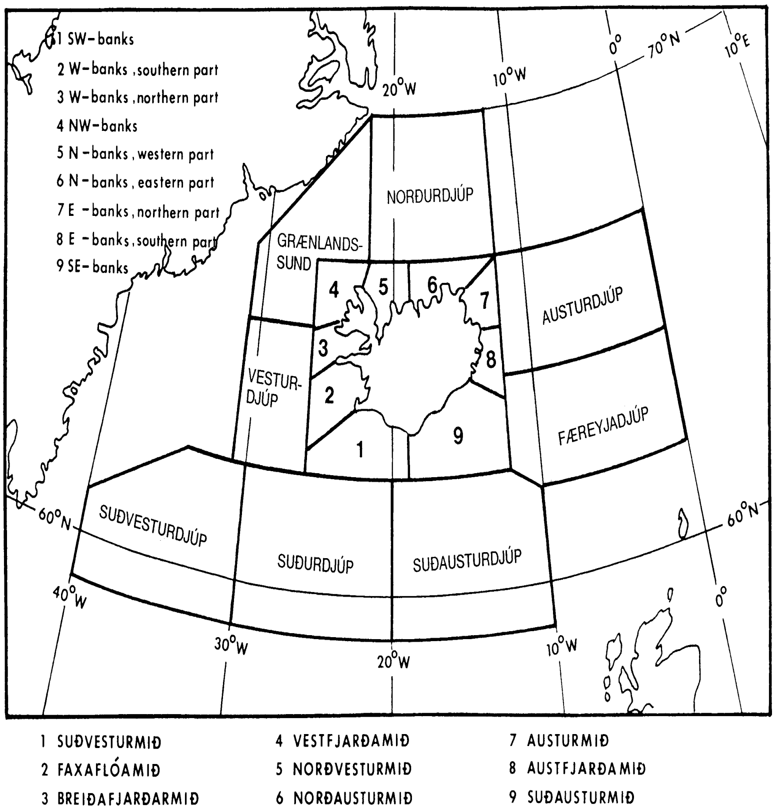


Figure 10. Areas used in Icelandic maritime forecasts.

The following products are planned to be the contribution of IMO, Radiomidun and The University of Iceland to the IWICOS project. The products will be a combination of new products and an improvement of existing products and cover the areas shown in Figure 10. Some of the planned products are quite extensive and will only be partly developed during the three years time of the IWICOS project.

Existing products:

- Weather forecast and warnings
  - written text
  - maps
- Wave forecast
  - maps
- Weather observations
  - list of observations
  - maps
- Sea ice forecast
  - written text
- Sea ice observations
  - written text
  - maps

Improved Products:

- Sea ice maps
  - based on reconnaissance flights
  - based on satellite images
  - based on subjective outlook according to weather forecasts
- Enhancement of numerical weather forecasts by graphical interaction with gridded fields.
  - implement methods of interfering with numerical weather forecast fields. Such methods are under development within the Cost 78 project
- Monitoring of numerical weather forecasts
  - comparing numerical weather forecasts with real time observations
  - issue warnings when forecasts start to diverge from real time observations
- Improve the flexibility of MaxSea to make it capable of visualizing any relevant parameter, for example
  - sea ice information
  - waves including dangerous waves
  - additional weather parameters, for example air temperature, precipitation and cloud cover
  - risk of icing on ships
  - currents for Icelandic waters
  - altimetric data
  - raster charts

New Products:

- Sea ice forecast development based on numerical prediction models
- Icing forecast for ships based on numerical forecasts of wind speed, air temperature and sea temperature
- Dangerous waves forecast predicted from wave forecasts and risk assessments, based not only on the sea state but also on accident frequency and acceptable risk level.
- Tidal currents influence by weather factors will also be estimated.

3.5.3 Data sources and parameters

Table 16 shows an overview of IMO's products and parameters. Units are SI units or exceptions recommended by WMO.

Table 16. Overview of IMO products and parameters.

Name	Parameter(s)	Units	Spatial resolution	Temporal frequency	Origin
Short range weather forecast	wind air temperature pressure weather		17 forecast areas 0.5°x0.5°	8/day 3/day 2/day	IMO DMI/HIRLAM
Medium range weather forecast	wind air temperature sea temperature pressure		1.5°x1.5°	1-2/day	ECMWF
Wave forecast	significant wave height mean wave period mean wave direction		0.5°x0.5°	1/day	ECMWF
Wave measurement buoys	significant wave height mean wave period wave length		8 buoys	24/day	IMA
Synoptic weather stations	wind weather visibility		app. 30 coastal stations	up to 8/day	IMO

	sea state temperature pressure				
Automatic weather stations	wind (mean speed and direction) gust temperature pressure		15 stations	24/day	IMO
Harbor automatic weather stations	wind (mean speed and direction) gust temperature pressure sea level		14 stations	24/day	IMO
Sea ice forecast	sea ice edge position sea ice concentration		1-3 km	Irregular, when required	IMO
Sea ice analysis and warnings	latitude/longitude of ice edge subjective estimation of sea ice conditions on sailing routes		1-3 km	Irregular, when required	IMO
Sea ice reports	observations from ships sea ice reconnaissance flights coastal observations		variable	Irregular, when sea ice is observed	IMO ICG

3.5.4 Data Presentation

Each weather parameter can be presented in many different ways to the end user, depending on the user and also on the type of software he is using. If it will be decided to involve manufactures of different Electronic Chart Systems (ECS) like MaxSea, it is evident that symbols and feature presentations will never be fully compatible as manufactures/software houses are using different developing tools. For example, if a wind parameter is presented as a vector, length and colors can vary from one manufacturer to another.

Weather and ice information can be presented in two different ways:

- Text
    - Text in Icelandic and English, using WMO standard (according to Manual on Marine Meteorological Services)
    - Point forecast in table form
    - Observations, list of parameters

- Graphics
    - Contour lines, suitable for some parameters like pressure, temperature, etc.
    - Wind arrows or flags
    - Objects, i.e. observations plotted on maps
    - Objects, i.e. sea ice egg symbols, ice edge and ice concentration
    - Meteograms for plotting forecasts and observations

Different end user systems should work within these presentation rules, but they should be allowed to add special effects, for example:

- Wind: vector with different colors or conventional wind arrows to represent windspeed
- Pressure and temperature: color patterns instead of isolines
- Any parameter: By clicking on the screen the values of wind, pressure and temperature may be seen as well. As all values are associated with a fixed point at a certain time, the user is able to see interpolation between points. If the time value is changed, the forecast will change according to associated values.

3.6 Summary of expected main results

Table 17 summarises the expected main results of the IWICOS project.

Table 17. Summary of expected main results.

Partner	Expected main result
NERSC	Satellite ice data archive for the Arctic test area accessible via Internet
	Ice concentration and drift in the Arctic test area using integrated data sets
	Ice-ocean forecasts for the Arctic Ocean and the Nordic Seas
FIMR	SAR image presentation and classification in combination with ice chart in the Baltic Sea
	Ice drift and wave forecast presentations for ships in the Baltic Sea
	In situ ice drift, wave and water level presentations for ships in the Baltic Sea
VTT	Software for presentation and analysis of sea-ice, ocean and weather data onboard ships
	GIS components to build different of applications for handling met-ice-ocean data
DMI	Information system for Greenland waters integrating weather, ocean and sea ice related data
	Access to integrated data for Greenland waters via Internet
	Increased customer awareness of digital, integrated data delivered by DMI
DTU	Web/Java based ice information system for distribution of met/ice/ocean information
	Data mining system to collect data from the internet, produce value added products and redistribute via internet
IMO	Existing weather products
	Dangerous waves
	Sea Ice charts
	Sea Ice in MaxSea

4. End user and retrieval system

4.1 Architecture layout

4.1.1 Reference architecture

The logical architecture for IWICOS (and most dynamic multiproducer GIS-systems) can be divided into three subsystems (see Figure 11). The main subsystems include the *production*, *brokering*, and *presentation* of GIS-products. The actual tasks in these subsystems are determined by decisions related to issues such as distribution, delivery mechanisms (push/pull) and client model (thin/thick). In the production subsystem the GIS-data is produced and packed for delivery with a meta-data description of the product. The brokering subsystem receives this information (or plain meta-data and GIS-data address) and the user needs (either a profile or a request). Communication with other servers for locating and collecting data is also possible if the distribution solution supports this. Presenting the GIS-products provides the user a view of the products and means for selecting them. In the *thick-client* model the products can be customised and new user defined views created.

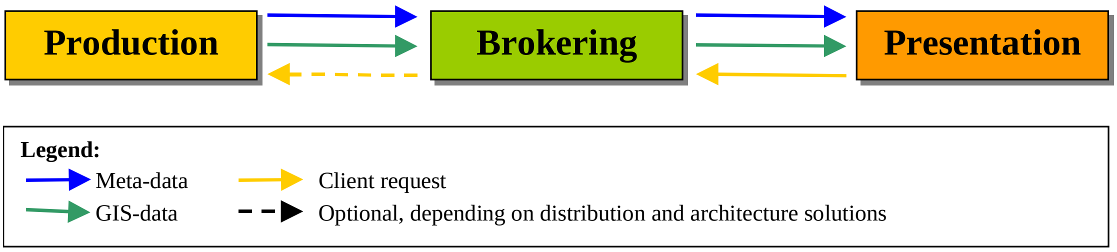


Figure 11. The reference architecture for IWICOS.

It is clear that many choices over technologies and solutions that are to be used have to be defined at the architecture definition phase. In the following sections we will discuss these issues and present a few alternative approaches to the division of tasks and distribution in the architecture.

4.1.1.1 Production Subsystem

The Production subsystem produces the raw-data or refines it to useful products. Within the reference architecture we do not define whether or not the production should have a dedicated server, we simply identify that for IWICOS system such a functionality is essential. The need for a server is further dicussed below. Closely related to the need of a server is the question of data-storage, it must be decided whether the data is stored in production subsystem, or brokering subsystem, or in both of them. Anyhow, to begin with at least the meta-data has to be passed on from the production.

4.1.1.2 Brokering

The main task for the Broker is to establish contact between Clients and Producers. This can occur in many forms wich are discussed on following sections. The storage issue above concerns also the Broker. It can be argued that a Broker is not needed at all. However, if a Broker is used, it should be responsible for locating other Brokers and Producers in addition to meta-data (and product-data) brokering. Thus, if no Broker is used, other means of locating services should be applied.

4.1.1.3 Presentation

The task for the client software is to present the data to the user. There are, however, two approaches to this task. The first one, called *thin-client* approach, is just to provide ready-made presentations of the data. The other one is the *thick-client* approach which may include complicated processing of the data to gain a presentation that is customized for that particular user. Both thin and *thick-client*s should be supported, due to the heterogenity of IWICOS users. Lately this division to *thick-* and *thin-client* systems has become a bit ambiquous, due to the Java-applet clients which have both *thick-* and *thin-client* properties. Based on this trend we define a *thick-client* to be a client that requires a separate installation process to be accomplished on the target computer before the client can be used.

4.1.2 Service chain / graph

The flow of data from the providers to customers forms a service chain, where the data is refined to a service through different processing in production and brokering servers, and client software. In this chain, the data that the user needs, is produced, processed for delivery, selected and presented to the user. The base for identifying the useful data and the varying processing it requires, is the meta-data that describes the attributes of the actual data, such as its location, time, nature and origin. Extensible Markup Language (XML), XML Schema and Resource Definition Framework (RDF) provide a good base for the definition of the meta-data presentation (Karttunen 1999, Lassila 1999). The main components in the service chain are the subsystems of the reference architecture described above. However, these subsystems consist of smaller separate processes. After each processing the data is shifted to the next phase, in these interfaces the data should preferrably be presented using open industry standard formats (if possible). In the service chain both client types can be served, by providing the data for client software on different levels of processing. In a *thick-client* the final processing of data is done by the client software and in *thin-client* this is done by the broker server. Thus *thick-client*s receive a kind of 'bulk-data' and *thin-client*s receive final products.

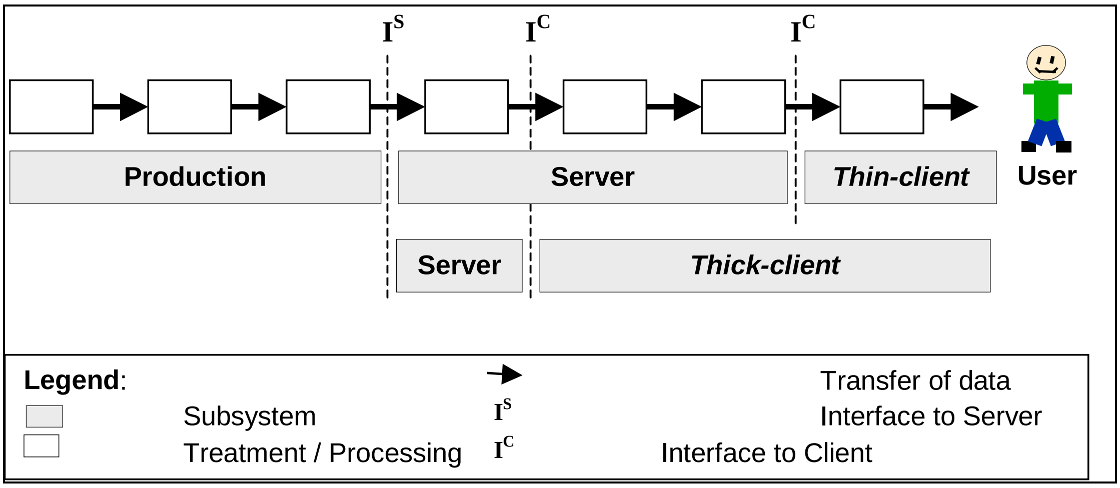


Figure 12: The service chain for Client-Server GIS-systems.

The use of the open industry standard formats in data transfers forms natural connection points for additional processing that may be applied on some data. Such processing will actually widen the service chain concept to a *service graph*. All data is not necessarily treated similarily and value added services can be provided by externalized service producers that apply some specific processing on the data that is not usually available in the basic service.

4.1.3 Interaction models

Our reference model defines the basic components required for a client-server GIS-service, however, the interaction between subsystems and the order in which they appear are still ambiguous. Four different basic models can be acquired from the reference architecture, they are described in this section. The distribution issues related with the models are discussed later in section distribution. In this section it is assumed that single producer, broker and client entities are communicating.

Let us first list a few questions that the models are based on:

1. Do we need a Broker?
2. Do we need a Production server?
3. Should the data be replicated to Broker?
4. Should the data reside on Production server and just address and meta-data be passed for Broker?

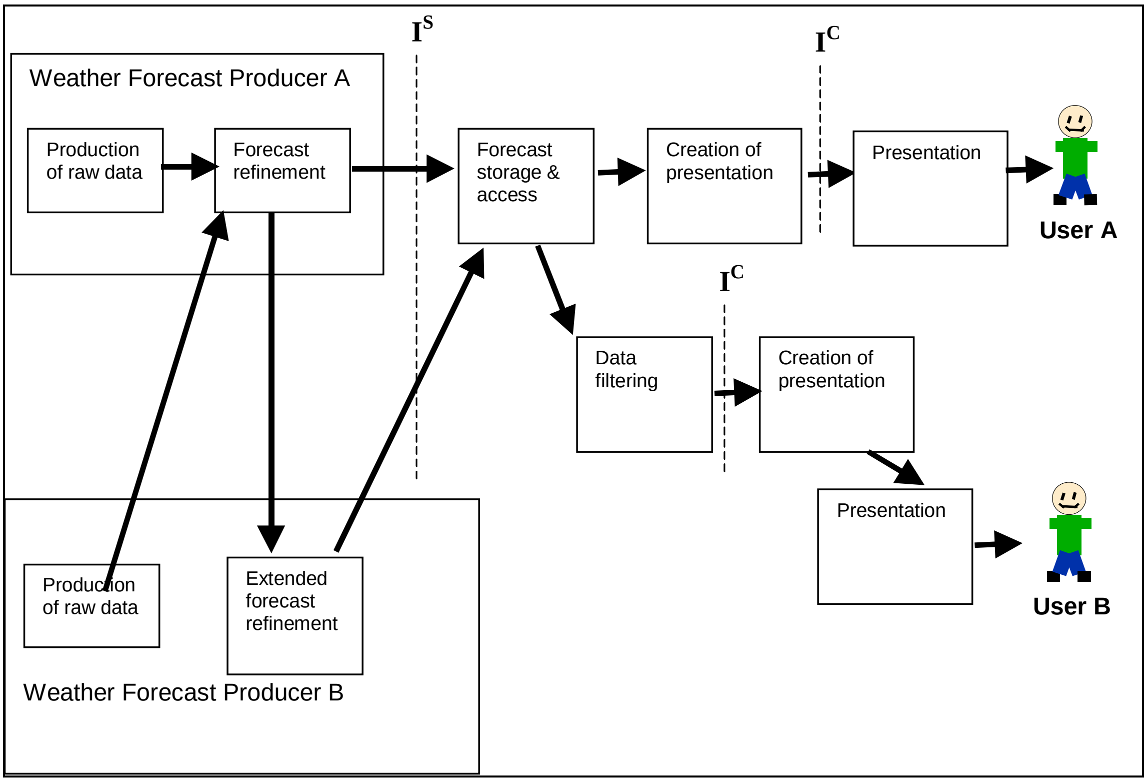
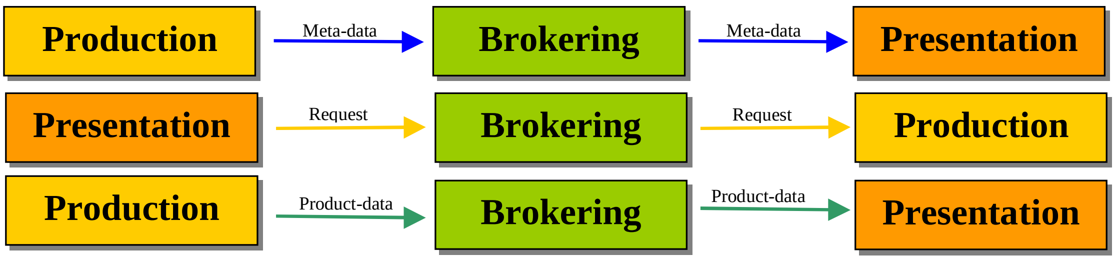


Figure 13: An example service graph.

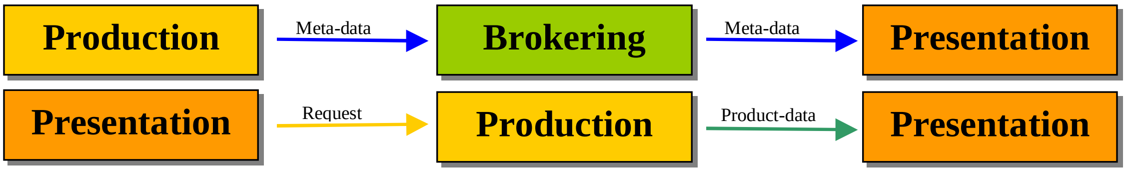
The first model is the *Basic-Service-Model* that separates the tasks of meta-data, client request, and product data transmissions to their own phases. When we consider a case with only single entities of each class operating together, this is clearly the most complicated model, requiring much communication between subsystems. The assumptions are that both Broker and Production servers are necessary, data is not replicated, and product data address is passed along meta-data.



***Basic-Service-Model*:** 1) Producer passes meta-data for Broker. 2) Broker passes this meta-data for the Client. 3) User selects suitable products, Client sends a corresponding request to Broker. 4) Broker passes the request to Production. 5) Production sends related products for Broker. 6) Broker passes the products for Client, which forms a presentation of them for the user.

Figure 14: *Basic-Service-Model*.

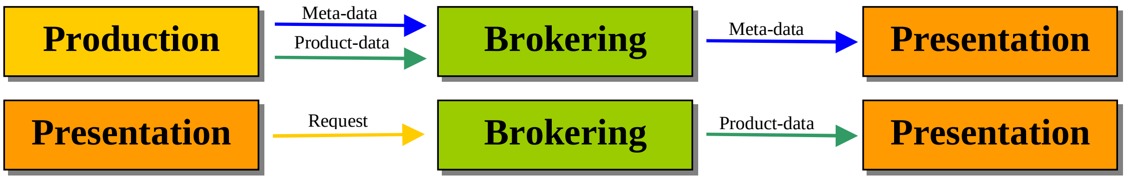
The second model is the *Diminished-Broker-Model*, where Broker tasks are withered to just meta-data brokering. Client software and Production server by-pass the Broker once the connection is establihed based on the metadata. The assumptions are that both Production and Broker servers are necessary, data is not replicated and just the product address is passed to the client software. Here the role of the Broker is just to support the user in finding appropriate service providers.



Diminished-Broker model: 1) Producer passes meta-data for Broker. 2) Broker passes this meta-data for the Client. 3) User selects suitable products, and Client sends a corresponding request to Producer. 4) Producer sends requested products for Client, which forms a presentation of them for the user.
Brokers role is here just to gather meta-data of products and their origin, the actual product delivery occurs between client and production.

Figure 15: *Diminished-Broker-Model.*

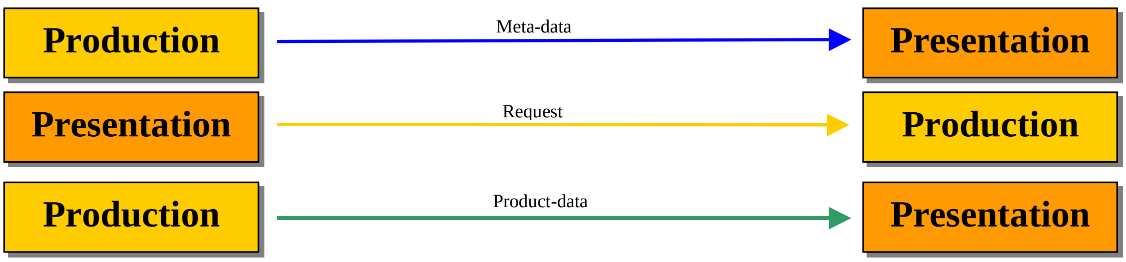
The third model is the *Diminished-Producer-Model*, where the producer role is minimized. The assumptions are that data is replicated (i.e. stored only on Broker server), production server is not needed, and addresses will not be passed . In this model the production can be a batch process and a separate server for that task is not necessary.



Diminished-Producer model (no Production server): 1) Producer passes both meta-data and product-data for Broker. 2) Broker passes meta-data for Client. 3) User selects suitable products, and Client sends a corresponding request to Broker. 4) Broker sends requested products for Client, which forms a presentation of them for the user.
In this model no production server is required and production can be implemented as a batch process that occurs from time to time.

Figure 16: *Diminished-Producer-Model.*

The fourth model is the *No-Broker-Model*, where Client software and Production server communicate directly without any third party. The assumptions are that a Broker is not needed, data resides on Production server, and meta-data is passed directly to the Client. In this model the task of establishing a connection between Producer and Client has to be implemented somehow. We can e.g. assume that the client knows the address(es) of relevant producer(s).



***No-Broker-Model*:** 1) Producer passes meta-data for Client. 2) User selects suitable products, and Client sends a corresponding request to Producer. 3) Producer sends requested products for Client, which forms a presentation of them for the user.

Figure 17: *No-Broker-Model.*

4.1.4 Distribution

The situation gets a bit more complicated than in the models above when multiple Producer, Broker and Presentation entities inter-communicate. Basically four types of communication contacts may occur, depending on the model and policy choices made:

1. Production – Broker.
2. Broker – Presentation.

3. Broker – Broker.
4. Production – Presentation.

The models and their distribution is described below, but first we will list some issues that should be kept in mind when choosing the proper distribution solution for IWICOS.

A single Broker server model can be used, where one Broker collects all the meta-data (and product data, depending on model) and provides it for all clients. This is quite vulnerable solution, due to the fact that everything will depend on that single server. However, in this solution the server intercommunication can be reduced to minimal, there is no need to inform other server of the existence of that particular server, nor the services available from it. This approach resembles an internet portal service, especially if the product data is stored or replicated on Broker server.

Another approach is to allow multiple servers, in this case the server architecture should be uniform and modular. Uniform architecture means that the basic server implementation can be cloned. Modularity means that the framework acquired by cloning can be outfitted with modules providing the desired services for that particular server. This solution requires a mechanism that allows the servers to gain the knowledge of each other's existence and status (ready to serve or down). This mechanism resembles the internet name-service server and is thus furher on called name-service.

In the actual implementation of the distributed solution many technologies, such as the use of the agents (Jennings, 1998, Nwana 1996, Wooldridge et al., 1995), remote method invocation (RMI (Sun00)), and common request broker architecture (CORBA (OMG00)), may be applicable and should be considered more closely before the final selection.

During the implementation the single and multiple server models can be used so that at the base-line system a single server architecture is used and in the extended system this server is cloned to district locations.

The distribution of the *Basic-Service-Model* is shown in Figure 18. In phase A) Producers pass the meta-data to Brokers which replicate it. When the clients connect to Brokers they get the full set of meta-data available. In phase B) the Users select appropriate products, and send corresponding requests for Brokers. Brokers pass these requests on to Producers. In phase C) Brokers collect the resulting product data from Producers to Client specific bundles and pass them along to Client software.

This model leads to relatively simple communications patterns and does not include complicated replication of product data. However, caching of already requested product data can optionally be added to this model. The model is best suited for mobile customers with narrow-band connection and a *thick-client* software. The Broker will do most of the communication for them using its fast internet connection. The communications load between Broker and Client can be further reduced by using a client profile that predefines the users set of interests. The communications form the bottleneck, once the Clients have the data they can derive the views on their local machine, instead of repeatedly requesting customized views from the server.

The distribution of *Diminished-Broker-Model* is shown in Figure 19. Here, phase A) is similar to the *Basic-Service-Model*. In phase B) the Clients contact Producers directly using the addresses passed along with the meta-data. Client does a direct request to each Producer with interesting data. In phase C) the Producers reply with the requested data.

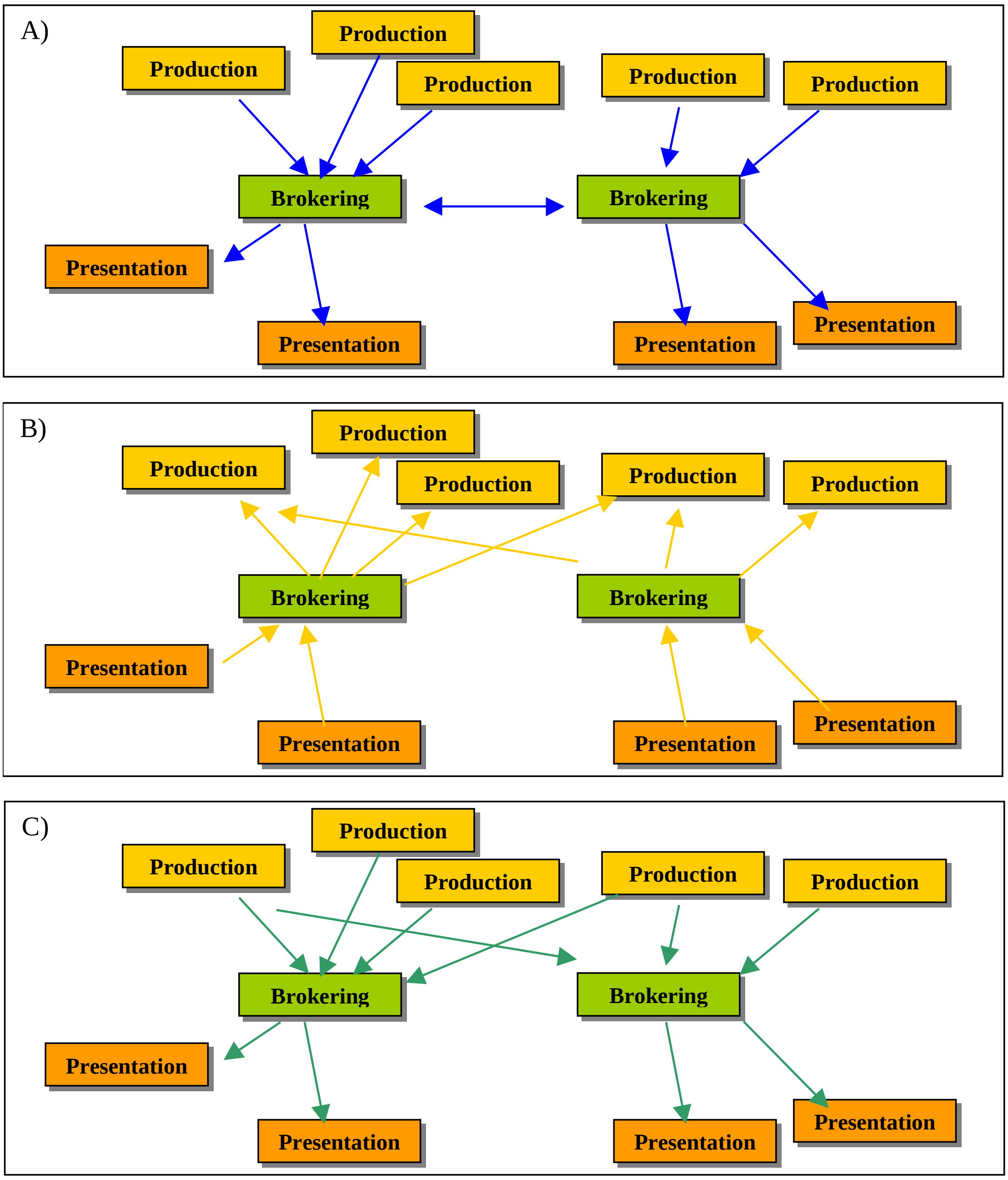


Figure 18: Distribution of the *Basic-Service-Model*.

This model suits best for the Clients with fast internet connection and *thin-client* software, they just need to know where the data is and can access it directly. Here the communications capability is not an issue, the Clients will request as many customized views as they need. This solution resembles an Internet portal service.

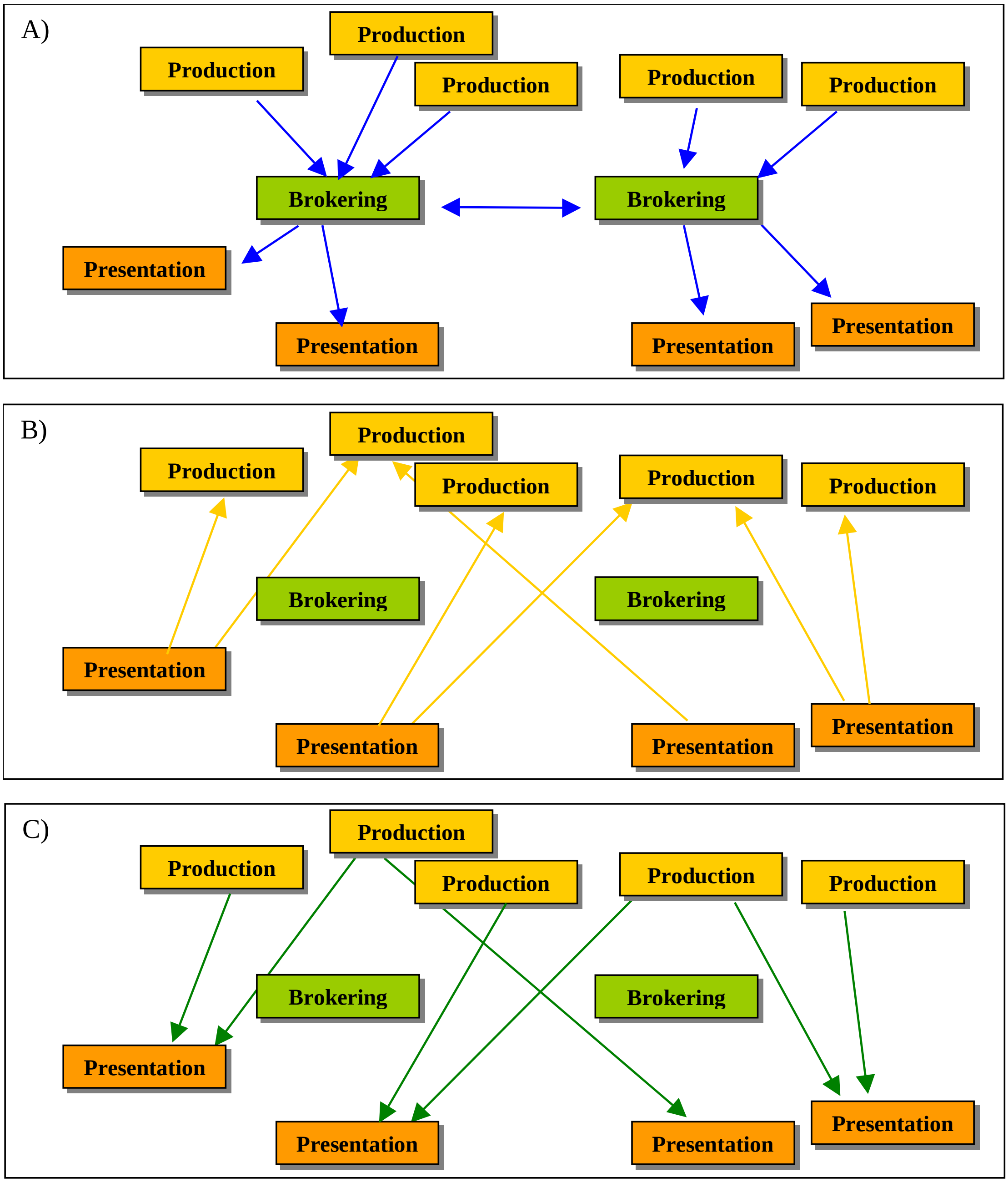


Figure 19: Distribution of the *Diminished-Broker-Model.*

The distribution of the *Diminished-Producer-Model* is shown in Figure 20. In phase A) the Producers pass the meta-data and product data for Brokers, which will replicate them among each other. Broker will provide the meta-data for connecting Clients. In phase B) the Clients send request to Broker. In phase C) the Broker answers with the requested product data. Here the producer role can be reduced to batch processing, and thus no Producer server is necessary. Replication of both meta-data and product data results in a more complicated Broker server, however, this solution decreases the number of end-to-end communication in the service chain. This approach resembles a pipe-lined process, where the data is shifted forward after each processing phase and the actor in the previous phase can concentrate on future tasks. This model is based on mutual trust between Producers and Brokers – the Producers have no means to verify that they get paid for all user accesses on their data.

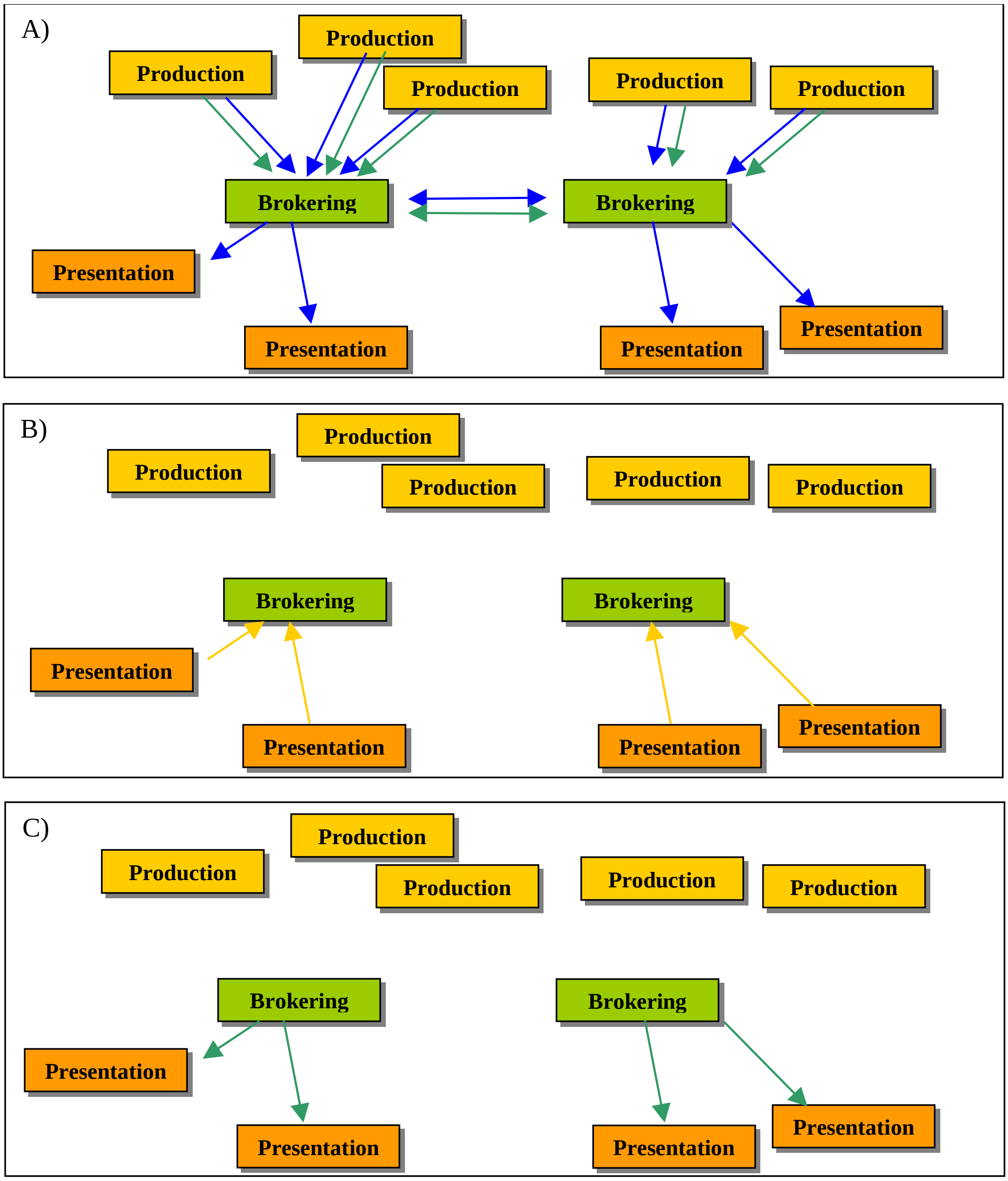


Figure 20: Distribution of the *Diminished-Producer-Model.*

The *No-Broker-Model* is shown in Figure 21. Here all communication occurs directly between Producer and Broker. In phase A) the Producers send meta-data for Clients. In phase B) Clients request the data they actually want. In phase C) the Producers send the requested data for Clients. This model is not very effective in economic terms because it requires a contract between each Producer and Client willing to operate together. As the number of parties in this market increase, the amount of connections required grows for each added member on a group by the number of members in the other group. Thus the amount of connections will soon be too large to be controlled.

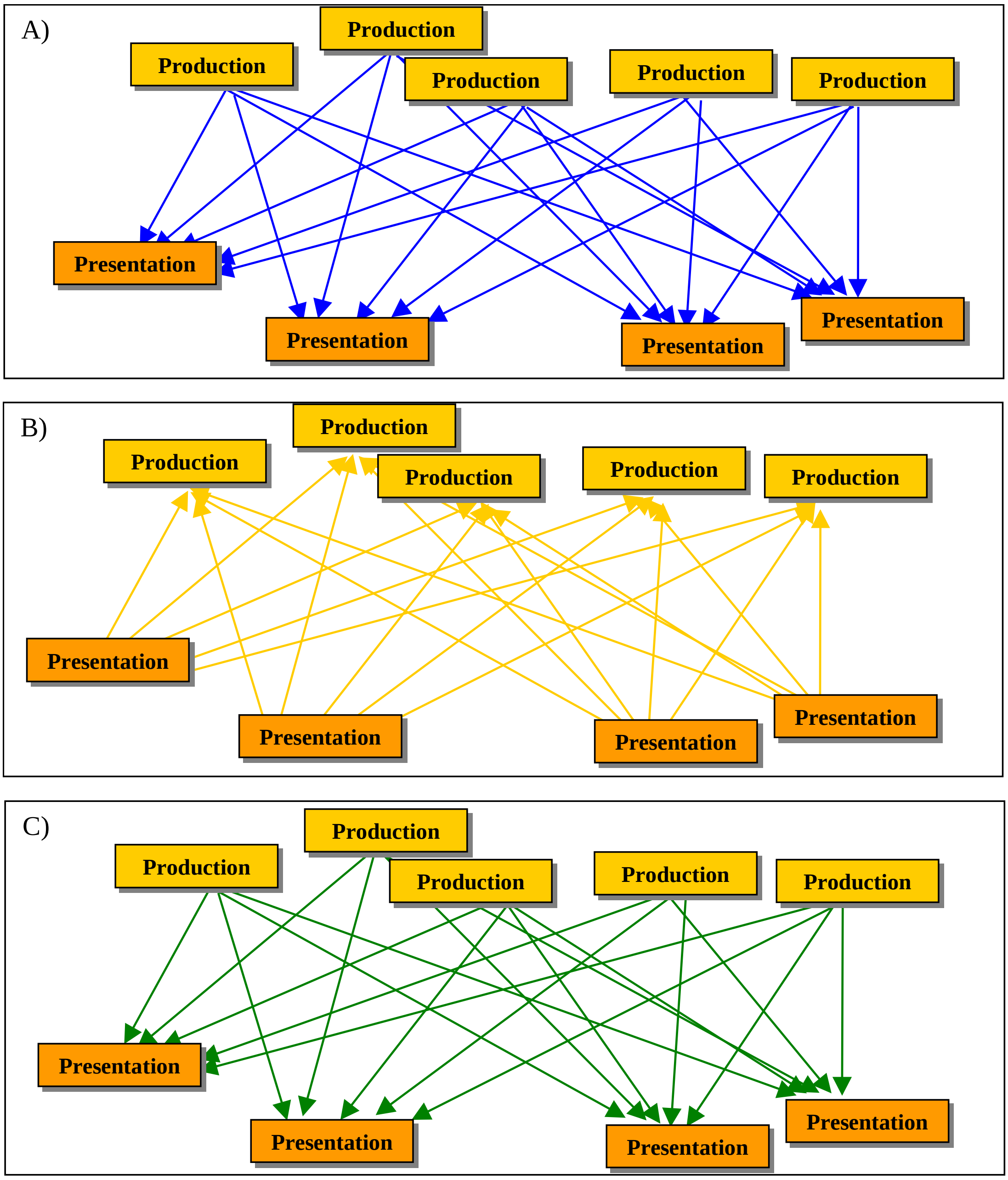


Figure 21: Distribution of the *No-Broker-Model*.

Best suited distribution architecture for IWICOS is, as far as we can see, a hybrid of basic service and *Diminished-Broker-Model*s. That model provides the *Basic-Service-Model* for *thick-client* mobile customers and a portal-like meta-data brokering service for *thin-client* Internet customers. Both of these services can be achieved through similar service chain, where the meta-data for *thick-client* customers is extracted to server earlier and later for the *thin-client* customers. Of course the products need also be further processed for the *thin-client* on the server side. But this is actually just a question of extraction time in the scope of the Production server. Thus the same raw-data can be used for producing the same services for different clients.

4.1.5 Layered Architecture

The server structure should be based on a common server frame providing the basic services and functionality for a server (see Figure 22). Within this frame separate service modules implementing different specialized services can be used. Thus the server frame can be cloned and furnished with appropriate modules, such as Name Service, Delivery system, or GIS-archive system, to get the desired server.

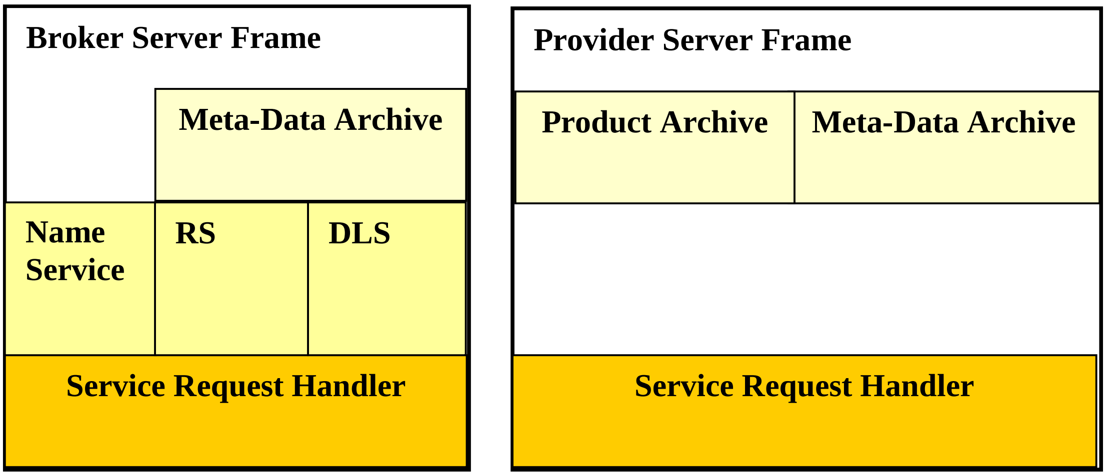


Figure 22: Example server frames and modules.

4.1.6 Conclusions

The IWICOS system should be based on a hybrid of the *Basic-Service-Model and Diminished-Broker-Model* to best serve both *thin-* and *thick-clients*. If possible, the servers should be built on a uniform server frame and furnished with modules implementing the services necessary for that particular server. This approach allows the concentration of effort, and results to better quality through reuse. However, a more detailed analysis in the implementation phase is necessary to identify the subsystems where reuse is applicable. In addition a meta-data format should be defined and used to present the available services for users and other servers, and to minimize the communication load for narrow-band clients. The representation of meta-data should be in XML and it's definition process based on RDF or XML Schema, or on some existing standard. Both thin- and thick-clients should be served using extraction of product-data on different points on service-chain. In the actual communications between the servers there are many technical approaches that must be considered before final selection, these include techniques such as CORBA, RMI, and agents. It may also be necessary to define a separate architecture model for the IWICOS-demonstration system(s) and the actual operative IWICOS service.

The following step in the development of the system is to provide a more detailed analysis of the system architecture and elaborate a specification for it and it's components. These specifications will be the basis for the actual implementation work of the system.

4.2 The prototype system

The table below maps the IWICOS reference architecture to the actual prototype system. The prototype demonstrates the objectives of the project in the various systems of the consortium members. It shows how these systems can be linked together with interchangeable data to form a richer set of services for the sea-farers working in the harsh arctic conditions. Furthermore, the prototype system addresses an open context of service-chain that can be joined by any organization wishing to contribute in this sector as data or service provider or as software vendor, as long as the common data description and a suitable subset of the selected data presentation formats is used. The service-chain approach is applied in the prototype system combined with a hybrid of the basic-service-model and diminished-broker-model. In some cases it may be reasonable to implement the provider and broker servers combined as long as this can be done without risking the interghangeability of the resulting data and the meta-data associated with it.

	Producer	**Broker**	**Presentation**
DMI Target group: • Cargo vessels • Passenger ships • Trawlers • Coast Guard • Ship brokers operating in Greenland waters	• Produce weather & sea ice information in IWICOS standard exchange format. (Observations, analysis & forecasts)	• Metadata & data exchange with other consortium members using IWICOS standard exchange formats • COTS broker will exchange data with COTS thin client	• Components-off-the-shelf (COTS) based thick and thin client implementation

	Producer	Broker	Presentation
DTU Target group: • Scientific users (on-line) • Expeditions • Selected fishing vessels	Several ice information products: • Ice concentration • Ice motion • ...	• Brokering (at least for own clients) • Meta-data & data exchange with other consortium members • Implement broker for thin-client (the service-chain model) • Brokering of satellite images (SSM/I, NOAA, ATSR, AMSR, ENVISAT) and weather & ocean forecasts (NCEP, NOAA ...) • Collection of data from free sources on the Internet and conversion to IWICOS format	• Java balanced-client[1] implementation (a thin-client that is capable working off-line) • Additional data types included to current DTU client • Client capable of merging, combining and visualising multiple data sources both off-line and on-line.
FIMR Target group: • icebreakers and vessels in the Baltic Sea	• Produce sea ice-information (in situ & forecasts) • Provide ice models • Provide ocean data and forecasts • Acquire weather data and forecasts (via DMI)	• Meta-data & data exchange with other consortium members • Provide meta-data and data for users at sea and on land in the Baltic Sea area	• End-user systems developed by the VTT
IMO / Radiomidun Target group: • Fishing fleet • Cargo vessels • Research vessels • Tourist ships • Yachts and pleasure boats • Harbour authorities	IMO / IMA / ICG Parameters: • Short range weather forecast • Medium range weather forecast • Wave forecast • Wave measurement buoys • Synoptic weather stations • Automatic weather stations • Harbor automatic weather stations • Sea ice forecast • Sea ice analysis and warnings • Sea ice reports	IMO / Radiomidun / IMA • Collect data and prepare for distribution • Prepare data for end-user presentation • Distribute data • Metadata and data exchange with other brokers and consortium members • Billing • Marketing	IMO / Radiomidun / IMA • Operational (conventional) weather service according to WMO-standards • Thin client • Thick client (End user system implementation) • Web based ordering system
NERSC Target group: • Shipping companies • Marine Operations Headquarters • Scientists and graduate students • Decision-makers in public sector and industry • The general public • Icebreakers, cargo and research vessels in the Northern Sea Route and the Barents Sea	• Generate weather, ocean and ice products (including observations, analysed data and forecasts) • Generate meta-data and IWICOS formatted products for the broker	• Meta-data & data exchange in IWICOS format, with other consortium members • Supply client-specific data formats to NERSC customers • Log access to the IWICOS products • Implement Java-based broker	• Java (thin & thick) client for users with medium/high speed network connection
VTT Target group: cargo vessels and icebreakers in Baltic Sea	• Not a data producer	• Not a service provider (co-operation with FIMR)	• Java (thick-client) implementation

Table 18 : Mapping of the Prototype System to the Reference Architecture - roles, focus areas, and demonstration objectives of the IWICOS participants in terms of the Reference Architecture.

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[1] *) Plewe, B., GIS online : information retrieval, mapping, and the Internet. Santa Fe, NM. Onword Press. 311 p. ISBN 1-56690-137-5.

4.3 Architecture and data flow

4.3.1 NERSC

4.3.1.1 Data flow

Figure 23 illustrates the production line at NERSC for the baseline products. The thick black line at the right of the production line box indicates that some format conversion will take place before the data is made available for the IWICOS End-User System and the Product Broker.

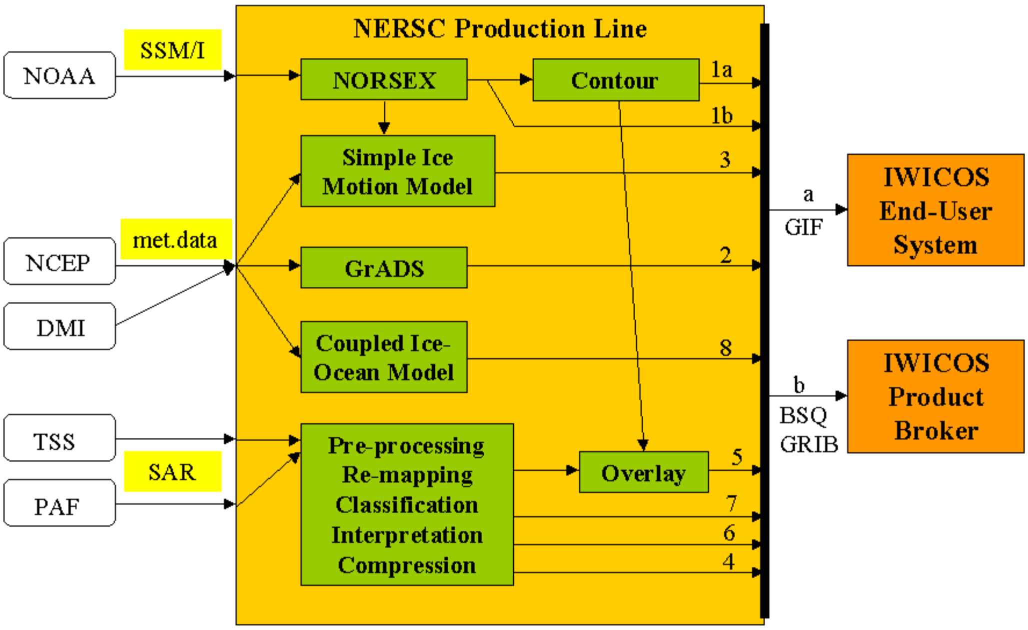

Figure 23. Generation of baseline products at NERSC.

SSM/I data from the DMSP satellites are converted to ice concentration using the NORSEX algorithm (Svendsen et al., 1983). These ice concentration data are either contoured and converted to GIF format for distribution to NERSC's End-User system (product 1a), or converted to RBG format for distribution via the IWICOS Product Broker (product 1b). The ice concentration contours from SSM/I can also be overlaid on top of a SAR quicklook image (product 5), either as GIF files for the End-User System or as a RGB file for the Product Broker. Both contouring and overlay is currently done by means of a commercial package named Uniras (Advanced Visual Systems, 2000).

Meteorological data from the operational MRF (Medium Range Forecast) model at NCEP (National Center for Environmental Prediction) and from the operational models at DMI will be used as input for the production line. The forecasted fields will be fed into the GrADS software package (Center for Ocean-Land-Atmosphere Studies, 1998), and selected parameters extracted for demonstration (product 2). In addition, meteorological data will be used as input to a Simple Ice Motion Model along with ice concentration derived from SSM/I, in order to estimate ice drift (product 3). The meteorological fields will also be input to a Coupled Ice-Ocean Model, which will produce an ice forecast (product 8). The Simple Ice Motion Model and the Coupled Ice-Ocean Model will be developed in Fortran during the baseline product development period, and build on the existing numerical model developments at NERSC. Products 2, 3 and 8 will be made available in GRIB format for the IWICOS Product Broker.

Selected SAR images from the ERS and RADARSAT satellites will be pre-processed, re-mapped to a map projection, classified (product 7), annotated with an ice expert's interpretation (product 6) or compressed (product 4) for demonstration in the baseline version of the IWICOS prototype. SAR data will mainly be taken from NERSC archives, but new images will also be used when made available through other projects, e.g. AO projects. Products 4, 6 and 7 will be made available in BSQ format for the IWICOS Product Broker.

For the extended version of the IWICOS prototype, the following products are planned:

- Monthly oceanographic data from climate models for the Arctic Ocean, the Nordic Seas and the Barents Sea, which will be put in an offline database and made available to end-users through Internet.
- Examples of ice dynamic datasets from time series of SAR images in combination with meteorological forcing fields. These datasets will be important for validation of the ice forecasting model under development at NERSC.
- Further development of ice forecasting products from the Coupled Ice-Ocean Model, for which a preliminary version will be developed during the baseline period.
- Examples of new met-ice-ocean products developed in cooperation with DTU.

4.3.1.2 System architecture

Figure 24 illustrates the system architecture for the baseline IWICOS prototype at NERSC, and links it to the common architecture developed by VTT. Black arrows show the communication paths for the Basic Service Model, while the blue arrows illustrate communication using the Diminished Broker Model. Since the latter model is the preferred one for the NERSC End-User System, which is a thin web client, this solution will be discussed in more detail below.

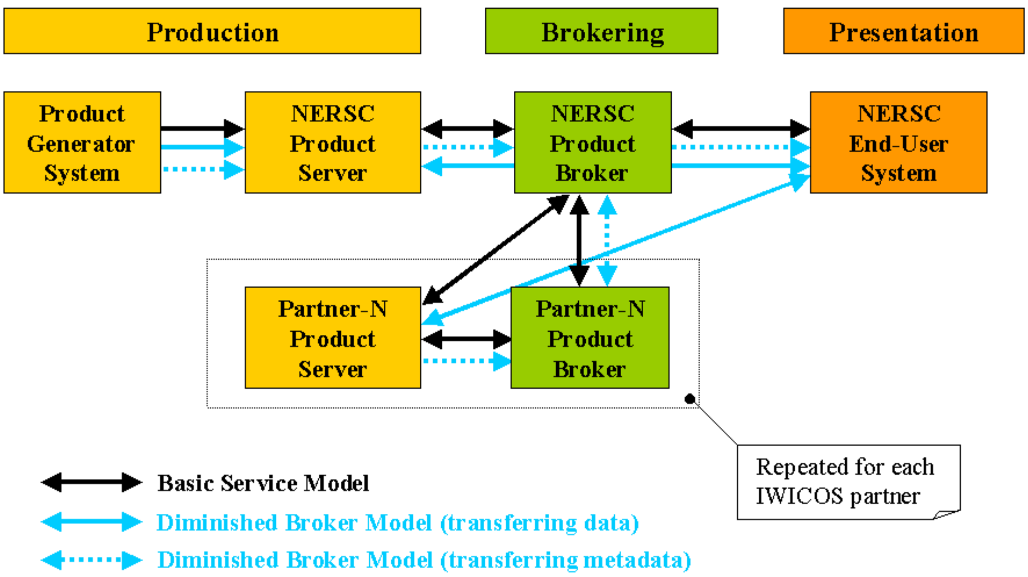

Figure 24. System architecture for the baseline IWICOS prototype at NERSC.

A Product Generator System will be used to generate the baseline products and convert them to the IWICOS format, including the appropriate metadata. The Product Server holds all products generated so far in the demonstration period, and each time it receives a new product, it passes on the associated metadata to the NERSC Product Broker. The broker, when notified of new products, sends these to the other brokers in the IWICOS prototype (i.e. it sends their metadata to the other brokers), and likewise receives metadata for products generated by the other partners. When a client (i.e. a NERSC End-User System) connects to the NERSC Product Broker, the broker sends all requested metadata to this client. Based on the provided metadata, the client selects one or more products and downloads them directly from the respective Product Server, which may or may not be located at NERSC.

This solution requires that all products developed by each partner are available for downloading through another partner's End-User System, or that each Product Broker only distributes metadata for products that are freely available to the other brokers. The second alternative is the most realistic, and will be simple to implement. All the Product Server has to do is to send an indicator Public/Restricted along with the metadata, and the broker will only pass on metadata for products with this indicator set to Public to the other brokers. In this way, the partner's client can access all products, while the other partners' clients only will be granted access to the free products.

Initially, the NERSC client will be based on the one demonstrated during the Arctic Ocean 2000 Experiment, i.e. a thin web client where the users selected data by clicking on an icon or a named link. Later in the baseline period, NERSC plan to investigate how Java can be used to develop a more sophisticated client, using e.g. applet and servlet technologies. The NERSC client will still be a thin client connected to the NERSC broker through a medium/high bandwidth network, and will use the same communication model for accessing metadata and data from the broker and server(s).

The "minimal" Product Broker is a standard web server supplying its metadata through an HTML document, as demonstrated during the Arctic Ocean 2000 Experiment. Similarly, a "minimal" Product Server will be sending its datasets by means of HTTP. Such a broker and server will work together with the initial NERSC client, but when a Java based client is developed these modules also have to be changed accordingly. For instance, the Product Broker may be developed as a Java application that communicates with the client through RMI (Remote Method Invocation) or CORBA (Common Object Request Broker Architecture).

In the baseline version, the NERSC Product Server will log access to its products, but not prepare any invoices nor include electronic payment. For the extended version of the IWICOS prototype such facilities should be considered, and may be partially solved by defining more classes of products with respect to payment, e.g. Public, PayPerView, MonthlySubscription, VolumeDiscount, etc.

All exchange of data and metadata between brokers and servers will be done by means of the IWICOS format. All metadata sent from a broker to the client will also be in the IWICOS format. Similarly, all data sent from a server to a client will be in the IWICOS format, unless another standard format has been agreed upon by the respective server and client developers. In this manner, each partner is allowed to continue to send his data to his own clients in the format already used by his customers, e.g. in GIF format for Netscape users or as *.ice files to ICEPLOTT users in the Baltic Sea. On the other hand, each partner is ensured that all products received from one of the other partners will always be in one of the common IWICOS data formats (BSQ, GRIB, Shapefile or ASCII).

4.3.2 FIMR

4.3.2.1 FIMR/VTT production line

Figure 25 illustrates the production line, data and product flow at the FIMR for the baseline and advantage products. Data formats are shown in colour code. The thick red lines indicate the IWICOS system and data flow. The IWICOS Servers (IWICOS Server and IWICOS Partner Server) shown in figure contain also the IWICOS Product Broker.

Sea ice data flow are shown top of the figure:

- AVHRR data will be received at the Finnish Meteorological Institute and delivered in *.pif format. RADARSAT SAR data will be received at the Tromso Satellite Station in Norway and downloaded manually into the FIMR. The satellite data will be re-processed: the AVHRR and SAR image format will be changed at the FIMR into *.ice used at icebreakers and ships and *.tiff format used at the ice service. Also smaller areas will be cut from the original images, geometric transformation will be made, and for those images set to icebreakers and ships, resolution must be decreased and image compression will be made.
- Apart from AVHRR data, the SST data is collected by ships and coastal stations. The data will be published part of ice charts.
- Ground truth means ground ice observations made by the icebreakers, ships and coastal stations.
- A 40 km grid ECMWF (European Centre of Medium Range Weather Forecasts) are used as inputs in ice drift model.
- ICEMAP is the Unix basis satellite image and ice analysis and chart production application at the Finnish ice service.
- Automatic SAR image classifications will be produced showing ice deformation degree.

Oceanographic data flow is shown at the bottom of the figure:

- HIRLAM data is used as input to wave models. Two types of models will be used PWM (Parametric Wave Model) and starting in 2001 also WAM.
- Sea level forecasts will not be included, only data will be made available.

Used data formats are shown in various colours. The thick arrows indicate the IWICOS system and data flow. IWICOS Partner Server contains also the IWICOS Product Broker.

Information products shall consist of sea ice products:

- Digital ice charts in WMO symbols,
- AVHRR and SAR images,
- Automatic SAR image classifications maps
- Ice drift forecasts in text and chart format.

and ocean products:

- Wave and water level measurements including last 24h data
- Wave forecasts in text and chart format over the Baltic Sea

Presentation system onboard ships will be developed. A part of products will be made available on Internet.

For the extended version of the IWICOS prototype (marked red in Figure 25), the following products are planned:

- Automatic SAR image classifications including ice history (ice thickness, ice type, ice concentration) (FIMR)
- Further development of ocean products including WAM products (FIMR)
- SAR ice image forecast (VTT)

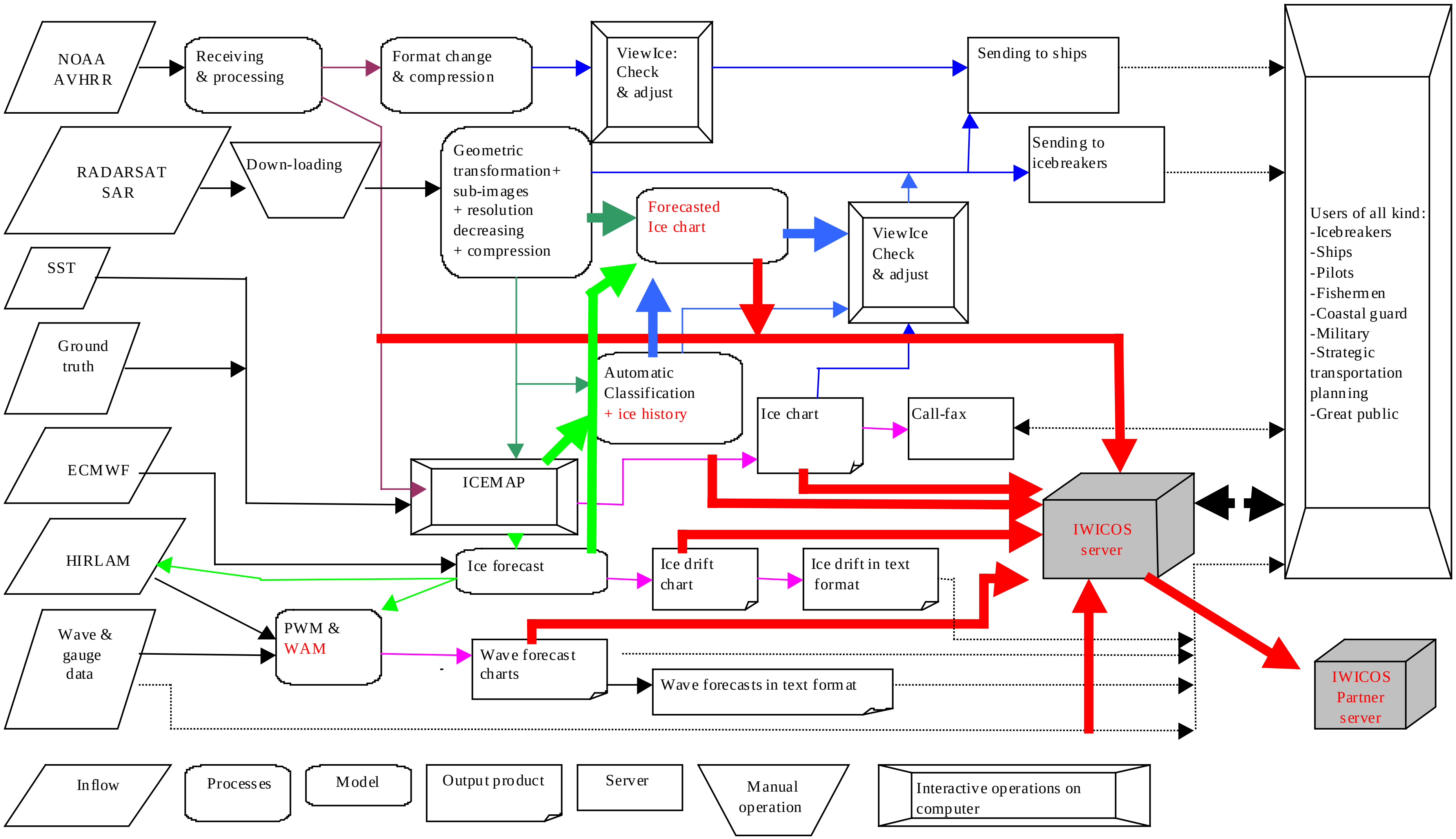

Figure 25. The IWICOS baseline and extended FIMR and VTT flow of data and information products (v 1.0).

4.3.2.2 FIMR and VTT system architecture

Figure 26 illustrates the system architecture for the baseline IWICOS prototype for FIMR and VTT.

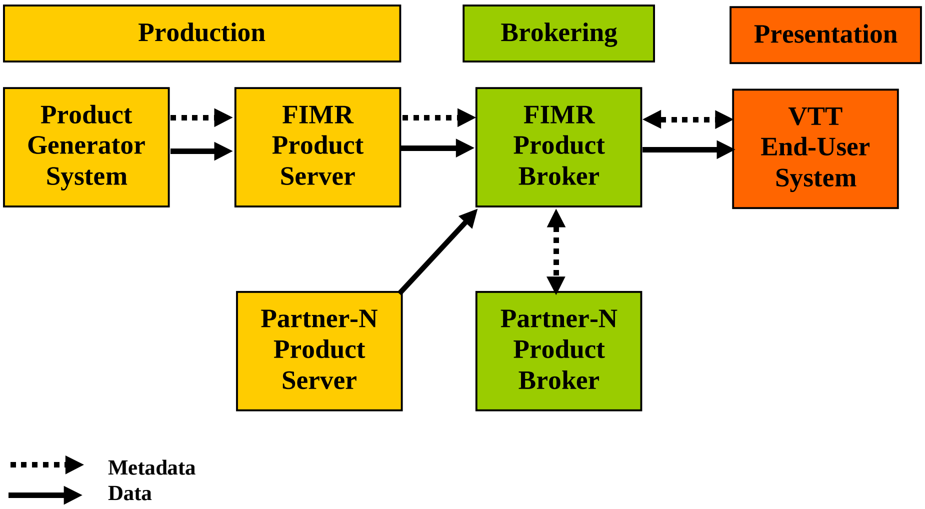

Figure 26. System architecture for the baseline IWICOS prototype at FIMR/VTT.

A Product Generator System will be used to generate the baseline products and convert them to the IWICOS formats, including the appropriate metadata. The Product Server holds all products generated so far in the demonstration period, and each time it receives a new product, it passes on the associated metadata to the FIMR Product Broker. The broker, when notified of new products, sends their metadata to the other brokers in the IWICOS prototype, and likewise receives metadata for products generated by the other partners. When a client (i.e. a VTT End-User System) connects to the FIMR Product Broker, the broker sends all metadata to this client (the metadata may be filtered somehow, this will be specified later). Based on the provided metadata, the client selects one or more products and makes a request for the FIMR Product Broker for them. The FIMR Broker then downloads them from the respective Product Servers and passes them on for the VTT End-User System. This solution is based on the fact that the communication between FIMR broker and VTT End-User System may be point-to-point only and no Internet access is possible for the End-User System itself.

This solution requires that all products developed by each partner are available for downloading through another partner's Product Server, or that each Product Broker only distributes metadata for products that are freely available to the other brokers. The second alternative is the most realistic, and will be simple to implement. All the Product Server has to do is to send an indicator Public/Restricted along with the metadata, and the broker will only pass on metadata for products with this indicator set to Public to the other brokers. In this way, the partner's client can access all products, while the other partners' clients only will be granted access to the free products.

The VTT client will be a thick client connected to the FIMR system. At Baseline System the implementation of downloading products from other servers may be optional.

In the baseline version, the FIMR / VTT System will log access to its products, but not prepare any invoices nor include electronic payment. For the extended version of the IWICOS prototype such facilities should be considered, and may be partially solved by defining more classes of products with respect to payment, e.g. Public, PayPerView, MonthlySubscription, VolumeDiscount, etc.

All exchange of data and metadata between brokers and servers will be done by means of the IWICOS formats. All metadata sent from a broker to the client will also be in the IWICOS format. Similarly, all data sent from a server to a client will be in the IWICOS format, unless another standard format has been agreed upon by the respective server and client developers. In this manner, each partner is allowed to continue to send his data to his own clients in the format already used by his customers, e.g. in GIF format for Netscape users or as *.ice files to ViewIce and IBPlott users in the Baltic Sea. On the other hand, each partner is ensured that all products received from one of the other partners will always be associated with metadata specifying the format that is used for the data whatever it may be (BSQ, GRIP, GIF, ICE, XML based IWICOS text format, etc.) .

4.3.3 DMI

4.3.3.1 Data flow

Figure 27 depicts the general IWICOS related data flow at DMI. A number of DMI products will be available to IWICOS, i.e. model fields from the HIRLAM weather model, meteorological observations, satellite data and analysed ice charts. Satellite data are received by DMI through a number sources, e.g. directly from DMI receiving stations and via ftp from foreign stations, in particular stations within the RADARSAT network. All satellite data are subsequently processed by DMI, e.g. calibrated, filtered and geometrically corrected.

Satellite data, model output and meteorological observations constitute the necessary input to the sea ice analysis process during which ice charts are produced by visual interpretation of available data by experienced ice analysts.

The DMI product generation layer will produce the IWICOS products and associated metadata including products using the IWICOS common exchange and metadata formats. The product generation layer will consequently, if required, reformat products and collect or produce metadata as defined by IWOCOS. The product generation layer will also generate new basic products from the available input data, e.g. contouring of model fields, extraction of an ice edge from an ice chart etc. Subsequently the products and associated metadata files will be transferred to the IWICOS product server(s) where they will be available to end user clients.

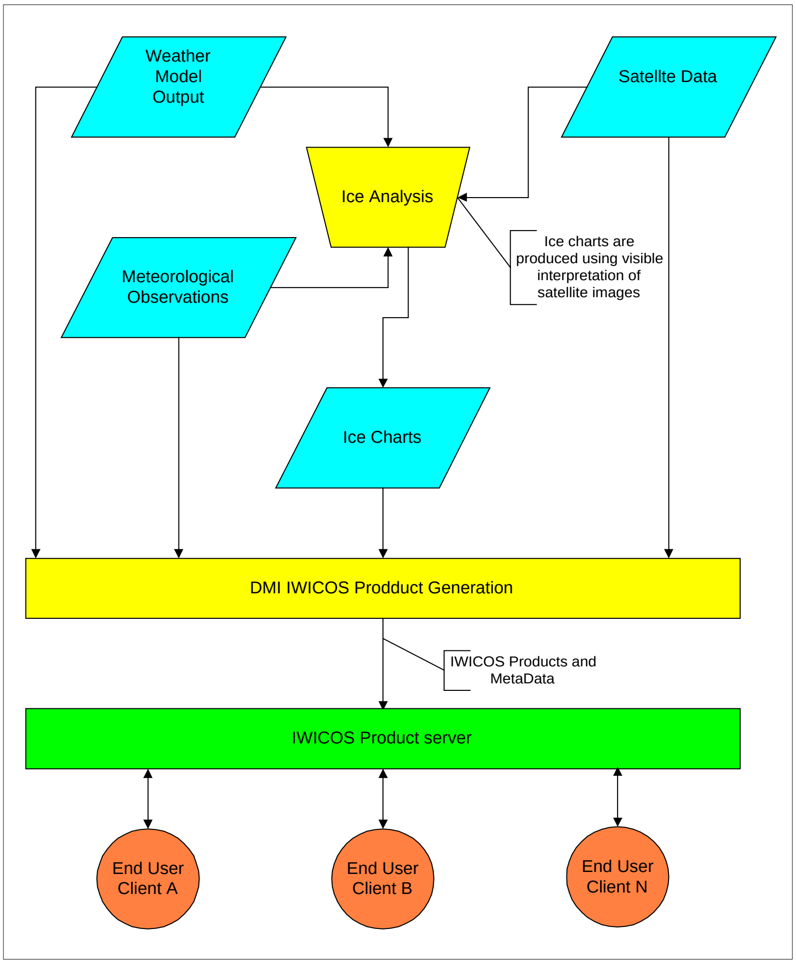

Figure 27. IWICOS product generation at DMI.

4.3.3.2 System architecture

The system architecture is illustrated in Figure 28.

Two solutions are shown: the thin client and the 'off line' thick client solution. The 'off-line' thick client solution will be described first. In the part of the development phase a profile of the 'off line' users involved in the demonstration will be maintained. This profile will include a description of the products that the given user is interested in. When a given product or product assemblage is available at the product server a package containing the product(s) will be emailed to the user. If the information package is send to the users mail server, which is only checked e.g. twice a day, an email is also send from the broker / mail handler directly to the user through INMARSAT Standard C. At a later stage during the development phase a more flexible method may be added, i.e. a product or metadata list will be emailed to the user enabling him or her to select products of interest and order these by sending an email request to the mail handler which will request the necessary product(s) from the product server through the broker. After reception of the package by email the information are unpacked to the local computer and thereafter available to thick 'stand-alone' client for display and analysis.

The thin client baseline solution is based on a commercial product called ESRI's Internet Map Server (ArcIMS). The system architecture for ArcIMS is described in (ArcIMS, 2000) and the architecture outline below will reference that document.

ArcIMS has a multitier architecture consisting of presentation, business logic tier and data storage tiers. The presentation tiers includes the ArcIMS viewers. The business logic tier includes the web server, ArcIMS application server, ArcIMS application server connectors and ArcIMS spatial server. The data storage tier includes the sources of data. Communication between the tiers is handled through ArcXML, which is the ArcIMS version of XML.

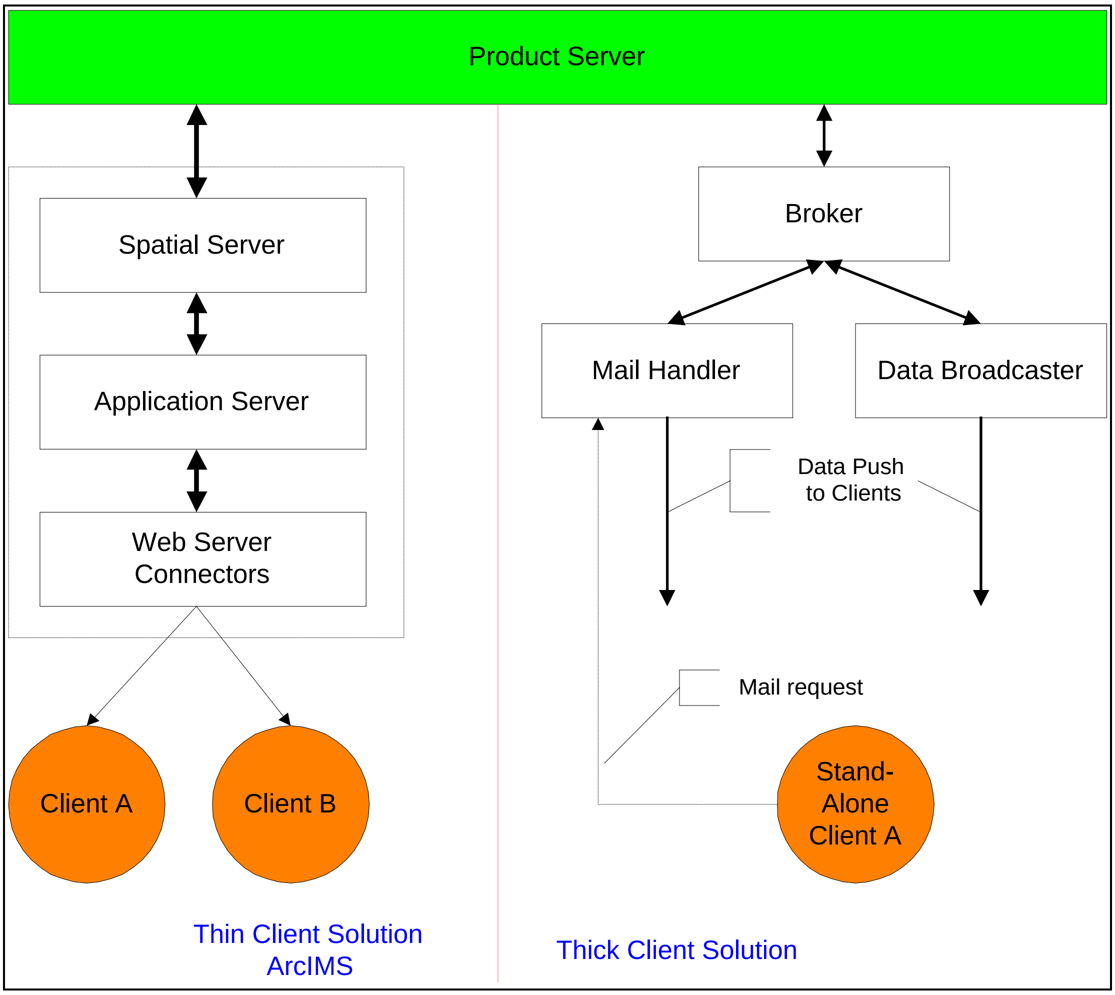

Figure 28. System architecture for DMI baseline system.

The client consists of the presentation tier components. The ArcIMS viewers are used to send requests and to view maps and data. The three viewer types are ArcXML clients, HTML/DHTML viewers, and Java viewers including the freeware viewer ArcExplorer 3.

The ArcIMS business logic tier contains the components that are needed to process requests and responses and to run MapServices. These components include the ArcIMS application server, the application server connectors (communication link) and the spatial server. A web server and Java servelet engine are an integral part of this tier. When an ArcIMS request is made, the request is first handled by the web server, passed through the servelet connectors and then handed to the ArcIMS application server. The application server hands the request to an ArcIMS spatial server.

The application server runs as a daemon and handles the load distribution of the incoming requests and tracks which of the Mapservices are running on which ArcIMS spatial servers.

The ArcIMS spatial server is the backbone of the ArcIMS. The spatial server provides the functional capabilities for accessing and bundling maps and data into the appropriate format before sending the data to a web server. When a request is received several functions may be performed i,e,

- *Image rendering* generates maps to the web browsers as JPEG, PNG or GIF.
- *Feature streaming* sends shapefiles in a compressed binary format to a Java Applet in the client web browser. Feature streaming is a temporary format that remains only as long as the Java Applet is open. The Java Applet receives instructions on how to assemble the data once it is received. Feature streaming allows for more funtional capabilities on the client side such as labeling, change of appearance and spatial selection.
- *Query* returns associated data for spatial tabular queries. Queries can be build against shapefiles.

- *Data extraction* return data in the shapefile format. A request is sent to the server to extract data from shapefiles and the associated data is sent back to the client.

A MapService is a process that runs on the ArcIMS spatial server. It provides instructions to a spatial server on how to draw a map when a request is received. ArcIMS supports to types of MapServices: Image and Feature.

- An Image MapService uses the image rendering capability of the spatial server. When a request is received a map is generated on the server and the response is returned as a JPEG, PNG pr GIF image. A new map image is generated each time a client requests more information.
- A Feature MapService uses the spatial server's feature streaming capabilities. Because more processing is performed on the client, requests are only sent to ArcIMS spatial server when additional data is needed.

The ArcIMS clients may be one of the following:

- The HTML/DHTML viewer is written using HTML, DHTML and JavaScript. In this environment only one Image MapService ca be displayed at a time.
- Java viewers. As compared to the HTML/DHTML viewer these viewers are thicker clients because these support both Image and Feature MapServices. Multiple MapServices can be combined with local data and viewed in the same Java Viewer. The viewers use a Java 2 Applet for displaying the information and handling requests. The Java viewers support feature streaming and more client side processing. Data that are streamed to the Java viewers is temporarily cashed on the client machine. ArcIMS includes to Java viewers: a custom (using JavaScript) and a standard with predefined functionality. Java viewers necessitates two downloads. The first is the Java run-time environment, which is required when Java 2 Applets are used. The second is a one-time download for the ArcIMS viewer components so that the Applet can communicate with the server. ArcIMS also includes an ArcExplorer 3 stand-alone Java based client that does not require a browser.

4.3.4 DTU

The philosophy of the DTU/DCRS processing system (Figure 29) is based on the following:

- Original data are gathered from the internet on a regular basis (several times per day/hour depending on the type of data and the source).
- Import functions to transform images to a common DCRS image format are used
- Import functions to transform vector data to a common DCRS format are used
- Image processing is performed at the DCRS format stage
- Output data are converted to formats that allow high compression rates and are suitable for easy WWW distribution (gif/jpeg for images, ascii for most other data)

The DCRS baseline products will be integrated into DCRS's existing end-user system as well as into the IWICOS broker system. However, data from certain sources may only be available in the DCRS system due to copyright issues.

The DCRS client (end-user) system is a hybrid thin/thick client that allows a certain amount of manipulation of the data on the client side while maintaining a small code-size for easy use in a standard web browser using no auxiliary software. The same client is used on-line as well as off-line.

4.3.5 IMO

Figure 30 illustrates the production line at IMO, both current products and baseline products for the IWICOS system. The thick black line at the right of the production line box indicates that some format conversion will take place before the data is made available for the IWICOS End-User System and the Product Broker.

The baseline products will be integrated into IMO's and Radiomidun's existing End-User Systems as well as into the existing Broker Systems. Special care will be taken to comply to WMO standards for Marine Meteorological Services.

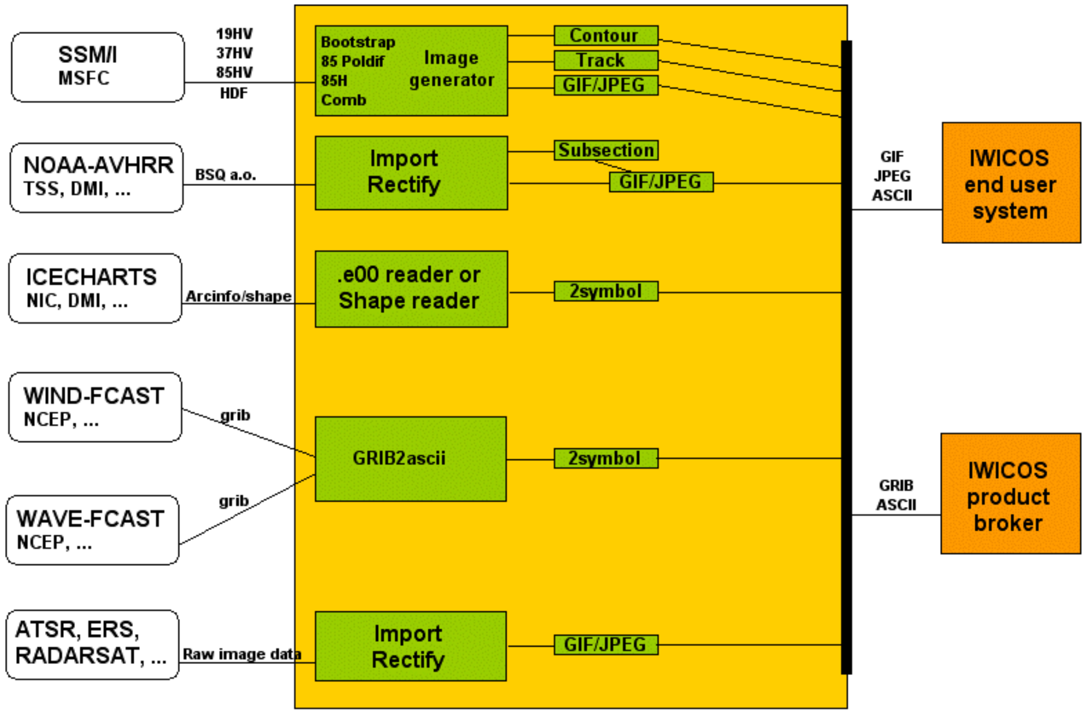

Figure 29. IWICOS product generation at DTU/DCRS

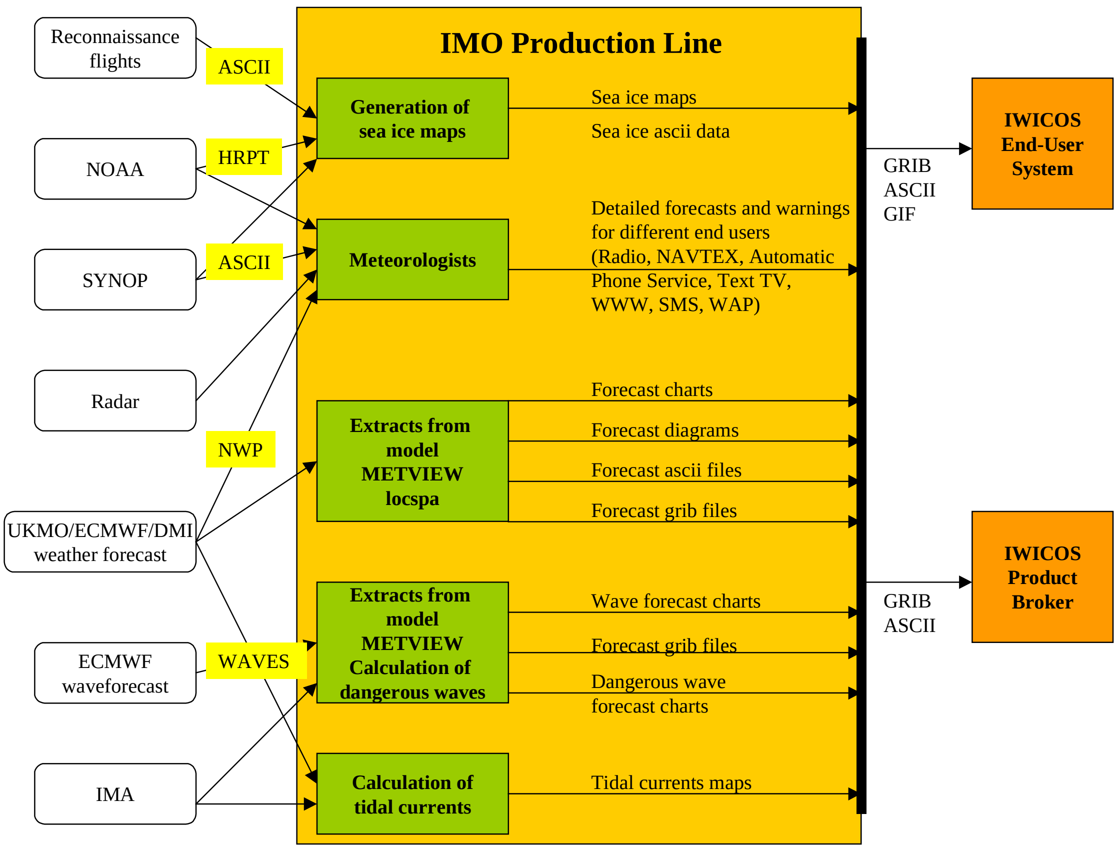

Figure 30. IWICOS product generation at IMO.

4.4 Functionality

4.4.1 NERSC

A simplified view of the processing chain in IWICOS is shown in Figure 31, with the terminology used in the Technical Annex above the terms used in the reference architecture defined by VTT.

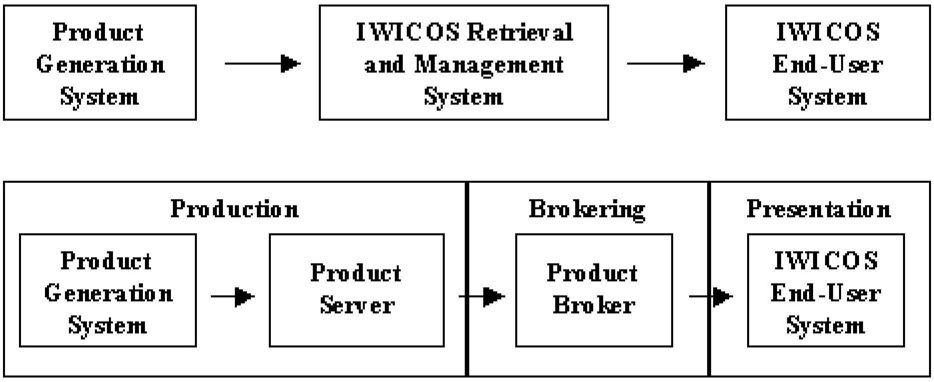

Figure 31. NERSC view of processing chain in IWICOS.

The Product Generation System (PGS) consists of software and hardware facilities installed at the different providers' sites. The PGS is responsible for preparing the products that will be made available through the IWICOS Retrieval and Management System, which in turn is responsible for transmitting a selection of products to the IWICOS End-User System. In VTT's reference architecture the Retrieval and Management System is composed of two main subsystems termed the Product Server and the Product Broker. The Server will hold all products generated by a data/ice centre and forward metadata describing the available products to the Broker, which is responsible for disseminating this to the End-User System that enables the end-user to to choose among the products and download those selected.

All providers already have a PGS in place, and further development/customisation for use in IWICOS is for the purpose of generating products for the demonstration periods. Thus, the PGS must adhere to the common IWICOS format, but the programming tools used for implementing the various met-ice-ocean algorithms/models are up to the individual data provider. As a consequence, the software or hardware components in these systems will not be part of the IWICOS demonstrator system, which is a deliverable to the EC (D4 and D5).

The IWICOS Retrieval and Management System will be designed and implemented in the project (in WP322 and WP522), and will manage clients' requests and delivery of products. This system has now been split into the Product Server and the Product Broker, whose functionality and architecture are described in Section 4.1. Each Product Broker must be able to communicate with the other brokers, and the Server of each partner must also satisfy product requests from the other partners' brokers as well as thin/thick clients.

The baseline version of the IWICOS End-User System for the Northern Sea Route will be a thin Internet client, with limited (if any) analysis capabilities. The baseline version must support ordering, downloading and display of data/products (including overlay of ice parameters on top of SAR images, but not animation facilities).

It is foreseen that the extended version of the IWICOS End-User system will run onboard vessels, and enable the captain or other crew members to obtain, display and (optionally) further process a suite of met-ice-ocean products. The extended version will then have to include a module that allows products to be downloaded via satellite communication from data centres on land. It will also provide simple analysis facilities, to be defined during the revised design phase undertaken after the evaluation of the first version of the prototype.

The baseline PGS at NERSC will provide the following functionality:

- Standard pre-processing of SAR data (normalisation, resampling, georeferencing, etc.)
- Standard pre-processing of SSM/I and AVHRR data
- Extract ice motion from pairs of SAR, SSM/I and AVHRR images
- Classify ice types in SAR imagery
- Estimate ice concentration from SSM/I data
- Extraction of the ice edge from ice concentration data
- Combine SAR and SSMI/I ice concentration data into a new product
- Export all products in the IWICOS common data format

The extended PGS will in addition provide the following functionality:

- Composition of ice charts using standard WMO or Russian egg code notation
- Combine SSM/I data with predictions from coupled ice-ocean models
- Generate ice dynamic data sets from time series of SAR
- Extract fields of sea surface temperature, wind speed and wave height from ocean models

The baseline IWICOS Retrieval and Management System at NERSC will

- Handle orders from the End-User System, and prepare and transmit the requested products in a format that is suitable for transmission via Internet
- Log downloading of products (all products will be free, so there is no need for invoicing)
- Link to other IWICOS Server systems if the requested product was not available at the NERSC site, retrieve it from the data owner and transmit it to the end-user
- Provide metadata for NERSC products for access through the other providers' sites
- Handle requests from other data providers for products that reside on the NERSC server

The extended IWICOS Retrieval and Management System at NERSC will in addition

- Maintain a database of customers that can order products from the system, and lists of products actually downloaded by each of these
- Perform authorisation checks to ensure that only registered customers and other IWICOS servers access 'commercial' products
- Handle orders from the End-User System, and prepare and transmit the requested products in a format that is suitable for transmission via satellite communication
- Provide facilities for electronic payment and invoicing

The baseline End-User System for NERSC's customers will

- Provide facilities for downloading products from the NERSC or other partner's Product Server
- Enable the user to display the downloaded products
- Enable the user to overlay satellite imagery from different sensors or dates
- Enable the user to overlay ice parameters from SSM/I (e.g. ice edge) on top of a SAR image
- Enable the user to overlay meteorological and ocean parameters on top of SAR imagery

The extended End-User System for NERSC's customers will in addition

- Provide facilities for ordering and downloading products via NERSC's Product Broker
- Enable the user to display all products, and to perform operations like zooming and printing
- Support simple image processing functions like contrast-stretching, edge enhancement, etc.
- Animate ice dynamics from time series of SAR images
- Based on end-users' feedback: May include SAR ice algorithms, direct download of satellite data (AVHRR) onboard vessels, link to instruments onboard to obtain in situ data, integration of Russian satellite data, etc.

Comments:

- For inclusion of e.g. SAR algorithms, it is required to transmit the original SAR data to the vessel and not just compressed version like JPEG, from which the original data cannot be reconstructed. Compression of image data will still be needed, but the algorithms used must be information preserving, i.e. the end-user system must be able to decompress the files without loosing any information.

4.4.2 FIMR & VTT

The functionality can be divided according to what is needed in different parts of the production chain. The functionality required for generation of the products is depicted in Figure 25. In addition to the functions shown in this figure, the automated parts of the production chain need managing and monitoring functions. The FIMR Product Broker needs functions for handling Metadata and communicating with other Partners' Brokers and presenting a compiled list to the users.

On the Client side a thick client solution will be used. The application contains the basic functions for viewing images and other georeferenced data using overlay techniques. The user is able to zoom and pan the map with its overlaid images and charts. When connected to a navigation device such as a GPS, the map is autoscrolled to always keep the current position visible.

If the image is too light or dark, the contrast can be adjusted interactively. The histogram of the adjusted image is then shown as a guide to the user.

A route can be drawn by clicking on the map. The route can then be saved and opened later on. Editing the route, i.e. changing the position of a waypoint in the route, is done by dragging. The coordinates of the waypoints and the length of the route can be displayed in a separate window. Thus different route alternatives are easy to compare both graphically and in numerical form.

The main focus of the further development will be on designing a User interface suited for presenting time dependent (dynamic) georeferenced data. The Client application will be enhanced with functions for easy change of time of reference, tailored to the forecast products.

In the case the products come from different sources, although displayed as overlays, the source of the data should be made visible to the user (for responsibility and quality control reasons) .

4.4.3 DMI

At the moment there is in praxis two sorts of users one who has continuos access to the Internet (typically land based users) and one who will log on a server, twice a day or when needed, and gets the information via an email service (typically ship based users).

Two different clients will be developed, a so-called thick client for the ship based user and a so-called thin client for the land based user. The functionality available and type of data flow will depend the type of client. Typically, the thick client will come with a lot of build in functionality while the thin client will perform some of the tasks but other will be executed by the server on which the data reside. The thick client which will be developed by DMI will only work on local data as it is impossible to be continuously connected to a server due to communication constraints. On the other hand the thin client may work on both local and server based data sets.

One may try to identify a set of basic functions which should be available on both type of clients. In particularly it should be possible to:

- View and combine raster and vector (local and server based) data sets
- Display of attribute values (tables)
- Viewer zoom and roam
- Cursor id and query
- Get positional information
- Turn layers on and off
- Use different symbology schemes and change size of symbols and lines etc.
- Project of vector data
- Display lat / lon grid
- Annotation
- Print

Furthermore for applications oriented towards ships:

- Insert and edit way points
- Digitise legs
- Calculate distance and course
- Connect to GPS

On the production / server side some of these functions may be appropriate:

- Product generation
- Production of satellite images and products based on satellite data
- Compression of satellite images
- Extraction of information from ice analysis
- Contouring of model fields
- Re-projection of vector layers
- Re-format data sets
- GIS analysis

4.4.4 DTU

Our primary users has a number of requirements to functionality. Some want simple standard products that they can zoom in and out, click and get further info etc. Others want large flexibility so they can perform their own analysis with the client tool.

Most of our users are anonymous Internet users, and they require a reasonably thin client that can be transferred over a reasonable line in short time. Megabyte clients will not work. Other users will have the software installed on-board from a CD or floppy-disk, and there will be no restrictions to the size of the client.

All users want data packages to be small (less transfer time), we have found that package sizes in the order of 30-50 KBytes can be handled by most users.
The user should be able to combine raster and vector layers.
The user should be able to print out from the client.

Cruise planning tools (cruise track, distance, heading etc, ice ocean and weather conditions along the route.

Ice forecasts (24 –48 hours) would be very helpful to bridge the gap between observations. We might think of implementing a simple free drift ice model in the code for the client, so the user can perform her own ice forecast using either winds supplied from us, or winds from other sources. If he receives an ice chart that is already 12 hours old, and he wants to use it for the next 24-48 hours until he gets a new one, he will have already his own wind data for the first 12 hours. Weather forecasts are used a lot.

There will be an interest in swell/wave height and direction forecasts.

4.4.5 IMO

The functionality will greatly depend on the user’s requirements. As said earlier, the functionality differs from one customer to another. A user who has access to a good Internet connection will only need a browser, as a user with limited access to the Internet will need a more sophisticated stand-alone software. The service providers should be able to provide data or information at different production levels.

There should not be any problem to view different data from different offices as long as it is relevant. Ice data from different offices could for example be interesting to view as layers.

Users with Internet connection:
- need a browser
- are able to select the appropriate server (Met/Ice office) on-line

- are dependant on the functionality implemented by the service providers
- can receive big quantities of information
- can choose between various available versions of end products with similar but not necessarily the same functionality

Off line users:
- need a stand-alone software package which is able to use standard data formats
- need to have a service agreement with one or more content providers
- are dependant on communication capabilities and may therefore need highly compressed data
- must rely on the functionality offered by the software package

Examples:
A captain of an icebreaker in the Baltic will most likely want to use an Internet browser to wiew some Finnish webpages as he already has an Inmarsat A or Inmarsat B satellite communication terminal with a full access to the Internet. A research vessel off the coast of West-Greenland might be more interested in data from Danish webpages.

The functionality of the Internet servers can then be copied and implemented in the commercial stand-alone software packages. It depends on each manufacturer what functionality will be relevant for his clients. The data will be transmitted through Inmarsat Mini M (for example) and the captain will use software package to display the data on board. An Icelandic captain will use the same method of receiving the data but he might be more interested in Icelandic data for his integrated navigation system, which is of different type than that of the research vessel off West-Greenland.

Distribution of data/information

When new met-ice-ocean products are developed, one shall have in mind what kind of data/information services is available and what might be foreseen in the nearest future. Due to the narrow bandwidth that is available to off line users (ships), it is necessary to structure the services accordingly.

The following services are available today.

- Radio broadcast
- Coastal station services
- Navtex system
- Text TV (teletext)
- IMO’s premium rated phone service
- IMO’s fax service
- IMO’s web side
- Icelandic Maritime Administration’s web side
- Radiomiðun’s Service Bank

The above services are based on phone lines, the NMT mobile phone system, Inmarsat satellites, Iridium satellites and radio waves.

4.5 Possible software solutions

4.5.1 NERSC

- NERSC is currently developing software for ice and ocean applications using commercial packages such as Matlab and ER Mapper, as well as by traditional programming languages (C, C++, Fortran) and public domain packages (Utah Raster Toolkit, Pbmplus, libtiff, etc.)
- As a demonstration in IWICOS, NERSC is currently providing SSM/I ice concentration, AVHRR, SAR and meteorological data for TV2 (commercial TV channel) in during the Arctic Ocean 2000 expedition. (URL: http://sofia.nrsc.no/ao2000/)

- In the MARSAS project for the Norwegian Space Centre, NERSC will implement a set of ice algorithms in a pilot version of an ice monitoring system. This activity is linked to the development of ice products in IWICOS.
- The development of algorithms for ice kinematics from SSM/I will be done in another project for the Norwegian Space Centre. This work is also linked to the product development in IWICOS.
- Use/Selection of GIS in IWICOS: TBD.

4.5.2 FIMR

See sections 4.5.3, 4.3.2.1 and 4.3.2.2.

4.5.3 VTT

VTT will base its client software solutions on the existing ViewIce application (URL: http://www.vtt.fi/tte/pub/tte1/viewice/) and possibly on prototypes that are built using the JGIS framework developed by VTT. Also other JAVA-language packages for performing specific tasks may be relevant for the implementation.

4.5.4 DMI

The following list of software solutions have been selected because they fit nicely into the current COTS strategy adopted by the Ice Service. However, the final selection of software will depend on the outcome of the IWICOS design phase.

A thick client solution may be prototyped using ArcView, a commercial desktop Geographical Information System. ArcView, that is used for many different applications at the Ice Service, provides various out of the box capabilities but may also be customised using an object oriented programming language called Avenue. Thus focused application may be build. From our point of view ArcView seems to be an excellent tool during the prototyping phase during which various different functions, presentation scenarios and user requirements have to be tested and refined and also for demonstration purposes. However, due to the cost of an ArcView license it is not feasible to let more than a few users test and use an ArcView based application and the development will be strongly dependent on one particular commercial software package. But the experiences, identification of useful functionality and user responses may be beneficial for more public domain oriented applications developed within IWICOS. ArcView seems to be an appropriate choice if flexibility is a key issue and if it is important to shorten the distance from idea to implementation, i.e. focus on the products rather than software development, due to resource shortage.

On the server side a high end GIS (Arc/INFO) may be used for complex GIS analyses, data processing and formatting.

A thin client / server solution may be tested using the new Internet Map Server technology, e.g. ArcIMS from ESRI. The Internet Map Server technology is developing rapidly at the moment and many examples can be viewed on the Internet, e.g. http://maps.esri.com/. Using this technology we will also get a lot out of the box capabilities but still at the expense of control over the software components, especially the clients. However, we anticipate that this may change in the future.

4.5.5 DTU

DTU’s software solution consists of a server side and a client side. The Server side handles product generation in terms of acquiring the raw input data, performing geocoding, performing data compression and performing simple subsection extraction. These tasks are almost fully automated via a set of UNIX shell scripts.

The client is a Java applet that runs within a web browser (IE or Netscape). It allows the user to

- Select and load image data
- Manipulate colour
- Pan/zoom in and out
- Calculate distances
- Lat/lon coordinates of any point at a mouseclick

- Add vector graphics such as
  - Depth contours
  - Lat/lon grids
  - Ice concentration contours from SSM/I (todays, yesterdays and others)
  - Coastlines
  - Cruise track
  - Vector ice charts (with ice egg info at a mouseclick)

4.5.6 IMO

The goal is to enable the user to access and use the output from met-ice-ocean forecasts in as efficient way as possible.

It is evident that user's requirements are very different, as previously stated. This mainly depends on:
- The type of user (off-line users, yacht owners, icebreaker captains, fishermen, on-line users who are connected to the Internet)
- The location (Baltic ocean, Barents, Iceland etc.)

When products are improved or new invented for different users in different locations, participants must take into account the limitations in today's bandwidth.

The communication possibilities today are:
- Radio broadcasting
- Navtex
- NMT mobile phones
- GSM mobile phones
- Satellites (Inmarsat, Emsat, etc.)

In order to meet our objectives we belief that the following points have to be respected:
- Met-ice-ocean information shall be presented on the Internet in an easy and understandable way (on-line users).
- Met-ice-ocean data shall be available for anyone who requests to process the data off line (off-line users).
- Met-ice-ocean information can be presented in many different ways, all depending on the producer of the software used.
- Each met/ice office shall be fully independent of how they want to display their data to the public in each country.
- All met/ice offices shall agree on specific formats regarding different type of data in order enable users to use data from different countries.

It is our strong belief that each meteorological office shall not be restricted from developing its own presentation of met-ice-ocean data. However, it is vital that the format of the data, which will be sent between all parties, is standardised.

Data produced by one party shall be sent by the producer to those who request it, but not collected and distributed from a centralised server.

It might be efficient to standardise the programming language among participants (i.e. Java) but it shall not be a restriction if someone wants to use another programming language. Development time could obviously be shortened if software modules could be shared.

By following the guidelines above, we believe that we will increase competition between participants regarding presentation of the data, and at the same time give ordinary users access to the best data and information available.

Content providers like Radiomidun shall distribute data to off-line users.

Commercial software products which are relevant for the IWICOS project, probably count in hundreds. The main purpose of these products is to integrate the various fishfinding and navigation equipment on board a vessel, process the data and display various types of information in a graphical way. Later on these integrated information systems have been improved in such a way that they can visualize or display any kind of information, including weather. This enhances the captain's work drastically and increases safety.

The International Maritime Organization has issued a standard for such products, which is called ECDIS (Electronic Chart Display and Information System). Special electronic charts (S-57) are made for the ECDIS system, which the International Hydrographic Office has issued. The ECDIS system, with its S-57 charts, has the function of sounding an alarm when a ship is approaching or entering into potentially dangerous areas. Various powerful functions of ECDIS will assist the chart works and radar images as well as ARPA (Automatic Radar Plotting Aid) data can be superimposed onto the ECDIS system.

Only few producers are able to comply with the ECDIS standard today, but those systems that do not comply are often referred to as Electronic Chart Systems (ECS) or Integrated Navigation Systems (INS). Owners of cargo vessels are the potential customers of ECDIS systems were as owners of fishing vessels are buying ECS or INS systems. The most advanced ECS or INS systems can already read GRIB format and display weather information graphically.

The most known products on the market are:

- MaxSea, Mainly Fishing, Cargo and Pleasure boats
- Quadfish, Mainly Fishing and Cargo
- Sodena, Mainly Cargo and Fishing
- SeaPlot, Mainly Fishing
- NavTreck, Mainly Pleasure
- Infonav, Mainly Fishing and Cargo
- Transas, Mainly Cargo, Pleasure and Fishing
- Norcontrol, Mainly Cargo and Fishing
- Hitec (Kværner), Mainly Cargo
- Littion Marine, Mainly Cargo and Fishing
- Atlas Electronics, Mainly Cargo
- Kelvin Huge, Mainly Cargo
- Furuno, Mainly Cargo
- Maris, Mainly Cargo

4.5.7 Java technologies

Below is brief descriptions of some Java/GIS toolkits. Most of the text is from the listed web pages.

OPEN GEOSPATIAL DATASTORE INTERFACE (OGDI) products from Global Geomatics:
The OGDI product line comprises three software components for use in geographic data access and distribution; System Integrators and Independent Software Vendors now can integrate these components into their own applications thereby eliminating the need for the costly data conversion that is frequently required to access geospatial data.
The three products are:

- OGDI Client APIs (for Java™ and C Client)
- OGDI Servers
- OGDI Adapters (supports various data formats)

The products interact together and may be configured in single-, two- or multi-tiered modes, according to the target computing environment. For use on the Internet a single OGDI Server can disseminate geodata to a large number of widely dispersed users; in a LAN (Local Area Network or any other intranet environment) an OGDI server may be used with a number of local client applications (applets). Complete documentation on these OGDI components follows, together with directions for their complementary usage.
URL: http://www.globalgeo.com/products/

LuciadMap is an API for spatial data visualization in a Geographical Information System. Being entirely written in Java, it is ideally suited for developing Web applications with geographical content that require a high level of interactivity with the end user. It satisfies the real-time performance requirements of operational display systems. LuciadMap is open to multiple data formats and not dependent on any particular proprietary data server. LuciadMap combines raster and vector data, both 2D and 3D. LuciadMap supports multiple map projections and handles all necessary transformations when displaying multiple data sources with different geographical references. The geodetic calculations on the ellipsoidal model of the earth are fast and accurate.
URL: http://www.luciad.com/

The ACA ToolKit is a set of functions, utility programs, and objects, designed to support the efficient building of interactive information and decision support systems in the domain of environmental planning and management. The main objective of the ACA ToolKit is to provide users of our software products the option to modify the systems at the source code level. The ACA ToolKit , developed over the last ten years, has undergone several revisions and complete re-implementations, and represents a cumulative development effort of more than 50 person years. The ACA ToolKit , including a maintenance and support program, is available for licensing for end users and our application development and user support partners. Contains libgisdb 89 - a GIS map handling and data management library. Developed by Environmental Software and Services GmbH, Austria.
URL: http://www.ess.co.at/toolkit/toolkit.html

Spatial FX Server is a Java-based Application Server that can deliver highly detailed, fully interactive mapping applications to thousands of users through the Web, as well as through client/server deployments. It can read e.g. ESRI shape and DXF files, as well as link to Oracle (and other) databases. The Spatial FX Component Suite provides a suite of high-level Java components that can bring geographic visualization to a wide variety of new or existing applications. Developed by ObjectFX Corporation. URL: http://www.objectfx.com/

CARIS Spatial Fusion is the premiere internet-based technology for accessing, visualizing, and analyzing heterogeneous, distributed data sources in a highly transparent, user-friendly environment. It combines the speed and convenience of the Internet with the ability to read multiple data sources in their native format. By fusing the latest Java Bean technology with Orbix, the leading CORBA Object Request Broker (ORB) from IONA technologies, Spatial Fusion is setting the standards for on-line Spatial Information Management.
With Spatial Fusion, you can

- create maps by merging data from ESRI shapefiles, CARIS files, MapInfo, Tiff, and data stored in Oracle 8i
- view multiple map layers made with different projections
- navigate through multiple map layers
- query a layer’s attributes
- classify features within a layer by range or unique value
- annotate features within a layer with any of its associated attributes

One of the key features of Spatial Fusion is data independence. It can read the following data sources in their own format, without the need for translation: CARIS files, ESRI shape files, Oracle 8i Spatial, GeoTiff. Spatial Fusion consists of a customized Java client and a number of Fusion Data Services. The building blocks for Spatial Fusion are also sold as a collection of Java Bean packages for Java developers working on spatial applications.
URL: http://www.spatialcomponents.com/products/fusion.html

The Lava GIS browser is a 100% Java GIS browser, completely hardware independent, fast, customizable, and the ideal solution for corporate intranets, or the Internet. It supports map integration from different servers, access to large, seamless databases, raster and vector data, and advanced caching to reduce network traffic. The **Magma GeoData Publisher** connects your http server to various geospatial datastores. Download the **FREE EVALUATION KIT** of **Lava + Magma,** the pure Java solution for Geographic Information on the Internet! Developed by Professional Geo Systems BV, the Netherlands. URL: http://www.pgs.nl/

ION, *IDL On the Net*, is a product family that brings the power of IDL to the Internet. Making use of technologies such as Java and XML, ION provides the tools to deliver efficient data analysis and visualization capabilities to Web-based applications. The ION Product Family is made up of two separate products; ION Script and ION Java. ION Script is the perfect solution for users who need to publish IDL data and visualizations to the Web but do not want to be burdened with the complexity of Java programming, or burdening the users of their application with the overhead required to run a Java application. ION Java, however, is well suited for developing full-featured, distributed, network-based applications for visualization and analysis. URL: http://www.rsinc.com/ion/index.cfm

4.6 Communication issues

4.6.1 NERSC

Northern Sea Route: Inmarsat A have been used to transmit compressed SAR images of 100 – 200 kbyte to icebreakers in typical 5 minutes. There is a dead zone for Inmarsat in eastern Kara Sea and the Laptev Sea between the Indian Ocean and the East Atlantic satellite. Cost aspects: Inmarat is relatively expensive for transmission of large data sets.

For land-based users with medium/high speed bandwidth connections, the size of the IWICOS products will not be as critical as for offshore users, but for thin client end-users system each file should not be larger than a few hundred kbyte.

4.6.2 IMO

See appendix B.

4.6.3 FIMR

The Baltic Sea: The terrestrial cellular telephone systems (NMT-450 and GSM) have been used in data transfer to the users at sea since 1980s. They have rather low data transfer capasity: NMT-450 has capasity of 4.8 Kbits/sec and GSM 9.6 Kbits/sec. Further more, the coverage at sea has gaps in the high sea areas. However, the system is inexpensive to use and it has been used for years despite its limitations. Communication satellite use so far has been rather modest. Most of the shipping companies are not using them and only few icebreakers are able to communication satellites.

Users at land have access to IWICOS information products via Internet.

4.6.4 DTU

European Arctic (Baffin Bay to Kara Sea) Most of our users access the data via the Internet. Either via fixed lines (companies and universities), via dial-up land lines (smaller companies, shipping agencies etc.) or via dial-up satellite telephony service (Inmarsat, Iridium etc.)
Accordingly operation costs vary a lot from no charge to in the order of 3-5$ per minute. Typical transfer times for a 50 Kbytes data package is 1-6 minutes using satellite telephony, and much less that a minute using fixed lines or dial up land lines.

Typical land based users will download a suite of products for their area of interest, or work on-line with the Java client, whereas typical shipborne users will log in, download 1-2 data packages, shut down connection, unpack the packages and work off-line accessing the newly downloaded data with the pre-installed Java client.

4.6.5 DMI

Most of our present shipbased users accesses digital ice information through Inmarsat B. Iridium or similar may be the only alternative north of 75°N. If we intend to serve customers using Iridium or similar we have to tailor existing products or develop new products that respects the narrow bandwidth of these systems. All, or most of, the landbased users are easily accessible through the Internet. The landbased user segment in many cases have access to more information covering larger areas than shipbased users but not necessarily more detailed. Interaction between a landbased agent or institution and a given ship should be considered, e.g. the agent may act as an intelligent filter or the landbased application may serve as an up-to-date information service for a user before going to sea.

5. Format standardisation

5.1 Standard vector and raster formats to be considered

Some standard formats for scientific data are outlined below. No evaluation or recommendation for use in IWICOS is done at this point; it is simply a list of potential formats.

Raster data may be divided into two broad categories namely raster files with embedded metadata (header) and files which may or may not have an external metadata file. Open file formats which support embedded metadata is GeoTiff and HDF. GeoTiff has a well defined set of 'geo' tags that may be used to describe the projection parameters. Using a raster format like GeoTiff will ensure that a wide range of commercial and public domain software packages will be able to read IWICOS image data including information about geolocation and projection. The HDF file is much more flexible and virtually any kind of information may be embedded with the image but the metadata can only be read by an application that knows which information it should look for. Some applications may read industry standard formats like TIFF, JPEG, BMP and GIF and accept a so-called world file. This world file is in ASCII and should follow certain naming rules and contain six numeric parameters describing a first order image-to-world transformation. Whereas some applications may read generic binary files (BSQ, BIP, BIL) simultaneously with an attached header file. The header file contains a set of predefined keywords and provides a minimum amount of information enabling an application to read the file and to geolocate it.

There seems not to be many open industry standard vector formats which are relatively simple but still capable of holding all necessary information and widely accepted. However, there are (at least) three possible candidates namely BUFR, GRIB and shapefile which may be used to exchange vector data. The use of both GRIB and BUFR are somewhat restricted, GRIB is intended for gridded data, e.g. model output and BUFR is developed for point data. Consequently, the only general purpose vector format is the shapefile format.

HDF (Hierarchical Data Format) is a file format and library for storing scientific data. Developed by NCSA (National Center for Supercomputing Applications), which also provides free source code for file I/O. Most recent version is HDF5. Earlier versions 4.x are also available.
Note: HDF (4) includes C, Fortran, and Java calling interfaces, and utilities for analyzing, visualizing, and converting HDF data files. HDF5 is a completely new format that includes a C interface and utilities for analyzing HDF5 files. The development of HDF5 was motivated by a number of limitations of the HDF (4) library. HDF5 is NOT compatible with HDF (4), but we are currently working on conversion routines for converting HDF5 objects into HDF (4) objects and vice-versa.
URL: http://hdf.ncsa.uiuc.edu/

NetCDF (network Common Data Form) is an interface for array-oriented data access and a library that provides an implementation of the interface. The netCDF library also defines a machine-independent format for representing scientific data. Together, the interface, library, and format support the creation, access, and sharing of scientific data. The netCDF software was developed at the Unidata Program Center in Boulder, Colorado, and is freely available.
Some additional information from the FAQ:
NetCDF data is:

- *Self-Describing*. A netCDF file includes information about the data it contains.
- *Architecture-independent*. A netCDF file is represented in a form that can be accessed by computers with different ways of storing integers, characters, and floating-point numbers.
- *Direct-access*. A small subset of a large dataset may be accessed efficiently, without first reading through all the preceding data.
- *Appendable*. Data can be appended to a netCDF dataset along one dimension without copying the dataset or redefining its structure. The structure of a netCDF dataset can be changed, though this sometimes causes the dataset to be copied.
- *Sharable*. One writer and multiple readers may simultaneously access the same netCDF file.

URL: http://www.unidata.ucar.edu/packages/netcdf/

GeoTIFF represents an effort by over 160 different remote sensing, GIS, cartographic, and surveying related companies and organizations to establish a TIFF based interchange format for georeferenced raster imagery. The TIFF imagery file format can be used to store and transfer digital satellite imagery, scanned aerial photos, elevation models, scanned maps or the results of many types of geographic analysis. Over the past several years many users of such images have urged geographic data suppliers to provide imagery in TIFF format. TIFF is the only full-featured format in the public domain, capable of supporting compression, tiling, and extension to include geographic metadata. GeoTIFF implements the geographic metadata formally, using compliant TIFF tags and structures.
Libgeotiff is a public domain library normally hosted on top of libtiff for reading, and writing GeoTIFF information tags. Please contact warmerda@home.com for more information, or to get involved.
URL: http://www.remotesensing.org/geotiff/geotiff.html (lots of links to specification, software etc.)

GEOGRAPHIC INFORMATION CEN/TC 287
URL: http://forum.afnor.fr/afnor/WORK/AFNOR/GPN2/Z13C/indexen.htm (to be updated)

ISO/TC 211 Geographic information/Geomatics: This work aims to establish a structured set of standards for information concerning objects or phenomena that are directly or indirectly associated with a location relative to the Earth. These standards may specify, for geographic information, methods, tools and services for data management (including definition and description), acquiring, processing, analyzing, accessing, presenting and transferring such data in digital/electronic form between different users, systems and locations.
URL: http://www.statkart.no/isotc211/welcome.html

Geographic Data Exchange Standards: The Info2000 programme generated a *OII Standards and Specifications List*, which provides information on the following standards used to interchange geographical and other spatially organized data: Some of these standards are national standards, such as SOSI in Norway, others are European or US/global standards.
(OII = Open Information Interchange)
URL: http://www2.echo.lu/oii/en/gis.html

CEO's Recommendations on Metadata, version 2.0, February 1999, describes a metadata standard for describing datasets, documents, courses, and other resources/products that an organisation can offer. It will be implemented in INFEO, and used to hold inventories of spatial and non-spatial data, project descriptions, courses, etc.
Note: Does not hold the data themselves, only metadata.
URL: http://www.ceo.org/

SDTS (Spatial Data Transfer Standard): SDTS is a FIPS(173) and FGDC (STD-002) standard that defines a non-proprietary format for packaging vector or raster spatial data with attributes, metadata, a data quality report and usually a data dictionary. SDTS is primarily intended to be used for spatial data product distribution and archiving. The format and structure of a SDTS file set is designed to enable blind transfer of information between different hardware/software environments without loss of contextual information. The SDTS is not intended to replace the internal processing structures of any geographic information system. SDTS is not a database or a product specification or a software package.
Developed by USGS (United States Geological Survey). Some public domain software is available.
URL: http://mcmcweb.er.usgs.gov/sdts/

GRIB (Gridded Binary) is the WMO format for storage of weather product information the exchange of weather product messages in gridded binary form as used by NCEP central operations.
GRIB is the standard format for the storage and interchange of meteorological data. Several "flavors" of GRIB exist, prompting the original format to be called WMO GRIB. The format specification and software may be found at:
ftp://ncardata.ucar.edu/libraries/grib/
ftp://nic.fb4.noaa.gov/pub/nws/nmc/docs/gribguide/guide.txt
The specification for the ECMWF GRIB format is at:
ftp://ncardata.ucar.edu/datasets/ds111.2/format
ftp://ncardata.ucar.edu/datasets/ds111.2/software
URL: : http://www.faqs.org/faqs/graphics/fileformats-faq/part3/index.html

XML (Extensible Markup Language) is a universal format for structured documents and data on the Web. It can be used to hold both data and metadata.
URL: http://www.w3c.org/xml and http://www.xml.com

XML Schema is an XML document structure definition language. It can be used to define various data formats, such as the FIMR Parametric Wave Model format defined by VTT Information Technology.
URL: http://www.w3.org/XML/Schema.html

The Geography Markup Language (GML) is an XML based language providing means for presenting geographical data content in an html like format. GML presentation encapsulates the geometry and properties of a feature in textual representation. URL: http://www.w3.org/XML/Schema.html

The Resource Description Framework (RDF) integrates a variety of web-based metadata activities including sitemaps**,** content ratings**,** stream channel definitions**,** search engine data collection (web crawling), digital library collections, and distributed authoring, using XML as an interchange syntax.
URL: http://www.w3.org/RDF/

Dublin Core Metadata Initiative: The Dublin Core is a simple content description model for electronic resources. The Dublin Core is a metadata element set intended to facilitate discovery of electronic resources. Originally conceived for author-generated description of Web resources, it has attracted the attention of formal resource description communities such as museums, libraries, government agencies, and commercial organizations.
URL: http://www.oclc.org/oclc/research/projects/core/index.htm

The Extensible Scientific Interchange Language (XSIL) is a flexible, hierarchical, extensible, transport language for scientific data objects. The entire object may be represented in the file, or there may be metadata in the XSIL file, with a powerful, fault-tolerant linking mechanism to external data. The language is based on XML, and is designed not only for parsing and processing by machines, but also for presentation to humans through web browsers and web-database technology.
URL: http://www.cacr.caltech.edu/SDA/xsil/index.html

ECDIS. The following section is mainly based on information available at www.sevencs.com. An Electronic Chart Display and Information System (ECDIS) is more than an electronic nautical chart. ECDIS is used to present and symbolise nautical charts on computers but it also acts as an information system which enables the user to get additional information about objects. The system replaces the conventional chart table onboard the ship and is intended to permit all types of work traditionally connected with the paper chart and to make these activities easier, more precise and faster. These include route planning, entry of observations, instructions and notes, position determination and efficient updating of charts. The ECDIS software component consists of a user interface and the so called ECDIS kernel, the module that makes it possible to read the data and display the chart. The official S-57 data is also called Electronic Nautical Chart (ENC).

Several international authorities are involved in the standardisation of ECDIS. The International Hydrographic Office (IHO) has the responsibility for standardising the digital chart objects for ECDIS. The IHO has drawn up a data model, an object catalogue, format description of the exchange format for digital nautical chart data and an ENC product specification. These standards are published in Special Publication no. 57.

S-57 data does not contain any information concerning the symbolisation, the presentation of the data on the screen. The presentation is controlled by the presentation library published in the Special Publication no. 52. In addition to the static presentation of objects there are also conditional symbology procedures.

An ECDIS system must offer the following basic functionality:
- Reading ENC data (S-57)
- Presentation of objects according to the presentation library (S-52)
- Anti grounding function
- Warning of obstructions to shipping

- Updating
- Basic functions e.g. Entering position, Route planning, Entering notes and observations, Sounding and measurement of distances

Presentation of the chart is generated on the fly in ECDIS upon reading of the chart data. The appropriate symbolisation for each object is described in the presentation library.

S-57 is a data standard developed by IHO for the exchange of digital hydrographic data. The present version of S-57 is edition 3 1996. Each S-57 exchange data set contains one catalogue file and one or more base cells. The catalogue file contains a list of all files in the exchange set. Each base cell file contains hydrographic feature data for a particular geographic area, which is called a cell. The cells store all nautical chart objects as well as objects created during the operation of the system, such as way points and leg lines, notes and positions. Each base cell also contains descriptive information. S-57 uses an object oriented approach toward modelling hydrographic data.

The S-57 data represents a specific kind of attributed vector data. Positional information in S-57 data is always given in geographic coordinates and are therefore not projected. The ECDIS system must be able to project the data using standard projections, e.g. Mercator.

A certified ECDIS system will meet all the described requirements and only certified data must be used for navigational purposes. A system that does not meet all requirements is called an Electronic Chart System (ECS) and can may be utilised like an ECDIS but may not be employed as the sole item of navigation equipment.

ECDIS is presently not able to handle neither sea ice nor weather information. However, there has been attempts to define sea ice object types and presentation standards. This work has been lead by the Canadian Hydrographic Service and Bundesamt für Seeschiffahrt und Hydrographie which hosted two workshops on ECDIS and sea ice information in 1995 and 1996. According to available information a sea ice object catalogue will be part of the next S-57 edition which will be ready 2002. The International Ice Charting Working Group has also contacted IHO to express interest and to offer their expertise with respect to incorporation of sea ice information into ECDIS.

BUFR. The WMO code form FM 94 BUFR (Binary Universal Form for the Representation of Meteorological Data) is a binary code designed to represent any meteorological data. It is defined in The WMO Manual on Codes; WMO Publication Number 306; Volume 1, Part B; 1995 Edition, plus Supplements. BUFR is mainly used for meteorological observations at discrete points as opposed to gridded data. However, the code form may be applied to any numerical or qualitative data type. The key to understanding the power of BUFR is the code’s self-descriptive nature which means that it is relatively easy to decode. BUFR is a open format. To decode BUFR messages a decoding program and a set of tables are required. Readers and libraries to include into software modules already exist. You can find more information on www.wmo.ch.

GRIB is a WMO format for gridded data. GRIB is used by meteorological centers for storage and exchange of gridded fields. GRIB fields are self describing, storage effective, platform independent and GRIB is an open international standard. Readers and libraries to include into software modules already exist. See wesley.wwb.noaa.gov/reading_grib.html for more information on how to display and read GRIB files.

VPF. The following section is mainly based on information found on 164.214.2.59/vpfproto/.The Vector Product Format (VPF) is a standard format, structure and organisation for large geographic databases that are based on a georelational model and is intended for direct use. VPF has been adopted into an international standard as the Digital Geographic Information Exchange Standard (DIGEST). VPF is designed to be compatible with a wide variety of applications and products. VPF allows application software to read data directly from computer-readable media without prior conversion to an intermediate form. VPF uses tables and indexes that permit direct access by spatial location and thematic content and is designed to be used with any digital geographic data in vector format that can be represented using nodes, edges, and faces. VPF defines the format of data objects, and the georelational data model provides a data organization within which software can manipulate the VPF data objects. A Product Specification corresponding to a specific database product determines the

precise contents of feature tables and their relationships in the database. In this context, each separate product or application is defined by a Product Specification implemented by using VPF structures. VPF data is stored in a structure described in the Military Standard, Vector Product Format, MIL-STD-2407. The Standard specifies the structure for directories, tables, table columns, table join relationships, and media exchange conventions for all VPF data. The data structure itself can be thought of as a template or skeleton within which the geospatial features and metadata are stored. While the Standard describes the structure, it does not describe the contents of a set of VPF data; this is the role of "VPF Product Specifications." VPF has three basic data structures. Namely "Directories", "Tables", and "Indices". All VPF data is defined in terms of one of these structures. There are several hierarchical directories in VPF which are described below. Tables are either ASCII or binary files which are stored within the directories. There are several types of tables, each of which has a specific structure of "columns" or fields for different kinds of information and many "rows" of records. Feature, attribution, location, geometry, and topology information is stored in various VPF tables. Indices are a special kind of table which have pointers between other tables and records.
A typical VPF Product has "VPF Databases" which contain "VPF Libraries" grouped by geographic area. A "VPF Library" contains "VPF Coverage" directories where "Feature Tables" store information about thematically similar geospatial features and their attributes over the geographic extent of the library. The location, geometry, and topology of the area, line, point, and text features that make up VPF data are stored in the lowest level VPF structure called a "Primitive Table". To facilitate faster access to primitive data, most VPF products are tiled. That is, the extent of the library is broken into tiles of equal size. Primitive tables are stored in "Tile Directories" within a VPF coverage. Topology among VPF features is only maintained within each coverage. Therefore VPF does not store topology between features which are in different coverages. The VPF structure is known as a "relational" structure, because pointers and joins or "relationships" are used between the various tables to store the topology and attribution of the geospatial features. Without these "relational" structures the data would contain nothing more than simple geometry of the features not their topology. This makes VPF products attractive to developers and users of Geographic Information Systems (GIS) where spatial analysis is important.

Shapefile. The shapefile format is a simple, non-topological format for storing the geometric location and attribute information of geographic features developed by ESRI. The shapefile format defines the geometry and attributes of geographically-referenced features in as many as five files with specific file extensions that should be stored in the same project workspace. All file are binary. They are: .shp - the file that stores the feature geometry. .shx - the file that stores the index of the feature geometry. .dbf - the dBASE file that stores the attribute information of features and .sbn and .sbx - the files that store the spatial index of the features. Shapefiles can support point, line and area features and attributes are held in a dBase format file. Each attribute record has a one-to-one relationship with the associated shape record. The shapefile format is open, is supported by a large number of different applications and used by many data suppliers. The shapefile format is defined in Shapefile definition. In the present format there are no explicit way of defining information about projection. This may change in the future as a .prj file is now supported by some applications.

The Scalable Vector Graphics (SVG) is a language for describing two-dimensional graphics in XML. It contains 6 predefined objects: rectangle, circle, ellipse, polyline, polygon and line. SVG is still a Working Draft. The second last call phase has ended 31 March. URL: http://www.w3.org/TR/2000/03/WD-SVG-20000303/

5.2 Currently used formats and information content of data

5.2.1 NERSC

The following formats are currently used by NERSC (for ice applications):

GOP image file format. This is an internal data format for 8 bits/pixel images, which also includes metadata (geographic position, orbit parameters, date, etc.).

TIFF/GIF/JPEG: Also used for image display and transfer. JPEG is used for transmission to vessels.

ER Mapper's image format: Also used for image analysis, display and transfer (to other landbased institutions).

PostScript/EPS: Used for products such as ice concentration from SSM/I, ice kinematics from SAR, ice type classification from SAR, etc. For display on web pages and transfer to vessels, a raster version is generated from the PostScript/EPS files (e.g. GIF or JPEG format).

Ice model formats: The output from the ice models at NERSC are stored in binary files. When subsets of the model results are extracted for display and analysis, these are typically converted to ASCII for easier integration into COTS or public domain tools.

ASCII files are used in some cases, when data need to be imported into commercial packages like Matlab or IDL for further analysis. For instance if SAR-derived ice kinematics is to be further processed and displayed in Matlab. These proprietary file formats used by these packages may also be delivered to customers/project partners upon request.

5.2.2 FIMR / VTT

Users at sea:

- Ice charts: raster data in *.ice format
- SAR image classifications: raster data, *.ice format
- AVHRR and SAR images : raster data, *.ice format
- Ice drift forecasts: text format (ascii)
- Wave forecasts: text format (ascii)
- In situ wave and water level: text format (ascii)
- Textual products: Ice reports and ice drift forecasts in text format.

Users at land:

- As users at sea and *.html for distribution via Internet.

Raw data exchange formats (BSQ, GRIB and Shapefile) are used between producers (Figure 32). IWICOS product consists of IWICOS metadata and some data format that the client software understands. At this point we find it not necessary to restrict the formats that will be used in IWICOS products. Each producer produces a subset of all formats.We can make a list of formats that we are using now, but the list should be extendable for future needs.

5.2.3 DMI

The internal satellite image format at the Ice Service is ERDAS Imagine but images may be exported to a wide range of standard raster formats. However, varying loss of metadata information may be expected depending on the particular raster format.

A given ice analysis is stored in a so-called workspace which typically contains two Arc/INFO coverage and an ASCII metadata file. If an ice analysis or part of it is send to a customer normally it is converted into the shapefile format.

Both ERDAS Imagine and Arc/INFO coverage formats are proprietary but may in many cases be used directly by other commercial software packages or may be exported to a standard exchange format.

HIRLAM model output is stored in GRIB files. At the Ice Service we often extract a subset of the information (limit area or number of parameters or both) by using a GRIB reader which outputs data in a comma separated ASCII file.

5.2.4 DTU

Image formats: jpeg, gif, tiff. ASCII files for other data as far as possible will make the IWICOS system more flexible and easier to tailor to specific applications. The system should use latitude/longitude for geographic coordinates in vector files and elsewhere, and not UTM or image coordinates.

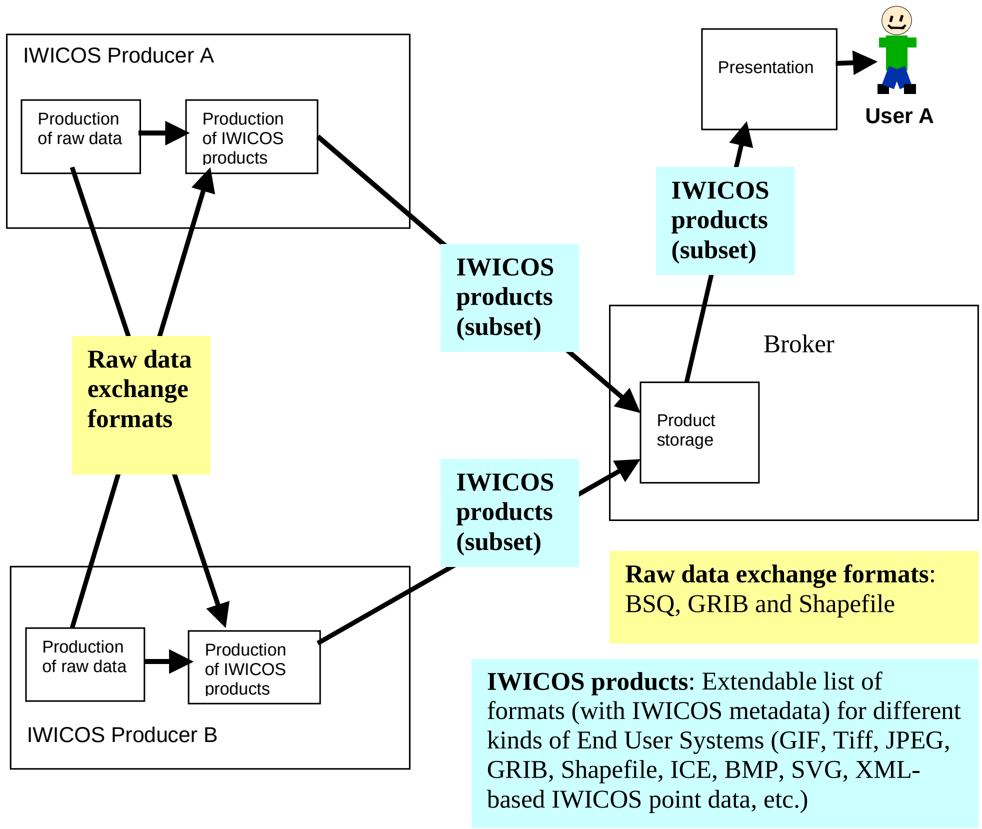

Figure 32. Illustration of main modules and data flow in the IWICOS system.

5.2.5 IMO

Table 19 lists different types of end products for IMO. For each product one should as far as possible use standard formats, such as the WMO codes SYNOP, GRIB, BUFR, CREX and SIGRID.

Table 19. Different types of IMO end products.

	Type of Product	**Format for end products**
Weather forecast	Written text	ascii
	Tables	ascii
	Diagrams	vector or raster graphic
	Pictograms	vector or raster graphic
	Maps, continuous single-valued numerical parameters	vector or raster graphic, GRIB
	Maps, a set of arbitrarily shaped areas or lines	vector or raster graphic, BUFR
Wave forecast	Written text	ascii
	Maps, continuous single-valued numerical parameters	vector or raster graphic, GRIB
Weather observations, wave observations	List of observations	ascii (written text) ascii (SYNOP code) binary (BUFR)
	Pictograms	vector or raster graphic
	Maps, plotted observations	vector or raster graphic
	Remote sensing	
Sea ice forecast	Written text	ascii
	Maps, a set of arbitrarily shaped areas or lines	vector or raster graphic, BUFR
Sea ice observations	Written text	ascii
	Maps, a set of arbitrarily shaped areas or lines	vector or raster graphic, BUFR
	Remote sensing	

5.3 Common exchange formats

At the workshop it was decided to adopt a limited number of common exchange formats to be used for products available to all partners. The intention is to keep this list as short as possible because all product producers will have to implement a conversion between formats previously used and the common exchange formats. Likewise all partners must be able to read products stored in one of the common exchange formats. The current list is showed in Table 20.

To ensure that all essential information preserved a metadata file will be attached to each of the products. The metadata file format and content is described in Section 5.4. All the chosen formats are open and thoroughly described so software importers and exporters may be easily programmed or may even be available from the Internet. Table 21 - Table 25 list the exchange formats to be used for IWICOS products by each partner.

Table 20. Common IWICOS exchange formats.

Format	Used for
BSQ	Image data and other binary files
GRIB	Model data in regular spaced grids
Shapefile	Vector data i.e. points, lines and areas with attributes
ASCII	Text messages, weather forecasts in text format, etc.
XML	Metadata

Table 21. Common exchange formats used for NERSC baseline products.

Product	IWICOS data format	Client data format
SSM/I ice concentration contours	BSQ	GIF
Met model simulations	GRIB	GIF
Sea ice motion from satellite data and a simple model	GRIB (a)	GIF
SAR quicklook images	BSQ	GIF
SAR quicklook images combined with ice concentration from SSM/I	BSQ (b)	GIF
Interpreted SAR images	BSQ	GIF
SAR ice classification maps	BSQ	GIF
Ice forecasting using a coupled ice-ocean model	GRIB	GIF

(a) Product contains only the ice motion vectors and not the satellite data used to generate the field.
(b) Products will have the ice concentration contours from SSM/I overlaid on the SAR images.

Table 22. Common exchange formats used for FIMR/VTT products.

Product	IWICOS data format	Client data format
Sea ice chart	BSQ	*.ice
Wave height (in situ)	XML	ASCII (Text)
Water level (in situ)	XML	XML, ASCII (Text)
Wave forecast	XML	GIF
Classified RADARSAT SAR	BSQ	*.ice
Ice drift chart	BSQ	GIF
Ice drift prediction	XML(a), GRIB(a)	XML
Predicted ice chart/image	BSQ	*.ice
Sea ice chart: concentration, thickness, ice type (b)	GRIB	-
SST (b)	BSQ, GRIB(a)	-
NOAA AVHRR (b)	BSQ	*.ice

(a) Preliminary choice of format.
(b) To be decided later.

Table 23. Common exchange formats used for DMI products.

Feature	Source	Entity type	Data model	Attributes	Format
MSL pressure grid	HIRLAM	Point	Grid	Pressure	GRIB
MSL pressure contours	HIRLAM	Line	Vector	Pressure	Shape
10 m wind	HIRLAM	Point	Grid	U,V	GRIB
10 m wind	HIRLAM	Point	Vector	Wind speed, direction	Shape
10 m wind	HIRLAM	Area	Vector	Wind speed	Shape
2 m air temperature	HIRLAM	Point	Grid	Temperature	GRIB
2 m air temperature	HIRLAM	Point	Vector	Temperature	Shape
2 m air temperature contours	HIRLAM	Line	Vector	Temperature	Shape
Sea ice analysis	DMI	Area	Vector	WMO SIGRID	Shape
Satellite images	NOAA RADARSAT DMSP	-	Raster	Digital numbers	BSQ

Table 24. IWICOS exchange formats used with DTU products.

Feature	Source	Entity type	Data model	Attributes	Format
SSM/I satellite image products	MSFC/DCRS		Raster	Digital numbers	BSQ
SSM/I ice concentration	MSFC/DCRS		Raster	Ice concentration	BSQ
Ice concentration contours	SSM/I - DCRS	Line	Vector	Ice concentration	Shape
Satellite images	TSS, ESA,		Raster	Digital numbers	BSQ
Ice motion vectors	SSM/I - DCRS	Line	Vector		ASCII

Table 25. IWICOS exchange formats used with IMO products.

Type of product	IWICOS FORMAT	End User Format
Weather and wave forecast: • written text • tables Warnings • written text Weather and wave observations • written text • SYNOP code • list of observations Sea ice forecast • written text Sea ice observation • written text	ASCII (Text)	ASCII (Text)
Weather and wave forecast: • diagrams • pictograms • maps, continuous single valued numerical parameters • maps, a set of arbitrarily shaped areas or lines Weather observations, wave observations • pictograms • maps, plotted observations Sea ice forecast • maps, a set of arbitrarily shaped areas or lines Sea ice observations • maps, a set of arbitrarily shaped areas or lines	BSQ (Vector or raster graphic)	GIF
Weather and wave forecast maps, continuous single valued numerical parameters	GRIB	GRIB,GIF

5.4 Metadata content

This section defines the metadata available for IWICOS products. First, the focus is on content, i.e. what information do we need about the different product types. Secondly, we discuss information content of data/products and finally, a potential implementation of the chosen metadata definition.

5.4.1 Information content of the metadata (NERSC contribution)

High level requirements for metadata in IWICOS products include:

- We need to minimize the amount of metadata since many users will only have a low bandwidth connection. Thus, part of the metadata definition will be made optional.
- We need to find a common (minimal) definition of metadata that all servers, brokers and end-user presentation systems (i.e. both thin and thick clients) will support.
- Existing metadata standards or recommendations should be drawn upon, e.g. (UNESCO, 1999; ISO; Kuhn 1985)
- The metadata definition must not enforce a specific data format. (I.e. must be possible to use client-specific data formats in prototype development, and not just the exchange formats agreed upon during the design workshop.)

Structure of the IWICOS product: (nesting is shown by indentation; comments are included after '//')

- PRODUCT
    - CATEGORY // standardized name, e.g. "ice chart" and "weather forecast" for product type
    - NAME // more detailed specification of product type, area, time, etc.
      // e.g. "Barents Sea ice chart for 17-JAN-2001"
    - PRODUCTIONDATE // date when product was generated, formatted as YYYY-MM-DD
    - PRODUCTIONTIME // time of day, formatted as HH:MM:SS.mmmuuunn
    - PROCESSINFO // information about how the product was generated
        - GENERATOR // e.g. what numerical model was used, which version, etc.
        - QUALITY // indication of product quality (optional)
        - DATASET // description of dataset(s) used to generate the product (optional)
          // multiple entries must be allowed
          ... (subelements to be defined)
        - AUXINFO // any additional information about the processing (optional)
    - PRODUCER // contact information for the producer
        - NAME // name of organisation, contact person and/or help desk
        - ADDRESS // postal address (optional)
            - STREET // name of street (optional)
            - POBOX // post box (optional)
            - POSTCODE // postal code (including country prefix, e.g. N-5059)
            - CITY // town or city
            - REGION // state, county or province (optional)
            - COUNTRY // country (full name)
        - PHONE // phone number for questions
        - FAX // telefax number
        - EMAIL // e-mail address
        - URL // web page with product information, FAQ, feedback option, etc.
        - AUXINFO // any additional information about the producer (optional)
    - DATA // the actual product
      ... (subelements to be defined)

Elaboration of DATASET element: (nesting is shown by indentation; comments are included after '//')

- PRODUCT
  ...
    - PROCESSINFO // information about how the product was generated
      ...
        - DATASET // description of dataset(s) used to generate the product
          // multiple entries must be allowed

- DATASETID // unique identifier of the dataset
- NAME // full name of the dataset
- OWNER // name of organisation owning the dataset
- COVERAGE // minimum bounding box
  - LATMIN // minimum latitude (degrees North, -90 to +90) of the dataset
  - LATMAX // maximum latitude (degrees North, -90 to +90)
  - LONMIN // minimum longitude (degrees East, -180 to +180) of the dataset
  - LONMAX // maximum longitude (degrees East, -180 to +180)
- STARTDATE // date the acquisition started
- STARTTIME // time of day, formatted as HH:MM:SS.mmmuuunn
- ENDDATE // date the acquisition ended
- ENDTIME // time of day, formatted as HH:MM:SS.mmmuuunn
- PARAMETER // name of parameters included (multiple entries must be allowed)
- SENSOR // name of instrument or model used to collect the dataset (optional)
  ... (subelements to be defined)
- ABSTRACT // short description of the dataset (optional)
- AVAILABILITY // if the dataset itself is available
- DATA // the actual data values (optional)
  ... (subelements to be defined)

5.4.2 Information content of datasets and products (NERSC contribution)

Elaboration of DATA element: (nesting is shown by indentation; comments are included after '//')

- PRODUCT
  - DATA // the actual product
    - WIDTH // the number of columns in the image
    - HEIGHT // the number of lines
    - CHANNELS // the number of channels
    - PIXELTYPE // the number of bits per pixel (after uncompression)
    - LUT // lookup table
    - TRANSPARENCY // if image is to be displayed transparently
    - GEOINFO // definition of mapping from image coordinates to lat,lon
      - PROJECTION // definition of a standard or user-defined map projection
      -
        ... (subelements to be defined)
      - DATUM // datum used
        ... (subelements to be defined)
      - RESOLUTION // spatial resolution
        - RANGE // in range
        - AZIMUTH // in azimuth
      - POSITION // (to be defined)
      - ORIENTATION // (to be defined)
    - FORMAT // name of the format used for the data, e.g. "JPEG"
    - STORAGE // either "external" or "internal"
    - DATAFILE // name of external data file, e.g. "e2sar991012_1250.jpg"
    - DATAVALUES // the actual data values (for internal storage mode)
      ... (subelements to be defined)

5.4.3 The data (DMI contribution)

There will be three basic data types, raster or images, grids (regularly spaced cells) and vector. The parameters used to describe the may be different, e.g. the file format used may hold different levels of information, e.g. positional information. The question is if we should select different data sections for each of the three data types or if we should use one generic data section.

- Data
  - Image

  - Type // Format type, e.g. BSQ
  - Lines // Number of lines in image
  - Samples // Number of samples per line
  - Bands // Number of bands in image
  - Pixel_depth // Bits per pixel
  - Pixel_type // Byte, Integer, float
  - Compression // Compression algorithm - if used
  - Lookup_table // LUT, e.g. conversion DN -> temperature
  - Coverage // Coverage of image
    - Lat_min
    - Lat_max
    - Lon_min
    - Lon_max
  - Coordinate_system // Image coordinate system
    - Units
    - Dimension_x
    - Dimension_y
    - Upper_left_x
    - Upper_left_y
  - Projection // Projection used (see below)
- Grid
  - Type // Format type, e.g. GRIB
  - Lines // Number of lines in grid
  - Cells // Number of cells per line
  - Compression // Compression algorithm - if used
  - Coverage // Coverage of grid
    - Lat_min
    - Lat_max
    - Lon_min
    - Lon_max
  - Coordinate_system // Image coordinate system
    - Units
    - Dimension_x
    - Dimension_y
    - Upper_left_x
    - Upper_left_y
  - Projection // Projection used (see below)
- Vector
  - Type // Format type, e.g. shape
  - Compression // Compression algorithm - if used
  - Coverage // Coverage of vector
    - Lat_min
    - Lat_max
    - Lon_min
    - Lon_max
  - Projection // Projection used (see below)

5.4.4 The projection (DMI contribution)

Here is a ‘projection’ definition for some common projections. Datum and spheroid are just defined by name. The relation between a given name and parameters describing the datum or the spheroid may be defined in a separate file or will often be defined by the conversion tool used, e.g. the ‘proj’ library. Note that the parameters used to define the projection can only bed interpreted correctly and controlled when the projection name is known. Not all parameters are mandatory, often false easting and northing are assumed 0.0 and default values for units may be ‘meter’. We will have to define default values for optional elements.

- Projection
    - Name = *Lambert conformal conic*
    - Units = e.g. meters
    - Parameters
        - P1 // 1st standard parallel
        - P2 // 2nd standard parallel
        - P3 // Central meridian
        - P4 // Latitude of projection origin
        - P5 // False easting
        - P6 // False northing
    - Datum
        - Name // Name of datum, e.g. WGS 84
    - Spheroid
        - Name // Name of spheroid, e.g. WGS 84

- Projection
    - Name = *Polar stereographic*
    - Units // e.g. Meters
    - Parameters
        - P1 // Longitude of central meridian
        - P2 // Latitude of true scale
        - P3 // False easting
        - P4 // False northing
- Datum
    - Name // Name of datum, e.g. WGS 84
- Spheroid
    - Name // Name spheroid, e.g. WGS 84

- Projection
    - Name = *Mercator*
    - Units // e.g. meters
    - Parameters
        - P1 // Longitude of central meridian
        - P2 // Latitude of true scale
        - P3 // False easting
        - P4 // False northing
- Datum
    - Name // Name of datum, e.g. WGS 84
- Spheroid
    - Name // Name of spheroid, e.g. WGS 84

- Projection
    - Name = *Geographic*
    - Units // DD = decimal degrees
    - Parameters
        - - // No parameters needed
- Datum
    - Name // Name of datum, e.g. WGS 84
- Spheroid
    - Name // Name of spheroid, e.g. WGS 84

5.4.5 Metadata content (IMO contribution)

To define the content of a metadata file we use a few different examples of data. To be able to fully define some of our example data files we found that we needed to add a few new lines to the header proposed at the Design Workshop. Those new lines are highlighted below. Observe that some of the header definitions may not be properly filled out.

We also find it important that a metadata definition file is separated from the data file. This enables the user to download and examine the metadata files without having to download the data itself.

	Examples:					
	Weather forecast map, GRIB-file	Weather forecast area, written text	Weather forecast point, table	Weather observations	Weather observations	Sea Ice Charts
Header version	1	1	1	1	1	1
Data type	GRIB	ASCII	ASCII	ASCII	SYNOP, ASCII	GIF
Producer Info	IMO	IMO	IMO	IMO	IMO	IMO
Product Info	ECM12					
Parameter	Temperature	Wind, weather	Wind, temperature, pressure	Wind, weather, visibility, sea state temperature, pressure	All	Sea ice edge position, sea ice concentration
Reference time	2000-05-02 12:00	2000-05-02 06:45	2000-05-02 12:00	2000-05-02 12:00	2000-05-02 12:00	2000-03-22
Valid time	2000-05-06 00:00					
Valid time interval		24 hours	0 to 240 by 6			
Grid definition	Lat,long					
Area name		Norðurdjúp		Faxaflói, Faxaflóamið	Faxaflói, Faxaflóamið	Denmark Strait
Area definition	80,50W 48N,50W 48N,20E 80N,20E	67N,22W 70N,22W 70N,12W 67N,12W	63N,17W	63.7N,22.8W 36N,27W 64.5N,27W 64.9N,24W	63.7N,22.8W 36N,27W 64.5N,27W 64.9N,24W	
Projection						Mercator
Datum						Hjörsey 1955
Resolution	1.5x1.5					
Satellite info						
Imaging info						
Calibration & phys interpretation info						
LUT						
Pixel image dimensions						
File size	32K	2K	2K	2K	2K	15K
Compression	None	Zip	Zip	Zip	Zip	
Comment	Updated every 24 hours	Updated 1:00, 6:45, 19:30	Updated every 24 hours	All parameters may not be available from all stations		

5.4.6 Metadata content (DTU contribution)

We will need some time definitions, such as:

- Acquisition time (for satellite data etc.)
- Time of processing (probably less important)
- Production time (for model data incl. weather forecasts)
- Valid time (for ice charts, weather forecasts etc)

so that e.g. a 36 hour weather forecast can have a production time of 2000-05-11 12:00:00 and a 'valid time' of 2000-05-13 00:00:00 as an example. For satellite data and ice charts etc. that may be compiled from data from several satellites and/or several orbits from the same satellite, we will need start and end acquisition times as suggested by NERSC.

2) We suggest a time specification that is something like this:

```
<Acquisition>
    <time>
        <year>2000</year>
        <month>5</month>
        <day>11</day>
        <hour>13</hour>
        <minute>15</minute>
        <second>34</second>
        <second-fraction>32567289</second-fraction>
    </time>
</Acquisition>
```

3) The DMI image specifcation is almost identical to the specification of the EMI header for remote sensing images. We suggest adding a few things: We need to address the endianness problem (little endian - big endian etc.!) and a good idea would be to have a common specification. Then it will be up to the producer to convert.
<platform> for data collection platform (satellite name, ship name, met station name ...)
<sensor> for instrument (AVHRR, SSM/I, ...)
<channel> (needs to be defined, e.g. channel number, or 'name')
where it should be noted that there can be several of these in case of combined products.
<algorithm> (how was backscatter coefficients converted to ice thickness?.....)
<algorithmversion>

(4) For the LUT or DN to parameter discussion, we have come a long way with a simple linear expression like PARAMETER = gain * DN + bias where gain and bias are specified in the metadatafile. This reduces the size of the metadatafile substantially from the size with an entire LUT. Of course the LUT specification is more general and may be necessary in some cases, but we propose to use the simple linear transformation if possible.

(5) Concerning the Map projection specification, we suggest that we stick to the definitions in the USGS map projection books (Snyder, 1984). We have found a good way for preventing cunfusion about coordinate system origos etc. to have a specification of a fix-point in the image/grid. As a matter of fact there may be several fix points specified. We suggest something like:

```
<fixpoint>
    <fixpointnumber>1</fixpointnumber>
    <imgx >346.00</imgx>
    <imgy >537.5</imgy>
    <lat>76.34623</lat>
    <lon>-32.6578</lon>
</fixpoint>
```

where line and sample starts with (1,1) in the center of the upper left pixel. Latitude and longitude are specified in decimal degrees in the interval [-90,90] and [-180,180], respectively.

5.4.7 Metadata content (VTT contribution)

The ICE format is an example of a format that is in operational use (Appendix D). We suggest that the metadata contains (among other things) the fields mentioned in the ICE-format header.

6. Conclusions of the design and user requirements study

User requirements

The background and motivation for the IWICOS project is the general requirement from a wide range of users of met-ice-ocean data to have easier access to services and data provided by meteorological offices, ice information centres and oceanographical institutes. This means that monitoring and forecasting products in digital format should become easily available on Internet and that marine communication systems should be used to send text, images and graphical products to users at sea. Ship captains have expressed a clear requirement to have more integrated information available on the bridge. Ideally, all information should be accessible in digital form via one system, which is easy to operate and avoid to use many different computer systems onboard a ship.

In previous sea ice projects, user requirements for ice information have been identified for different regions and for the main users categories such as ice-going vessels, cargo vessels, fishing boats, oil companies, shipping companies, sea transport administrations, national ice and weather centres, research activities and other marine operations under rough conditions. The study refers to the main results from these projects covering the Baltic Sea, Greenland waters and the Northern Sea Route. These requirements have been supplemented by results from an ongoing user investigation in Iceland and the Design Workshop where invited users stated their opinion on how the IWICOS prototype should be developed.

The requirements for sea ice information are closely related to meteorological and oceanographical parameters. For example, the temporal changes in the ice conditions are always driven by atmospheric forces (winds, air temperature) or ocean forces (currents, waves, tides, ocean temperature). This means that ice data should in principle be accompanied by atmospheric and ocean data which govern the behaviour of sea ice. The requirements are related to products and their quality, time-space coverage, methods of delivery, timeliness, regularity and costs. There are different products which cover various spatial and temporal scales, for example short-term and long-term weather forecasts, ice maps for strategic or tactical operations. The cost-benefit ratio is an important factor which determines which product or service a user selects in a given situation.

The meteorological information needed by users at sea can basicly be divided into three groups:

- Tactical information, consisting of observations (ground observations and satellite products), very-short-range forecasts (nowcasting, < 3 hours) and warnings, issued whenever needed.
- Strategic information where traditional weather forecasts, issued at least two times a day as text according to WMO standards (up to 24 hours) are the most important item. These forecasts might be supported by prognostic charts from numerical models but they should be enhanced in such a way that they are in agreement with the worded forecast.
- Planning information is mainly based on medium range weather forecasts (up to 10 days). Such forecasts may be presented as fields but forecasts beyond day 4 should preferably be expressed in probabilistic terms, based on EPS (Ensemble Prediction System).

Overview of the products to be developed

Products in this context means both met-ice-ocean data at various processing levels (meteorological observations and forecasts, satellite data, ice data, etc.) and the presentation techniques used to show the data (text, images, graphical products, etc.). The partners have reviewed their existing products and suggested a plan for new development of products which integrate or displays data from several sources, combines meteorological, oceanographical and sea ice data. Some data products will be tailored to the geographical regions, the communication limitations and the specific user requirements in these regions, while other products will be more or less similar in all regions. For example, wind fields and air temperature can be used together with ice data, showing the dynamics of the ice fields. Use of GIS technology is an important element in the integration of several data types. Ice kinematics algorithms can be improved by including wind forcing, and ice type classification can be made more reliable if the time series of ice data from the preceding days and weeks are made available. The products can be divided into three main groups:

- Near-real time products which are used for monitoring
- Forecasts of weather, ocean and ice conditions which may be supported by output from numerical prediction models, and

- Archived products giving statistical information about mean and extreme conditions as well as snapshots of interesting events.

One type of product is planned to be SAR quick look images of Arctic sea ice available from a database, which give many examples of detailed ice images in different parts of the Arctic. Other archived products can be ice charts, AVHRR and SSM/I data and meteorological statistics. Improvements in operational ice monitoring is expected by the introduction of SAR images and ice classification from SAR images, providing better resolution in the ice maps. During IWICOS the digital GIS information about ice properties in the routine ice chart will be combined with SAR image classification algorithm. Daily and archived SSM/I ice maps, combined with AVHRR, SAR and other data products, are developed for presentation on Internet. Ice drift and wave forecast visualisations are planned to be improved in the Baltic Sea and in Icelandic waters. New methods for graphical interaction with gridded fields must be developed and implemented before operational weather forecasts and warnings can be issued as meteorological fields and presented as charts or graphical products.

Improved visualisation of the data will be tested in all study regions, Access to the products will be possible in several ways. In the Baltic Sea, products will be sent out to icebreakers and some ships using communication satellites and cellular telephone system. In Icelandic and other waters ice and weather information will be sent to fishing vessels by a special developed information system, the MaxSea system, which communicates via Inmarsat.

In general, the products will be developed to serve two types of users: typically ship based users using thick clients who want to download different types of data for own processing and presentation, and typically land based users using thin clients who only want readymade products which can easily be downloaded without further processing.

The IWICOS prototype system

The design study established the need for three major subsystems in the IWICOS processing chain: production, brokering and presentation. The production subsystem will be responsible for all processing required to generate the defined products. It will also maintain a repository of these products and make them available to the broker subsystem or directly to the presentation subsystem. The main task of the broker is to establish contact between the producers and users of met-ice-ocean products. Several broker interaction models were investigated to find the most suitable solution for the IWICOS prototype. It was found that a hybrid of the basic-service-model and the diminished-broker will best serve the needs for both thin and thick clients, which are needed by different user groups.

Communication issues

The server and broker subsystems will both be installed on powerful landbased workstations and can communicate via high bandwidth networks using standard web protocols. This also applies to land based clients, whereas for ship based clients the communication between broker and client must be done by means of satellite communication.

Functionality

The IWICOS system functionality will be partly server and partly client based. On the client side basic presentation and display methods will be available but also methods to combine and merge different data layers into new information. Special functionality applicable to spatial and temporal problems will be developed. On the server side the product generation and demanding processing will take place.

Preliminary conclusion about metadata

During the design study it was decided to investigate if the metadata standard (content standard for digital geospatial metadata, version 2.0) adopted by the US Federal Geographic Data Committee would be applicable within IWICOS. An important task is to identify important deficiencies and to verify that extensions may be added without loss of applicability.

To enable easy exchange and use of basic products between IWICOS partners a limited set of standard exchange formats were identified. The formats selected facilitate exchange of both raster, vector, grid and ASCII data and are all open and well documented.

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8. Appendix A

Name	Parameter(s)	Units	Geographical Coverage	Spatial Resolution	Temporal Frequency	Origin	Type	Provider
Short range weather forecast	wind air temperature pressure weather		59-70N 0-40W	17 forecast areas 0.5°x0.5°	8/day 3/day 2/day	IMO DMI/HIRLAM		IMO
Medium range weather forecast	wind air temperature sea temperature pressure		40-73N 0-60W	1.5°x1.5°	1-2/day	ECMWF		IMO
Wave forecast	significant wave height mean wave period mean wave direction		57-72N 20E-40W	0.5°x0.5°	1/day	ECMWF		IMO
Wave measurement buoys	significant wave height mean wave period wave length		up to 13 Nm from the coast of Iceland	8 buoys	24/day	IMA		IMO
Synoptic weather stations	wind weather visibility sea state temperature pressure		on the coast of Iceland	app. 30 coastal stations	up to 8/day	IMO		IMO
Automatic weather stations	wind (mean speed and direction) gust temperature pressure		on the coast of Iceland	15 stations	24/day	IMO		IMO
Harbor automatic weather stations	wind (mean speed and direction) gust temperature		at the harbors of Iceland	14 stations	24/day	IMO		IMO

Name	Parameter(s)	Units	Geographical Coverage	Spatial Resolution	Temporal Frequency	Origin	Type	Provider
	pressure sea level							
Sea ice forecast	sea ice edge position sea ice concentration		Denmark Strait and Iceland Sea	1-3 km	Irregular, when required	IMO		IMO
Sea ice analysis and warnings	latitude/longitude of ice edge subjective estimation of sea ice conditions on sailing routes		Denmark Strait and Iceland Sea	1-3 km	Irregular, when required	IMO		IMO
Sea ice reports	observations from ships sea ice reconnaissance flights coastal observations		Denmark Strait and Iceland Sea	variable	Irregular, when sea ice is observed	IMO ICG		IMO
Sea ice	In situ ice conditions		Baltic Sea/Baltic Sea north of 56° 44´	<1*1 km	Daily	Finnish ice service		FIMR
Sea ice	+72 h ice drift forecast	Direction in degrees, speed in 10/knots	Baltic Sea/Baltic Sea north of 56° 44´	40*40 km	Daily	ECMWF winds/ ice conditions Finnish ice service		FIMR
Sea ice	SAR image classifications	Classifies image information into 5 classes	RADARSAT SAR image 300*300km	500*500 m	When SAR data available	FIMR		FIMR
SST	In situ SST charts	°C in one deg. intervals	Baltic Sea north of 56° 44´	<1° C	Twice a week (mo & th	AVHRR, in situ measurements by ships and stations, IR air.borne measurements		FIMR
Wave	In situ wave height	Wave direction, wave height, wave period, water temperature	Two buoys: Bothnian Sea, N Baltic Sea	1 cm	Twice an hour	FIMR		FIMR
Wave	+48 h wave forecast	Significant wave height, direction, period	Baltic Sea	Parametric wave-ride model	Daily	HIRLAM / FIMR		FIMR

Name	Parameter(s)	Units	Geographical Coverage	Spatial Resolution	Temporal Frequency	Origin	Type	Provider
Water level	In situ water level	mm	13 stations along the Finnish coast	Resolution1 mm, operational accuracy <1cm	Four measurements per hour	FIMR		FIMR
Sea ice	Ice edge	None. (The ice edge is usually defined as a certain percentage of ice concentration, e.g. 50%).	Whole Arctic Ocean from SSM/I, 500 km wide swaths from RADARSAT SAR, 100 km wide swaths from ERS SAR.	Horizontal: 25 km from SSM/I; 100 m from SAR. Vertical: N/A	Daily from SSM/I or RADARSAT SAR. Every 3 days from ERS SAR.	SSM/I or SAR.		NERSC
Sea ice	Ice concentration map	Per cent	Whole Arctic Ocean from SSM/I	25 km.	Daily	SSM/I		NERSC
Sea ice	Ice type map	WMO ice type code	500 km wide swaths from RADARSAT SAR, 100 km wide swaths from ERS SAR.	100 m.	Daily from RADARSAT SAR. Every 3 days from ERS SAR.	SAR		NERSC
Sea ice	Ice motion	Km.	Whole Arctic Ocean from SSM/I, 500 km wide swaths from RADARSAT SAR, 100 km wide swaths from ERS SAR, 2800 km wide swaths from AVHRR.	Horizontal: 25 km from SSM/I, 100 m from SAR, 1 km from AVHRR. Vertical: N/A	Daily from SSM/I. Daily from RADARSAT SAR. Every 3 days from ERS SAR. Daily from AVHRR (provided cloudfree conditions)	SSM/I, SAR or AVHRR.		NERSC

Name	Parameter(s)	Units	Geographical Coverage	Spatial Resolution	Temporal Frequency	Origin	Type	Provider
Remote Sensing	SAR images	db	500 km wide swaths from RADARSAT SAR, 100 km wide swaths from ERS SAR.	Horizontal: 100 m from SAR. Vertical: N/A	Daily from RADARSAT SAR. Every 3 days from ERS SAR.	SAR		NERSC
Sea ice	Ice chart		TBD		Daily, weekly, biweekly, depending on user request.	All available sources of data (satellite data and in situ observations)		NERSC
Sea ice	Combined SAR image and SSM/I ice concentration product		Whole Arctic Ocean from SSM/I, 500 km wide swaths from RADARSAT SAR, and 100 km wide swaths from ERS SAR.	Horizontal: 25 km from SSM/I, 100 m from SAR. Vertical: N/A	Daily if RADARSAT SAR is used.Every 3 day if ERS SAR is used.	SSM/I and SAR		NERSC
Sea ice	SSM/I data combined with coupled ice-ocean model		TBD	TBD	TBD	SSM/I and a coupled ice-ocean model.		NERSC
Sea ice	Ice dynamics data set from time series of SAR data	Km. (ice motion)	TBD	TBD	TBD	SAR		NERSC
Ocean	SST	Degrees Celcius	TBD	TBD	TBD	Oceanographic model		NERSC
Ocean	Salinity	Parts per thousands	TBD	TBD	TBD	Oceanographic model		NERSC
Meteorology	Wind speed	m/s	TBD	TBD	TBD	Oceanographic model		NERSC
Ocean	Currents	m/s	TBD	TBD	TBD	Oceanographic model		NERSC

Name	Parameter(s)	Units	Geographical Coverage	Spatial Resolution	Temporal Frequency	Origin	Type	Provider
Ocean	Wave heights	m.	TBD	TBD	TBD	Oceanographic model		NERSC
Meteorology	Mean sea level pressure 10 m. wind (u,v) 2 m. air temperature 2 m. specific humidity Acc. Convective precipitation Acc. Stratiform precipitation High clouds Medium clouds Low clouds Fog Cloud	Pa m/s K g/g mm mm per cent per cent per cent per cent	HIRLAM area G45, N15 or E15	0.45 (G45) degrees or 0.15 (N15 or E15) degrees	6 hours up to +48 computed daily at 00 and 12	DMI HIRLAM		DMI
Sea ice	Ice concentration Ice type Floe size	SIGRID codes	Selected areas around Greenland	Varying	Varying	DMI Ice charts		DMI
Sea ice	Ice concentration Ice type Floe size	SIGRID codes	Whole area around Greenland	Varying	Weekly	DMI Ice charts		DMI
Remote sensing	Radarsat Scansar wide	Intensity / PMR	Selected areas around Greenland	Varying	As available	RSI		DMI
Remote sensing	NOAA AVHRR		Selected areas around Greenland	Varying	As available	NOAA		DMI
Remote sensing	SSM/I 85 GHz polarization difference	TBD	TBD	TBD	TBD			DTU
Remote sensing	Single and multi band AVHRR	TBD	TBD	TBD	TBD			DTU
Remote sensing	Scatterometer data	TBD	TBD	TBD	TBD			DTU
Remote sensing	SSM/I Ice concentration	Per cent	Nothern hemisphere	20 km.	2-4 times / day	Satellite data provider		DTU

9. Appendix B

	Data kbit/sec.	Weight of HW	Cost of HW	Airtime	Coverage	voice	fax	Availa bility	GMDSS approved	Communi cation	Antenna	Good for sending in each message
Inmarsat A (4)	9.6	50 kg.	(5)	$ 5,95	Up to 77 lat.	yes	yes	Now	Yes	Real-time	Directional	>
Inmarsat Mini M	2.4	2.5 kg.	$ 5.000	$ 2,40	Up to 77 lat.	yes	yes	Now	No	Real-time	Directional	400-2000 char.
Inmarsat B HSPD	64.0	25 kg.	$ 20.000		Up to 77 lat.	yes	yes	Now	Yes	Real-time	Directional	> 25.000 char.
Iridium (2)	2.4	3 kg.	$ 2.000	$ 2,99	World wide	yes	yes	Now	No	Real-time	Omni-Dir	
Globalstar	4.8	1 kg.	$ 2.000			yes	yes	2000	No	Real-time	Omni-Dir	
Orbcomm	(2.4)	1 kg.	$ 1.500			no	no	Now	No	Store/forw	Omni-Dir	< 128 char.
ARGOS		3 kg.	(6)			no	no	Now	No	Store/forw	Omni-Dir	
EMSAT	4.8	3 kg.	$ 4.000	$ 1,50		yes	yes	Now	No	Real-time	Directional	
VSAT	64.0	100 kg.	$ 60.000			yes	yes	Now	No	Real-time	Directional	
Teledesic	64.0-2MB	?			World wide	yes	yes	?	No	Real-time	?	
ICO	64.0		(7)			yes	yes	?	No	Real-time	Directional	
NMT (4)	4.8	3 kg.	$ 1.000	$ 0,25	Domestic	yes	yes	Now	No	Real-time	Omni-Dir	
GSM	9.6	1 kg.	$ 1.000	$ 0,30	Domestic	yes	yes	Now	No	Real-time	Omni-Dir	
Navtex		3 kg.	$ 1.500	$ 0,00		no	no	Now	No	Real-time	Omni-Dir	
Inmarsat C (3)		5 kg.	$ 5.000		Up to 77 lat.	no	(1)	Now	Yes	Store/forw	Omni-Dir	< 400 char.
F4	56.0-64.0				Up to 77 lat.	yes	yes	?	No	Real-time	Directional	> 25.000 char.

(1) Mobile to fixed only
(2) Data available 4Q 2000
(3) Store and forward
(4) Analogue Transmission
(5) Not available today, but many terminals in operation.
(6) Only sold in big configurations. i.e. Vessel Monitor System (VMS)
(7) Land terminal only available.

HW = Hardware
Store/forw = Store and forward (not real-time communication)
Omni-Dir = Omni directional antenna does not need any stabilizer
GMDSS = Global Maritime Distress Safety System. Cargo and Passenger vessels over 300 tons, must comply with the GMDSS regulation before 1st of February 1999.

10. Appendix C. Some existing services on Internet

Weather services: www.vedur.is, www.radiomidun.is and www.dmi.dk. They are most certainly an important provider of met-ice-ocean services on the Internet.

Near real-time data and forecasts
MARINE FORECASTS FOR US EAST COAST ON THE WEB
During February and March, mariners in the Chesapeake Bay and Atlantic coastal waters have forecasts designed specifically for them. Through the Coastal Marine Demonstration Project (CMDP), high-resolution forecasts of surface winds, currents, wave heights, water levels, and water temperatures and salinity are available to anyone for the demonstration area, stretching from New England to the Carolinas. This follows demonstration periods in Summer 1999 and Winter 2000.

The CMDP has forged a broad alliance of operational and research meteorologists and oceanographers that receives funding from the National Oceanographic Partnership Program (NOPP) to connect government, university and industry efforts. All five line offices of the National Oceanic and Atmospheric Administration (NOAA), the U.S. Coast Guard and Navy, the University of Maryland Horn Point Laboratory, Princeton University and the University of Rhode Island are working with Litton's TASC Inc. and Weather Services International (WSI).

During February and March, an experimental estuary forecast center at NOAAs' Coast Survey Development Laboratory in Silver Spring, MD is monitoring daily production and providing analyses of the experimental Bay products. Bay forecasts from the National Ocean Service and coastal ocean products from the NCEP Environmental Modeling Center, will be displayed on the web site maintained by Litton-WSI at
http://cmdp.wsicorp.com

MARINE FORECASTS FOR NORTHEAST ATLANTIC PROVIDED BY HALO

Halo Weather-Web
Halo is a "for-non-profit" organization conducting research and development in the field of ocean and atmospheric sciences. As a part of it ongoing research and development a operational weather prediction system has been established. The system has been in operation for 18 months and tested on various operating systems for different model configurations.

The weather prediction model system feeds to a World Wide Web server, "www.halo.is/fcst" which operation is supported by users and Internet service providers that are interested in the information provided by the system. The system is open for public use and the information is given as is. Sponsors can have their logos or labels attached to the pages.

Internet service providers, institutes or companies can have the pages uploaded at their Local Area Network to facilitate rapid access at their domains: ("www.domain.is/com"). The service requires proper user area, link to httpd server file system and Internet access.

Halo can provide similar system for use anywhere in the World. Further information is given by Halo@halo.is.

http://halo.hi.is
SERVICE ON INTERNET PROVIDED BY NOAA

NOAA offers a wide range of meteorological, oceanographical and sea ice products on Internet:
http://www.emc.ncep.noaa.gov/modelinfo/
For example, the Sea Ice Group announces the following:

The sea ice group is part of the Ocean Modeling Branch of the Environmental Modeling Center. Our responsibility, loosely speaking, is ice anywhere in the world, particularly ice which is floating on water. We start with remote sensing, analysis, and data assimilation of sea ice information to obtain the best possible (automated) estimates of current sea ice conditions. Once we have sea ice conditions, which are of interest in their own right, we then use the information to improve the weather forecast model(s), and to run sea ice forecast models.

We emphasise automated regarding our analysis because our work supports sea ice analysis by the NWS Alaska Region, the US National Ice Center, and a wide variety of users in the US and world. These users bring other data sets and methods to the analysis which may not be automatable, and can result in significant improvements in the final products relative to the strictly automatic. You may see the current day's automated analysis at
http://polar.wwb.noaa.gov/seaice/Analyses.html. The 3 times per week Alaska Region analysis is at http://www.alaska.net/~nwsar/html/ice/ice_marine.html.

After running a daily analysis for a number of days, we start to have a lengthy period of coverage and start thinking about climatic uses. The automated analyses are therefore used by some climate groups, both for analysis and modelling. Our analyses are available from September 1995 to the present at http://polar.wwb.noaa.gov/seaice/Historical.html, via anonymous ftp to
ftp://polar.wwb.noaa.gov/pub/cdas, and from 1979 to 1996 (as used by the NCAR/NCEP Climate Reanalysis Project. 1979 to 30 November 1991 was developed by Atsushi Nomura, then at the ECMWF) in ftp://polar.wwb.noaa.gov/pub/ice/reanl.ice .
Because of interest in the sea ice climatology, climate change, and improving both sea ice and sea surface temperature analyses, longer time series with improved (and more consistent) methods will become available in the future.

The automated analysis have been used by the NWS global atmospheric models for their sea ice conditions since February, 1998. The automated analysis provides a daily, 1/2 degree resolution in latitude and longitude, condition for the models as opposed to the former method, which gave a 2 degree condition once per week. During spring and fall, the sea ice edge can move by 200 km (2 degrees) in a week. The new analysis is capable of resolving this fact for the weather models. Discussion of the use and representation of sea ice in the global weather models is available at http://polar.wwb.noaa.gov/seaice/Models.html.

In addition to knowing where the ice is now, we would like to know where it is going to be. Sea ice coverage is important for shipping and fishing, as well as for weather forecast models. To support that effort we are developing a number of sea ice models. The simplest one, which is surprisingly useful in operations, is a sea ice drift model. This is currently operational for 6 day guidance and we have begun an experiment with the NWS Anchorage Forecast Office regarding how much further to the future it may be useful. The developmental model is a model which predicts sea ice motion, concentration changes, and ice thickness. While still developmental it is available only to certain internal users. Once we're satisfied that the model makes sense, we will make it publicly viewable.

Robert Grumbine seaice@polar.wwb.noaa.gov
Last Modified 7 January 1999

Other addresses to archived and re-analysed data sets

ECMWF Re-Analysis (ERA) Project
http://www.ecmwf.int/research/era/

NCEP/NCAR Global Reanalysis Project
http://www.scd.ucar.edu/dss/pub/reanalysis/index.html

Gridded Analyses at NCAR
Analyzed data from ECMWF, NCEP, and other sources.
http://www.scd.ucar.edu/dss/catalogs/gridded.html

11. Appendix D. ICE (ICEPLOTT) image header FORMAT

11.1 Introduction

This appendix describes the Iceplott image header format. The format is also called Merijää-format or just ICE format. The format is used in the Finnish Ice Service as well as at SMHI in Sweden when producing images for transfer to the icebreakers. The applications that can read this format are: ICEPLOTT, ViewIce and IBplott. The image has a 512-byte header and an optional trailer. The structure is defined as byte sequence. The size of the data types is described in Table 26.

Table 26. The size of the datatypes.

Type	Size (bytes)
CHAR	1
LONG	4
UBYTE	1
UCHAR	1
UWORD	2
WORD	2

NOTE! All integers (2 byte and 4 byte) are stored in so called little-endian byte order (most significant byte on right). (This was used on the Digital VAX computer).

Table 27. 512-byte header record.

Bytes	Datatype	Used	Description
1 - 3	CHAR	Y	"”JAA" magic string
4	CHAR	Y	“1” or “2”. Version ID
5 - 10	CHAR	Y	"881012" string, YYMMDD of header def. Indicates header subversion.
11 - 14	LONG	N Y	Version 1: Length of file including hdr. Unit: 512 byte blocks Version 2: Pointer to start of trailing records such as color table information (offset in bytes from the beginning of the file)
15	UBYTE	Y	Compression type: 0=NOT_COMPRESSED 1=MAKISARA_88 2=JPEG Compressed image 3=GIF Compressed image 4=FIMR wavelet compressed image
16			filler
17 - 56	CHAR	Y	Name of the image, shown in image window
57 - 60	LONG	Y	Height in pixels
61 - 64	LONG	Y	Width in pixels
65 - 68	LONG	Y	Bits per pixel
69 - 84	CHAR	N	Channel name
85	UBYTE	Y	Physical switch: 1 = image calibrated, 0 = not calibrated.
86			filler
87	UBYTE	Y	Physical unit value: 0=F_PHYSVALUE 1=ALBEDO 2=KELVIN 3=CELSIUS 4=FAHRENHEIT 5=WATT_PER_SQM
88			filler
89 - 90	UWORD	Y	Minimum pixel value
91 - 94	LONG	Y	Minimum physical value (times 1000)
95 - 96	UWORD	Y	Maximum pixel value
97 - 100	LONG	Y	Maximum physical value (times 1000)

101	UBYTE	Y	Projection type: 0=NONE_PR 1=POLAR_STEREO 2=MERCATOR 3=PLANAR
102			filler
103 - 106	LONG	Y	Left (west) longitude in 10e-6 degrees
107 - 110	LONG	Y	Up (north) latitude in 10e-6 degrees
111 - 114	LONG	Y	Pixel size in 61°40' in mm (10e-3m)
115 - 118	LONG	N	Center longitude (polar stereographic only)
119 - 124	CHAR	N	Satellite name
125 - 128	LONG	N	Orbit number
129 - 134	CHAR	N	Start date YYMMDD
135 - 140	CHAR	N	Start time HHMMSS
141 - 142	UWORD	N	Duration in seconds
143 - 144	UWORD	Y	Pixel value representing "null" area
145 - 146	UWORD	Y	Number of different values a pixel can take. Assumed that the values are consecutive starting from zero.
147 - 148	WORD	Y	LUT info: -1=No dedicated LUT 0=Name of LUT follows 1=LUT-data follows. Only 1) is used. NOTE: If the header version is 2 the LUT information is stored in the trailing record to which we have a pointer in bytes 11 -14.
149 - 270	UBYTE	Y	Name of LUT or LUT-values. -CASE LUT_info=0: (Not used). LUT-name. Must be less than 26 characters. Trailing blanks required. -CASE LUT_info=1: First character (byte) = number of LUT triplets following. The triplets are stored in RGB order. Each component takes one byte. 0=Black, 255=full intensity. Max 40 triplets can be given.
271 - 390	UBYTE	N	Class names. NOTE! Valid only in case LUT_info=1. Each pixel may be given a 3 character abbreviation. This is intended for classification result images. the abbreviations are stored consecutively starting from pixel value 0. 3 blanks => abbreviation not defined.
391 - 392	WORD	Y	Offset of image pixels in X direction with respect to the positions given by the header values. X is positive if image is moved to East but the header coordinates are preserved.
393 - 394	WORD	Y	Offset of image pixels in Y direction with respect to the positions given by the header values. Y is positive if image is moved to South but the header coordinates are preserved.
395 - 496	CHAR		filler
497 - 512	CHAR	N	Image identifier

Table 27 describes the header structure. The column "Used" in this table informs, whether the field is in use in ICEPLOTT system. All character strings must be filled with blank characters (not NULL!).

Pixel size in latitude 61°40' must be calculated in Mercator projection using the following formulas:

R = 6378.388 km (the radius of the earth)
e ** 2 = 2f -f ** 2, f = 1/297.0
X = R * Lo (Lo is longitude coordinate as radians)
m = (sqrt(1 - (e * sin (61°40')) ** 2))/cos(61°40')
(Mercator projection scaling factor for latitude 61°40')

For version 2 of the header,the bytes 11-14 point to a color table structure at the end of the file (trailer). This structure is as follows:

Table 28. Color table header record.

Bytes (from byte n)	Datatype	Used	Description
0 - 1	CHAR	Y	"”T1" Tag string, Start of Color table info

2 - 5	LONG	Y	Offset to next record. Zero if no next record exist. NOTE: In big-endian order.
6	UBYTE	Y	Value of white pixel limit. A value of 177 means, for example, that pixel values from 177 to 255 are displayed with the white value in the look-up-table (the value stored in position 255 of the table). This applies provided that the value of the black pixel limit is less than the white pixel limit. Otherwise the values from 0 to white pixel limit are displayed with the color stored in position 255 of the look-up table.
7	UBYTE	Y	Value of black pixel limit. A value of 77 means, for example, that pixel values from 0 to 77 are displayed with the black color in the look-up-table (the value stored in position 0 of the table unless this value is defined transparent). This applies provided that the value of the black pixel limit is less than the white pixel limit. Otherwise the values from the black pixel limit to 255 are displayed with the color stored in position 0 of the look-up table.
8 - 9	WORD	Y	Number of entries in the color table. NOTE! This value is given in big-endian byte order.
10	UBYTE	Y	RED value(0 - 255)
11	UBYTE	Y	GREEN value (0 - 255)
12	UBYTE	Y	BLUE value (0 - 255)
..	UBYTE	Y	RED, GREEN, BLUE triplets as many as indicated by the number of entries.

12. APPENDIX E. IWICOS Format Definition for FIMR Parametric Wave Model

19.06.2000, Jyrki Haajanen. VTT Information Technology.

This paper describes the data format specified for Finnish Institute for Marine Research (FIMR) Parametric Wave Model output data by VTT Information Technology. Format is based on Extensible Markup Language (XML) and is defined in XML Schema language (W3C Consortium 1999 version). XML technology was chosen because XML files are relatively easy to define, parse, and a browser representation can be constructed using XML Stylesheet Language (XSL). The overhead in space demand of the data introduced by the recurring elements can be eliminated with standard compression techniques, such as zip.

12.1 Introduction

A common intermediate format for weather, ice, and ocean data exchange will be defined in the IWICOS project. This document presents a proposal for such a format along with the FIMR Parametridc Wave Model product format.

XML [W3C98] is well suited for defining intermediate formats. It is relatively easy to define, produce, validate, and parse. Furthermore, it is quite understandable for a human as it is and can be further clarified with XSL definition that enables the browser presentation of the data.

XML provides means for defining formatted html like documents. However, instead of using fixed tags, purpose specific elements are defined with an XML definition language (i.e. Document Type Definition (DTD) [W3C98] or XML Schema [W3C99]). These elements then capsulate the actual data values. The actual data files can then be validated against this definition. Validated data files can be parsed using publicly available Java tools, such as Xerces [Apa00]. The parser then creates the application specific data objects.

12.2 Format Structure

The format contains both generic meta data required for any product and FIMR parametric wave model specific definitions (see appendixes).

We shall now iterate the format structure element by element see appendix A for a tree presentation of the format.

Format starts with <Products> element that capsulates all data belonging to file.

The <Products> element is expanded to <Locations>, <Times>, and <Product> elements. Only one instance of the previous two elements is allowed but the <Product> element can recur.

The <Locations> element capsulates all the spatial points referred in the products presented in the file. It expands to a set of <SpatialPoint> elements that have attributes for spatial identifier (SpatialID), spatial point name (Name), latitude value (Lat) and longitude value (Lon). Idea is to list all the spatial points related to the products presented in a single file to avoid redundancy. The value type for the coordinates is defined with the <Coordinate> element.

The <Coordinate> element is a string that contains one or two digits specifying the degrees followed by a space-character and one or two digits specifying the minutes, and then optionally a dot character and 1 to 10 digits specifying the fraction of a minute can be given. For example values such as "1 1", or "1 12.112" conform to the type definition (a regular expression is given in appendix B).

The <Times> element has similar purpose and functionality as the <Locations> element. However, now the target is a point in time. Thus the <Times> element expands to <TemporalPoint> elements which contain attributes for temporal point identifier (TemporalID) and a time value for that point (date). The value of date attribute conforms to the <Date> type definition in the grammar presentation (appendix B). Note all the times will be presented in UTC.

The <Product> element contains the actual product data and also meta data related to the product. The meta data is presented in attribute values. The attributes are IssueTime, ModelVersion, and Source. IssueTime expresses the time when the product was created (file date or model execution time), values of the attribute conform to the <Date> type definition. The ModelVersion element holds a string presentation of the producing model/entity version. The Source element value is a string expressing the producing organization. The <Product> element expands to <AvailableProduct> element.

The <AvailableProduct> element is an isolation of the different models. It can expand to one and only one product specific element, in this case the <ParametricWaveModel> element. In the future other product formats are also specified, they are currently presented with the <OtherProducts> element.

The <ParametricWaveModel> element expands to a <DataSet> element.

The <DataSet> element expands to a set of <DataItem> elements. Single <DataItem> element collects the model output on single spatial and temporal point.

The <DataItem> element expands to <Total> element and to three <Wave> elements. The location and time values for the model output values are defined with the references to temporal and spatial identifiers of corresponding temporal and spatial points. These references are stored as values of two attributes, namely TemporalID and SpatialID.

The <Total> element expands to a single <Wave> element which collects the sum effect of the wave components. Two attribute values for the sum wave values are also introduced, namely Uef and Hmax.

The <Wave> element has following attributes describing the wave component presented. Wtype attribute expresses the wave component name (total, 0, 1, or 2). The other attributes contain values for Hs, Tp, and Dw and are named respectively.

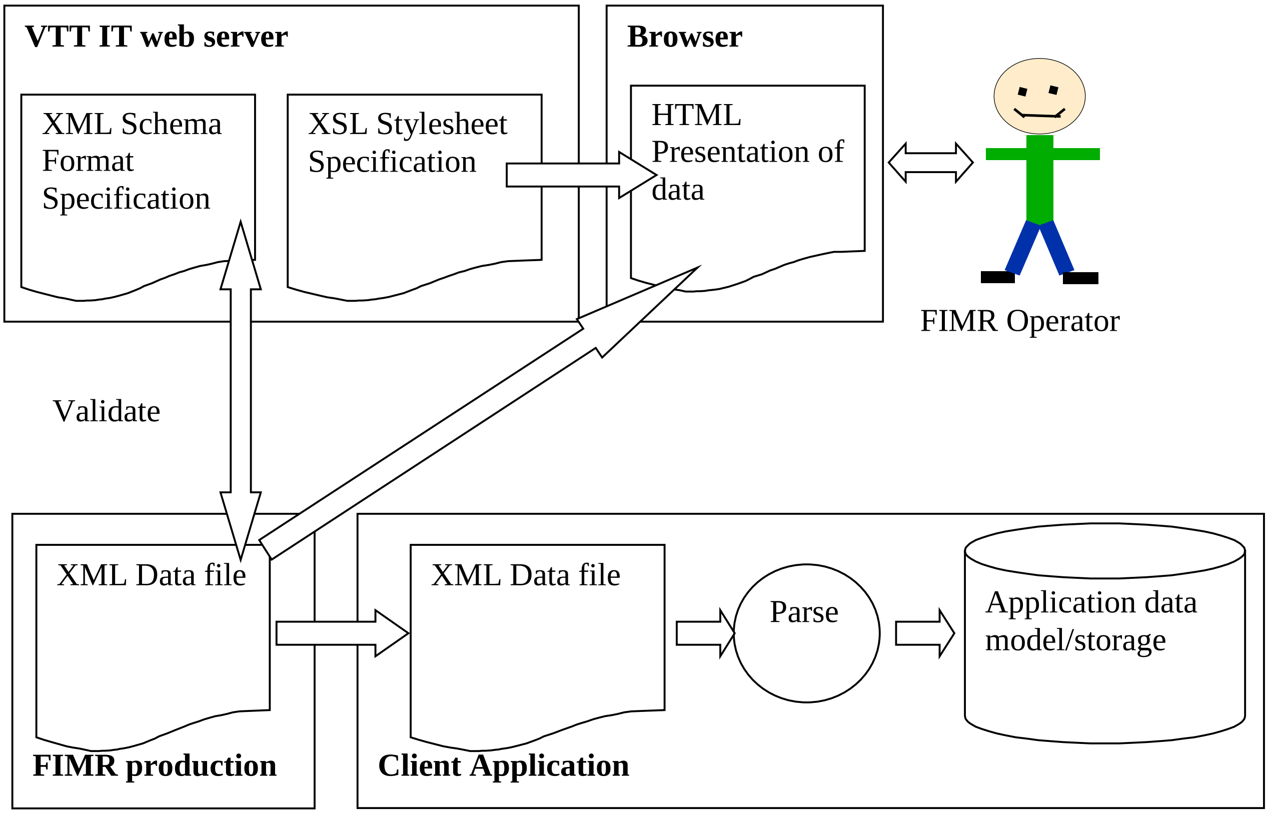
An example XML file conforming to the format is given in appendixes D and E. This file shows the data from Parametric Wave Model in Arkona Sea, Bogskar, and Bornholm Sea, during 31.5.2000 as provided to VTT Information Technology by FIMR in the meeting 6.6.2000.

12.3 Production of Files

The production of XML files conforming to the format is a straight forward task. Furthermore, the files contain recurring sections, such as model output spatial points, that can be copied among the files. Also, the basic structure for temporal points can be reused and only the time values updated. Examples of files are given in appendixes D and E, the parts that cannot be reused as they are from appendix D are highlighted in appendix E.

Validity of generated files is checked against an XML Schema definition available at VTT Information Technology's web server (*http://www.vtt.fi/tte/pub/tte1/mobilemarine/formats/*). This can be done using some XML validator tool, such as RUWF [RUW00]. If necessary the file can be viewed with an internet browser (MS Internet Explorer 5.X) by the FIMR operators, this is supported with the XSL definition that can also be found on VTT Information Technology's web server.

Figure below shows the Parametric Wave Model service chain and the parties and hardware and software entities involved.



12.4 Consumption of Files

Files can be used by application software, Internet browser, or a human. Application software parses the structure and generates corresponding internal representation of the file. Internet browser generates a presentation of the data using the XSL transformation available at VTT Information Technology's web server. Humans can view the formatted file as it is, although it may be easier to use the browser presentation.

Parsing can be done using publicly available parser APIs and software, such as Xerces.

References:

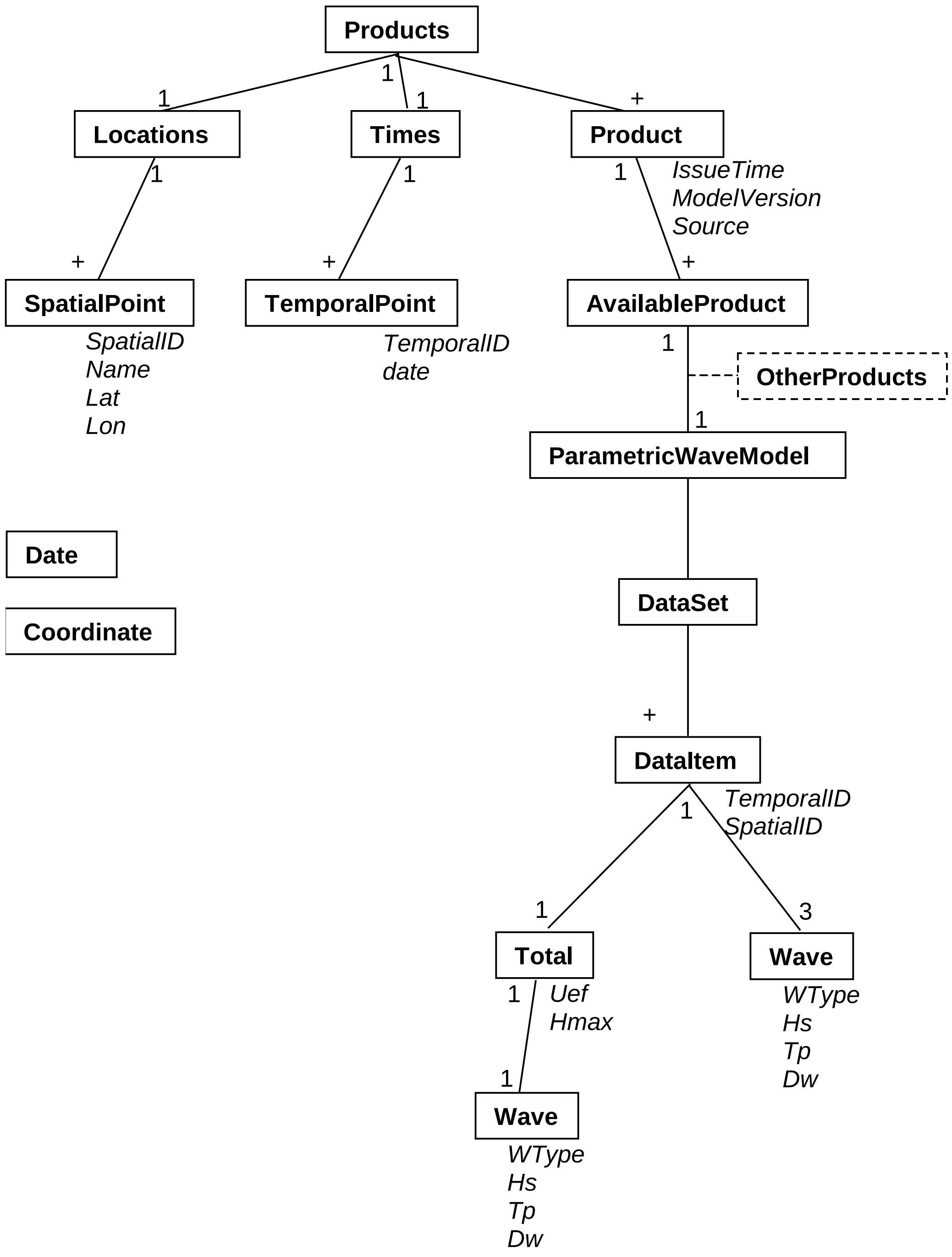
[Apa00] Apache XML Project, "Xerces homepage", 'http://xml.apache.org/xerces-j/index.html', 2000.

[RUW00] RUWF XML Validator, 'http://www.xml.com/xml/pub/tools/ruwf/check.html', 2000.

[W3C98] W3C Consortium, "Extensible Markup Language (XML) 1.0 - W3C Recommendation 10-February-1998 ", 'http://www.w3.org/TR/REC-xml', 1998.

[W3C99] W3C Consortium, "XML Schema homepage", 'http://www.w3.org/XML/Schema.html', 1999.

12.5 Tree Presentation of the Format Structure


Products
1
1
1
+
Locations
Times
Product
1
1
1
IssueTime
ModelVersion
Source
+
+
+
SpatialPoint
TemporalPoint
AvailableProduct
SpatialID
Name
Lat
Lon
TemporalID
date
1
OtherProducts
1
ParametricWaveModel
Date
Coordinate
DataSet
+
DataItem
TemporalID
SpatialID
1
1
3
Total
Wave
1
Uef
Hmax
WType
Hs
Tp
Dw
1
Wave
WType
Hs
Tp
Dw

12.6 Grammar Presentation of the Format Structure

XML format definition in XML Schema for the Parametric Wave Model of FIMR
Copyright VTT Information Technology
Version 1.2 14.06.2000 Jyrki Haajanen

Schema version: http://www.w3.org/1999/XMLSchema

Products	Locations Times [Product]$^+$
Locations	[SpatialPoint]$^+$
SpatialPoint	*Name:string Lat:integer Lon:integer SpatialID:integer*
Times	[TemporalPoint]$^+$
TemporalPoint	*TemporalID:integer date:*Date
Date	[Digit]^4 '.' [Digit]^2 '.' [Digit]^2 ' ' [Digit]^2 ':' [Digit]^2 ':' [Digit]^2 // Year.Month.Date Hour:Minute:Second e.g. 2000.06.14 15:04:00
Coordinate	[Digit] $^{1-2}$ ' ' [Digit]$^{1-2}$ ['.' [Digit]$^{1-10}$]$^{0-1}$
Digit:	definition from http://www.w3.org/1999/XMLSchema
Product	[AvailableProduct]$^+$ *IssueTime:*Date *ModelVersion:string Source:string*
AvailableProduct:	ParametricWaveModel | OtherProducts
ParametricWaveModel	DataSet
DataSet	[DataItem]$^+$
DataItem	Total [Wave]^3 *TemporalID:integer SpatialID:integer*
Total	Wave *Uef:float Hmax:float*
Wave	*WType:string Hs:float Tp:float Dw:integer*
OtherProducts	// Any products that are defined in the future

Legend:

Element	Element definition
Attribute:Type	(Note that type is non-italics if defined in this format, otherwise the definition comes from http://www.w3.org/1999/XMLSchema)
[]x	repeated x times or if x='+' atleast once
a | b	a OR b
'X'	character X as separator
//	rest of the line is comment

12.7 XML Schema Definition of the Format

```
<?xml version="1.0"?>
<!-- This is the XML format definition (Presented in XML Schema) for the Parametric Wave Model of FIMR
    Copyright VTT Information Technology Version 1.3, 14.06.2000 Jyrki Haajanen-->
<xsd:schema xmlns:xsd="http://www.w3.org/1999/XMLSchema">
    <!-- All available products will be listed under this choice-->
    <xsd:complexType name="AvailableProduct">
        <xsd:choice>
            <xsd:element ref="ParametricWaveModel"/>
        </xsd:choice>
    </xsd:complexType>
    <!-- Abstraction for product metadata-->
    <xsd:element name="Product">
        <xsd:complexType>
            <xsd:element ref="AvailableProduct" minOccurs="1" maxOccurs="unbounded"/>
            <xsd:attribute name="IssueTime" type="Date"/>
            <xsd:attribute name="ModelVersion" type="xsd:string"/>
            <xsd:attribute name="Source" type="xsd:string"/>
        </xsd:complexType>
    </xsd:element>
    <!-- List of the products in a single file-->
    <xsd:element name="Products">
        <xsd:complexType>
            <xsd:element name="locations" type="Locations"/>
            <xsd:element name="times" type="Times"/>
            <xsd:element ref="Product" minOccurs="1" maxOccurs="unbounded"/>
        </xsd:complexType>
    </xsd:element>
    <!-- definition for the parametric wave model all products will be represented with resembling XML structure
    -->
    <xsd:complexType name="ParametricWaveModel">
        <xsd:element name="dataSet" type="DataSet" minOccurs="1" maxOccurs="unbounded"/>
    </xsd:complexType>
    <xsd:complexType name="Locations">
        <xsd:element name="SpatialPoint" minOccurs="1" maxOccurs="unbounded">
            <xsd:complexType>
                <xsd:attribute name="Name" type="xsd:string"/>
                <xsd:attribute name="Lat" type="Coordinate"/>
                <xsd:attribute name="Lon" type="Coordinate"/>
                <xsd:attribute name="SpatialID" type="xsd:integer"/>
            </xsd:complexType>
        </xsd:element>
    </xsd:complexType>
    <xsd:complexType name="Times">
        <xsd:element name="TemporalPoint" minOccurs="1" maxOccurs="unbounded">
            <xsd:complexType>
                <xsd:attribute name="TemporalID" type="xsd:integer"/>
                <xsd:attribute name="date" type="Date"/>
            </xsd:complexType>
        </xsd:element>
    </xsd:complexType>
    <xsd:simpleType name="Date" base="xsd:string">
        <xsd:pattern value="\d{4}.\d{2}.\d{2} \d{2}:\d{2}:\d{2}"/>
    </xsd:simpleType>
    <xsd:simpleType name="Coordinate" base="xsd:string">
        <xsd:pattern value="\d{1,2} \d{1,2}(.\d{1,10}){0,1}"/>
    </xsd:simpleType>
    <xsd:element name="Wave">
        <xsd:complexType>
            <xsd:attribute name="WType" type="xsd:string"/>
            <xsd:attribute name="Hs" type="xsd:float" value="0.0"/>
            <xsd:attribute name="Tp" type="xsd:float" value="1.0"/>
            <xsd:attribute name="Dw" type="xsd:integer" value="0"/>
        </xsd:complexType>
    </xsd:element>
    <xsd:complexType name="DataSet">
        <xsd:element name="DataItem" minOccurs="1" maxOccurs="unbounded">
            <xsd:complexType>
                <xsd:element name="Total">
                    <xsd:complexType>
                        <xsd:element ref="Wave"/>
                        <xsd:attribute name="Uef" type="xsd:float"/>
                        <xsd:attribute name="Hmax" type="xsd:float"/>
```

```
            </xsd:complexType>
        </xsd:element>
        <xsd:element ref="Wave" minOccurs="3" maxOccurs="3"/>
        <xsd:attribute name="TemporalID" type="xsd:integer"/>
        <xsd:attribute name="SpatialID" type="xsd:integer"/>
      </xsd:complexType>
    </xsd:element>
  </xsd:complexType>
</xsd:schema>
```

12.8 XML File Example 1.

Model Output for 31.5.2000 as provided by FIMR on 6.6.2000 meeting


```
<?xml version="1.0" encoding="UTF-8"?>
<?xml:stylesheet type="text/xsl" href=" http://www.vtt.fi/tte/pub/tte1/mobilemarine/formats/FIMR-format-v-
1.3_XSL-v1.0.xsl" ?>
<!-- edited with XML Spy v3.0 NT (http://www.xmlspy.com) by Jyrki Haajanen (VTT Information Technology) --
>
<Products xmlns:xsi="http://www.w3.org/1999/XMLSchema-instance"
xsi:noNamespaceSchemaLocation="http://www.vtt.fi/tte/pub/tte1/mobilemarine/formats/FIMR-format-v-
1.3.xsd">
  <locations>
    <SpatialPoint SpatialID="0" Name="Arkona Sea" Lat="54 50.00" Lon="12 50"/>
    <SpatialPoint SpatialID="1" Name="Bogskar" Lat="59 28.00" Lon="20 21.00"/>
    <SpatialPoint SpatialID="2" Name="Bornholm Sea" Lat="55 23" Lon="16 30"/>
  </locations>
  <times>
    <TemporalPoint date="2000.05.31 03:00:00" TemporalID="0"/>
    <TemporalPoint date="2000.05.31 09:00:00" TemporalID="1"/>
    <TemporalPoint date="2000.05.31 15:00:00" TemporalID="2"/>
    <TemporalPoint date="2000.05.31 21:00:00" TemporalID="3"/>
  </times>
  <Product IssueTime="2000.05.31 12:00:00" ModelVersion="Parametric Wave Model" Source="FIMR">
    <AvailableProduct>
      <dataSet>
        <DataItem SpatialID="0" TemporalID="0">
          <Total Uef="3.9" Hmax="0.6">
            <Wave Hs="0.3" Tp="2.5" Dw="240" WType="total"/>
          </Total>
          <Wave Hs="0.0" Tp="1.0" Dw="0" WType="0"/>
          <Wave Hs="0.0" Tp="1.0" Dw="0" WType="1"/>
          <Wave Hs="0.0" Tp="1.0" Dw="0" WType="2"/>
        </DataItem>
        <DataItem SpatialID="0" TemporalID="1">
          <Total Hmax="0.5" Uef="3.8">
            <Wave Hs="0.3" Tp="2.2" Dw="270" WType="total"/>
          </Total>
          <Wave Hs="0.0" Tp="1.0" Dw="0" WType="0"/>
          <Wave Hs="0.0" Tp="1.0" Dw="0" WType="1"/>
          <Wave Hs="0.0" Tp="1.0" Dw="0" WType="2"/>
        </DataItem>
        <DataItem SpatialID="0" TemporalID="2">
          <Total Hmax="0.8" Uef="6.0">
            <Wave Hs="0.4" Tp="2.8" Dw="270" WType="total"/>
          </Total>
          <Wave Hs="0.0" Tp="1.0" Dw="0" WType="0"/>
          <Wave Hs="0.0" Tp="1.0" Dw="0" WType="1"/>
          <Wave Hs="0.0" Tp="1.0" Dw="0" WType="2"/>
        </DataItem>
        <DataItem SpatialID="0" TemporalID="3">
          <Total Hmax="0.6" Uef="5.0">
            <Wave Hs="0.4" Tp="2.6" Dw="270" WType="total"/>
          </Total>
          <Wave Hs="0.0" Tp="1.0" Dw="0" WType="0"/>
          <Wave Hs="0.0" Tp="1.0" Dw="0" WType="1"/>
          <Wave Hs="0.0" Tp="1.0" Dw="0" WType="2"/>
        </DataItem>
        <DataItem SpatialID="1" TemporalID="0">
```

```
          <Total Hmax="2.0" Uef="7.4">
            <Wave Hs="1.1" Tp="4.8" Dw="200" WType="total"/>
          </Total>
          <Wave Hs="0.0" Tp="1.0" Dw="0" WType="0"/>
          <Wave Hs="0.0" Tp="1.0" Dw="0" WType="1"/>
          <Wave Hs="0.0" Tp="1.0" Dw="0" WType="2"/>
        </DataItem>
        <DataItem SpatialID="1" TemporalID="1">
          <Total Hmax="2.2" Uef="8.0">
            <Wave Hs="1.2" Tp="5.0" Dw="200" WType="total"/>
          </Total>
          <Wave Hs="0.0" Tp="1.0" Dw="0" WType="0"/>
          <Wave Hs="0.0" Tp="1.0" Dw="0" WType="1"/>
          <Wave Hs="0.0" Tp="1.0" Dw="0" WType="2"/>
        </DataItem>
        <DataItem SpatialID="1" TemporalID="2">
          <Total Hmax="2.5" Uef="8.9">
            <Wave Hs="1.4" Tp="5.2" Dw="210" WType="total"/>
          </Total>
          <Wave Hs="0.0" Tp="1.0" Dw="0" WType="0"/>
          <Wave Hs="0.0" Tp="1.0" Dw="0" WType="1"/>
          <Wave Hs="0.0" Tp="1.0" Dw="0" WType="2"/>
        </DataItem>
        <DataItem SpatialID="1" TemporalID="3">
          <Total Hmax="2.6" Uef="9.0">
            <Wave Hs="1.4" Tp="5.3" Dw="220" WType="total"/>
          </Total>
          <Wave Hs="0.0" Tp="1.0" Dw="0" WType="0"/>
          <Wave Hs="0.0" Tp="1.0" Dw="0" WType="1"/>
          <Wave Hs="0.0" Tp="1.0" Dw="0" WType="2"/>
        </DataItem>
        <DataItem SpatialID="2" TemporalID="0">
          <Total Hmax="1.5" Uef="4.9">
            <Wave Hs="0.9" Tp="4.2" Dw="240" WType="total"/>
          </Total>
          <Wave Hs="0.8" Tp="4.2" Dw="240" WType="0"/>
          <Wave Hs="0.0" Tp="1.0" Dw="0" WType="1"/>
          <Wave Hs="0.0" Tp="1.0" Dw="0" WType="2"/>
        </DataItem>
        <DataItem SpatialID="2" TemporalID="1">
          <Total Hmax="1.1" Uef="4.7">
            <Wave Hs="0.6" Tp="3.7" Dw="240" WType="total"/>
          </Total>
          <Wave Hs="0.0" Tp="1.0" Dw="0" WType="0"/>
          <Wave Hs="0.0" Tp="1.0" Dw="0" WType="1"/>
          <Wave Hs="0.0" Tp="1.0" Dw="0" WType="2"/>
        </DataItem>
        <DataItem SpatialID="2" TemporalID="2">
          <Total Hmax="1.3" Uef="5.9">
            <Wave Hs="0.7" Tp="3.9" Dw="270" WType="total"/>
          </Total>
          <Wave Hs="0.0" Tp="1.0" Dw="0" WType="0"/>
          <Wave Hs="0.0" Tp="1.0" Dw="0" WType="1"/>
          <Wave Hs="0.0" Tp="1.0" Dw="0" WType="2"/>
        </DataItem>
        <DataItem SpatialID="2" TemporalID="3">
          <Total Hmax="1.2" Uef="5.9">
            <Wave Hs="0.8" Tp="4.2" Dw="240" WType="total"/>
          </Total>
          <Wave Hs="0.0" Tp="1.0" Dw="0" WType="0"/>
          <Wave Hs="0.0" Tp="1.0" Dw="0" WType="1"/>
          <Wave Hs="0.0" Tp="1.0" Dw="0" WType="2"/>
        </DataItem>
      </dataSet>
    </AvailableProduct>
  </Product>
</Products>
```

12.9 XML File Example 2.

Model Output for 1.6.2000 as provided by FIMR on 6.6.2000 meeting


```
<?xml version="1.0" encoding="UTF-8"?>
<?xml:stylesheet type="text/xsl" href="http://www.vtt.fi/tte/pub/tte1/mobilemarine/formats/FIMR-format-v-
1.3_XSL-v1.0.xsl" ?>
<!-- edited with XML Spy v3.0 NT (http://www.xmlspy.com) by Jyrki Haajanen (VTT Information Technology) --
>
<Products xmlns:xsi="http://www.w3.org/1999/XMLSchema-instance"
xsi:noNamespaceSchemaLocation="http://www.vtt.fi/tte/pub/tte1/mobilemarine/formats/FIMR-format-v-
1.3.xsd">
    <locations>
        <SpatialPoint SpatialID="0" Name="Arkona Sea" Lat="54 50.00" Lon="12 50"/>
        <SpatialPoint SpatialID="1" Name="Bogskar" Lat="59 28.00" Lon="20 21.00"/>
        <SpatialPoint SpatialID="2" Name="Bornholm Sea" Lat="55 23" Lon="16 30"/>
    </locations>
    <times>
        <TemporalPoint date="2000.06.01 03:00:00" TemporalID="0"/>
        <TemporalPoint date="2000.06.01 09:00:00" TemporalID="1"/>
        <TemporalPoint date="2000.06.01 15:00:00" TemporalID="2"/>
        <TemporalPoint date="2000.06.01 21:00:00" TemporalID="3"/>
    </times>
    <Product IssueTime="2000.06.01 12:00:00" ModelVersion="Parametric Wave Model" Source="FIMR">
        <AvailableProduct>
            <dataSet>
                <DataItem SpatialID="0" TemporalID="0">
                    <Total Uef="4.9" Hmax="0.7">
                        <Wave Hs="0.4" Tp="2.8" Dw="230" WType="total"/>
                    </Total>
                    <Wave Hs="0.0" Tp="1.0" Dw="0" WType="0"/>
                    <Wave Hs="0.0" Tp="1.0" Dw="0" WType="1"/>
                    <Wave Hs="0.0" Tp="1.0" Dw="0" WType="2"/>
                </DataItem>
                <DataItem SpatialID="0" TemporalID="1">
                    <Total Hmax="0.9" Uef="5.9">
                        <Wave Hs="0.5" Tp="3.1" Dw="220" WType="total"/>
                    </Total>
                    <Wave Hs="0.0" Tp="1.0" Dw="0" WType="0"/>
                    <Wave Hs="0.0" Tp="1.0" Dw="0" WType="1"/>
                    <Wave Hs="0.0" Tp="1.0" Dw="0" WType="2"/>
                </DataItem>
                <DataItem SpatialID="0" TemporalID="2">
                    <Total Hmax="1.1" Uef="7.0">
                        <Wave Hs="0.6" Tp="3.3" Dw="190" WType="total"/>
                    </Total>
                    <Wave Hs="0.0" Tp="1.0" Dw="0" WType="0"/>
                    <Wave Hs="0.0" Tp="1.0" Dw="0" WType="1"/>
                    <Wave Hs="0.0" Tp="1.0" Dw="0" WType="2"/>
                </DataItem>
                <DataItem SpatialID="0" TemporalID="3">
                    <Total Hmax="0.9" Uef="6.0">
                        <Wave Hs="0.5" Tp="3.0" Dw="160" WType="total"/>
                    </Total>
                    <Wave Hs="0.0" Tp="1.0" Dw="0" WType="0"/>
                    <Wave Hs="0.0" Tp="1.0" Dw="0" WType="1"/>
                    <Wave Hs="0.0" Tp="1.0" Dw="0" WType="2"/>
                </DataItem>
                <DataItem SpatialID="1" TemporalID="0">
                    <Total Hmax="1.9" Uef="6.4">
                        <Wave Hs="1.0" Tp="4.6" Dw="220" WType="total"/>
                    </Total>
                    <Wave Hs="1.0" Tp="4.6" Dw="220" WType="0"/>
                    <Wave Hs="0.0" Tp="1.0" Dw="0" WType="1"/>
                    <Wave Hs="0.0" Tp="1.0" Dw="0" WType="2"/>
                </DataItem>
                <DataItem SpatialID="1" TemporalID="1">
                    <Total Hmax="1.8" Uef="6.5">
```

```
                <Wave Hs="1.0" Tp="4.7" Dw="230" WType="total"/>
            </Total>
            <Wave Hs="0.0" Tp="1.0" Dw="0" WType="0"/>
            <Wave Hs="0.0" Tp="1.0" Dw="0" WType="1"/>
            <Wave Hs="0.0" Tp="1.0" Dw="0" WType="2"/>
        </DataItem>
        <DataItem SpatialID="1" TemporalID="2">
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            </Total>
            <Wave Hs="0.0" Tp="1.0" Dw="0" WType="0"/>
            <Wave Hs="0.0" Tp="1.0" Dw="0" WType="1"/>
            <Wave Hs="0.0" Tp="1.0" Dw="0" WType="2"/>
        </DataItem>
        <DataItem SpatialID="1" TemporalID="3">
            <Total Hmax="2.6" Uef="9.0">
                <Wave Hs="1.4" Tp="5.3" Dw="210" WType="total"/>
            </Total>
            <Wave Hs="0.0" Tp="1.0" Dw="0" WType="0"/>
            <Wave Hs="0.0" Tp="1.0" Dw="0" WType="1"/>
            <Wave Hs="0.0" Tp="1.0" Dw="0" WType="2"/>
        </DataItem>
        <DataItem SpatialID="2" TemporalID="0">
            <Total Hmax="1.2" Uef="4.9">
                <Wave Hs="0.7" Tp="3.8" Dw="240" WType="total"/>
            </Total>
            <Wave Hs="0.0" Tp="1.0" Dw="0" WType="0"/>
            <Wave Hs="0.0" Tp="1.0" Dw="0" WType="1"/>
            <Wave Hs="0.0" Tp="1.0" Dw="0" WType="2"/>
        </DataItem>
        <DataItem SpatialID="2" TemporalID="1">
            <Total Hmax="1.4" Uef="5.5">
                <Wave Hs="0.8" Tp="4.0" Dw="230" WType="total"/>
            </Total>
            <Wave Hs="0.0" Tp="1.0" Dw="0" WType="0"/>
            <Wave Hs="0.0" Tp="1.0" Dw="0" WType="1"/>
            <Wave Hs="0.0" Tp="1.0" Dw="0" WType="2"/>
        </DataItem>
        <DataItem SpatialID="2" TemporalID="2">
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                <Wave Hs="1.0" Tp="4.5" Dw="220" WType="total"/>
            </Total>
            <Wave Hs="0.0" Tp="1.0" Dw="0" WType="0"/>
            <Wave Hs="0.0" Tp="1.0" Dw="0" WType="1"/>
            <Wave Hs="0.0" Tp="1.0" Dw="0" WType="2"/>
        </DataItem>
        <DataItem SpatialID="2" TemporalID="3">
            <Total Hmax="1.6" Uef="6.9">
                <Wave Hs="0.9" Tp="4.2" Dw="190" WType="total"/>
            </Total>
            <Wave Hs="0.0" Tp="1.0" Dw="0" WType="0"/>
            <Wave Hs="0.0" Tp="1.0" Dw="0" WType="1"/>
            <Wave Hs="0.0" Tp="1.0" Dw="0" WType="2"/>
        </DataItem>
      </dataSet>
    </AvailableProduct>
  </Product>
</Products>
```