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

Revised system design and user requirements

IWICOS Report No. 3

NERSC Technical Report No. 211

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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.

In IWICOS, user requirements have been obtained from: (a) previous RTD projects where user requirements for sea ice information were 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, (b) a design workshop held in April 2000, where a group of invited users provided additional input for the IWICOS prototype, and (c) a dedicated survey of user requirements that was carried out in Iceland in the first half of 2001. Results from user requirements analysis from (a) and (b) are described in the System Design and User Requirements Study, IWICOS Report No.1 (Steen Andersen et al., 2000) and the Baseline system report, IWICOS Report No. 2 (Steen Andersen et al., 2001). Results from the survey for users in Icelandic waters are found in the Market Study Report for IWICOS (Deliverable D7-1, September 2001) and the Survey among sea-farers (Gallup Iceland, Feb/Mar, 2001).

The initial design of the IWICOS system architecture and of the proposed main modules are also described in the System Design and User Requirements Study, IWICOS Report No.1 (Steen Andersen et al., 2000). This design was successfully implemented in the baseline IWICOS prototype, using standard data representation and system interaction protocols, and consisted of subsystems for Production, Brokering and Presentation. The first subsystem, Production, is typically different from one data provider to another, while the Broker was implemented as a subsystem to be shared by all partners, enabling them to disseminate their data and products using the IWICOS metadata standard and industry standard data formats (BSQ, GRIB, Shapefiles and XML). The third subsystem, Presentation, is customised to the different target end-users. As a result a small number of different End-User Systems have been implemented, all relying on the Broker subsystem and the defined standards for metadata and data representation.

Towards the end of the baseline period, the design of the End-User System was refined into two smaller subsystems, the Façade and the Client Software. The Façade is a communication link between Producer subsystems, the Broker and the Client Software, which is the program running on the end-user's computer giving access to the IWICOS products. Depending on the type of client (thin, thick and balanced) and the type of communication used (high vs. low bandwidth), the Façade has different responsibilities to optimise the load distribution between this subsystem and the Client Software. After the baseline period ended, some minor design changes have been made to Client Software. These changes are additions and refinements of earlier design, as more user requirements were implemented.

Some of the design issues identified above were also covered in the Baseline System Report, IWICOS Report No.2 (Steen Andersen et al., 2001). For consistency and ease of reading, some of the material from that report is repeated in the current report.

The report is organised as follows. Chapter 1 gives an overview of the IWICOS project with focus on the initial user requirements analysis and design phase. Then, Chapter 2 summarises the main points of the developed IWICOS metadata standard, which is fully reported in the Baseline System Report, IWICOS Report No.2 (Steen Andersen et al., 2001). The IWICOS system architecture and the defined subsystems are described in Chapter 3, while the changes to Client Software design are presented in Chapter 4. The current status of IWICOS products are found in Chapter 5, while the last chapter gives a summary of the IWICOS design and the major conclusions drawn.

Acknowledgements

The IWICOS project group members wish to express their appreciation of the involvement of the University of Iceland by Dr. Ingibjörg Jonsdottir, and gratefully acknowledge the help of all end-users who have contributed with constructive ideas during the first phase of the project.

Contents

1. Introduction

The objective of IWICOS is to develop a prototype marine information system that 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 centers. 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 services 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 through a survey conducted in 2001.

The user requirements provide input to the design of the IWICOS system. These requirements for functionality and the developed design are documented so that both end-users and the partners can easily understand the main concepts. The system design was discussed at a dedicated workshop in Copenhagen in April 2000, where selected users participated. Figure 1.1 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.

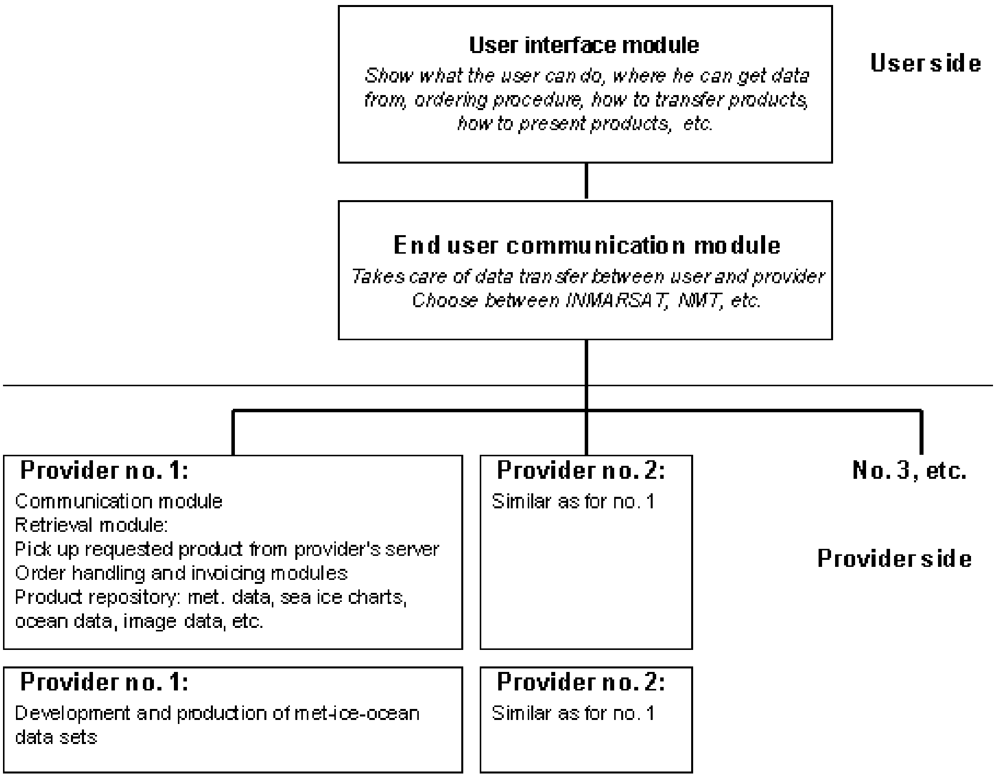


Figure 1.1 Graphical presentation of the IWICOS system.

2. The IWICOS metadata standard

A metadata standard (IMS-001-2001) has been developed specifically for the IWICOS project. Several existing standards have been investigated and tested including the comprehensive 'Standard for Digital Geospatial Metadata' (FDGC-STD-001-1998) established by the Federal Geographic data Committee (FDGC, 2000). However, none of the existing standards fully match the IWICOS product assemblage. The varied nature of IWICOS products combined with the fact that many of the investigated existing standards consist of superfluous components when considering the IWICOS requirements urged the development of an IWICOS specific standard. Although the majority of components in the IMS-001-2001 has been specifically designed for IWICOS products some generic components have been adapted from the FDGC-STD-001-1998 and implemented in the IMS-001-2001 structure. Establishing an IWICOS specific standard at the same time adds flexibility to the IWICOS, meaning that the standard continuously can be adapted and extended to IWICOS products.

The development of IMS-001-2001 has been carried out by means of XML and XML Schema in accordance with W3C recommendations (see W3C Recommendations 2000 a, b, c and d). The metadata definition itself consists of XML Schemas and the metadata files are XML documents instantiated from these schemas. The XML Schema definition consists of 17 schema files connected through common namespace declarations. The division into separate schema files is made as a database-like division into themes in order to simplify the development environment and ease revision/updating. Once the core structure of the schema definition has been established the maintenance of the IMS-001-2001 is not laborious. The implementation of new products/parameters, units, projections etc. is quite easily accomplished. Thus, the IMS-001-2001 has been continuously updated and extended to match IWICOS product requirements. All metadata XML documents are validated against the schema definition prior to release. This ensures that metadata files are IWICOS standard compliant and can be exchanged and understood by product servers, Broker and end-user systems.

The schema definition is build around a core element named 'Product'. From this core element a tree structure emerges consisting of generic child elements in an element-on-element structure with each element being associated with a set of attributes. A short description of each generic element follows:

- **Extent:** Defines the bounding geographical coordinates of the product
- **Reference Time:** Especially used for numerical prediction products where it defines the time of analysis
- **Valid Time:** Especially used for numerical prediction products defining the valid time (analysis + prognosis)
- **Scheduled Time:** Defines the time for next similar product
- **ProcessInfo:** Comprises information concerning data origin, quality and producer information
- **Data:** Comprises the actual data information for the four IWICOS exchange formats
- **Projection:** Defines the data projection - a set of 5 frequently used projections have been implemented

A metadata administration tool has been developed at NERSC during the baseline period. This tool (IwicosAdmin) is a graphical front-end to the baseline Broker at VTT in Finland, and enables the data producer to easily transfer IWICOS metadata files to the Broker. In addition, it is possible to check which metadata files have already been submitted, and to view selected metadata files in a standard web browser. With an XML-compliant browser this presentation will use the defined style sheets at the DMI server, providing a nicely formatted display of the metadata. After the baseline period ended, facilities for conversion of XML to HTML have been added to IwicosAdmin, to enable display of metadata also in non-XML-compliant browsers. Java and open XML tools (Apache's Xerces and Xalan) are used in the development of the IwicosAdmin.

3. The IWICOS system architecture

3.1 Interoperability

The IWICOS interoperability is based on a common description of available products and their features presented in XML. These metadata descriptions are submitted to the Broker. The customers can base their product selection on the metadata description, and then retrieve the actual products from the Producer Servers with the help of a Facade subsystem. Finally Client Software is used to acquire a presentation of the product data (Figure 3.1).

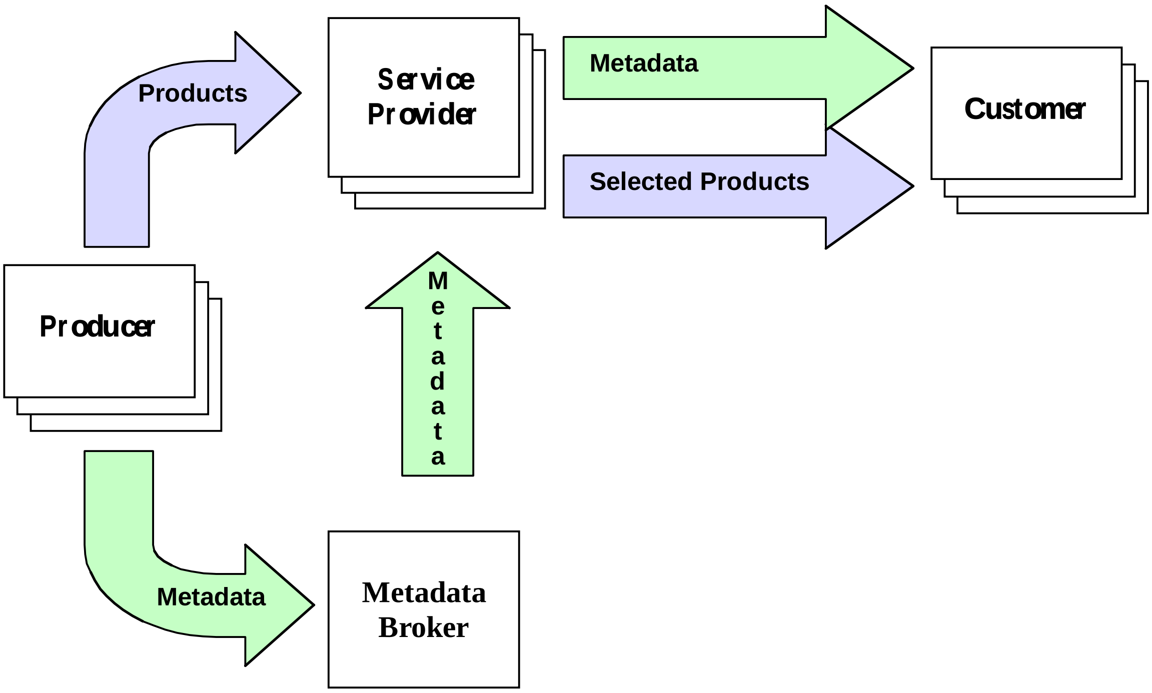


Figure 3.1 The IWICOS Service Chain.

3.2 Architecture

The Producer Server integrates the IWICOS system to the producer's existing production process. It communicates with the Broker using specific small stub programs designed for the messaging between these components.

The Producer Server consists of two parts (Figure 3.2):

a. An active part, that informs the Broker of the events, such as a new product becoming available or an old product getting outdated, that occur in the production process.
b. A passive part, that is basically a web server where the active part places it's output for the Broker (the metadata) and the Facades (the product data) to retrieve.

The set of data formats for the communication between the Producer Servers and the Facades was limited to Binary Sequential Files (BSQ), GRIB (GRIdded Binary), Shapefile, and XML for reducing the complexity of the implementation. Within the End-User Systems (Facade and Client Software pair) there are no such limitations. The Facades can use the base types listed above to generate products in any format. Basically the End-User System is a black box - the subsystems outside should and shall not be interested in what happens there.

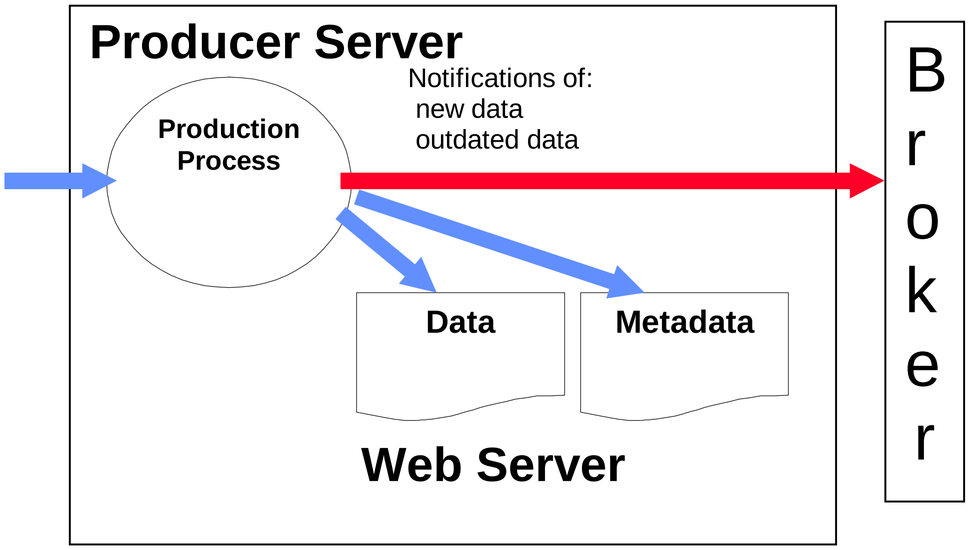


Figure 3.2 The IWICOS Producer Server Components and Internal Data Flow.

The Broker provides two interfaces for metadata operations. One is intended for the Producer Servers for managing the Broker's metadata content. The other one is the query interface for the End-User Systems through which they can access the Broker's metadata content. The Broker is based on freely available elements, Apache Tomcat web-server, Apache SOAP 2.0 implementation, MySQL database, and Linux OS (RedHat). The service programs are written in Java.

The Broker is divided into three main components: the Database, a storage for metadata; the Metadata Parser, that will process the metadata descriptions of the new products and store them to DB for later access by queries; and the Query Engine that will interpret the queries posed in an XML format to SQL and execute them on the DB and return the results for the caller (see Figure 3.3).

The Broker communication is implemented with the Remote Procedure Calls (RPC) implemented over the Simple Object Access Protocol (SOAP). The RPC uses a small program called a *stub* in both ends of the communication, which will marshal the required parameters and return values of the call. Example of stubs is shown in Figure 3.4.

The Facade implementations can vary a lot. For a simple web-browser based client it will be closely integrated to the Client Software and it is hard to say where one begins and the other one ends. On the other hand it may be very complicated element containing reasoning of user needs based on a profile, product generation based on the products provided by the Producer Servers, and filtering of unnecessary components of products (e.g. layers with unnecessary data content).

The Client Software is intended for presenting the acquired data and the implementations have a range from thin to thick clients. All types of clients (thin, balanced and thick) will probably be tested in the demonstrations during the project.

The IWICOS Architecture is illustrated by the four following communication scenarios between the various subsystems: **Producer Server - Broker, Facade - Broker, Facade - Producer Server, and Facade - Client Software**. These are explained in more detail below.

Producer Server - Broker
In this scenario the Producer Server manages the Broker metadata content with the following operations: *newProduct*, *outdatedProduct*, and *productList*. The operations are used for informing the Broker of new and outdated products, and acquiring of a list of the producer's products that have metadata stored to Broker.

Facade - Broker
In this scenario the Facades execute queries on metadata at the Broker to gain a list of products that might be applicable for user needs. This interface contains a single operation called *query*. However, it

is more complicated than the previous scenario hence the parameter and reply contents is more dynamic.

Facade - Producer Server
In this scenario the Facades acquire the actual product data based on the metadata retrieved in the previous scenario. The product data at the passive (web-server) part of the Producer Server is accessed using the HTTP-protocol and thus is not very complicated to implement.

Facade - Client Software
This scenario is actually a black-box one - the decision of what protocols and other means of communications to use here is left for the designer of the Client Software - Facade pair. In the scope of the IWICOS System it is enough for us to know that such implementation is present.

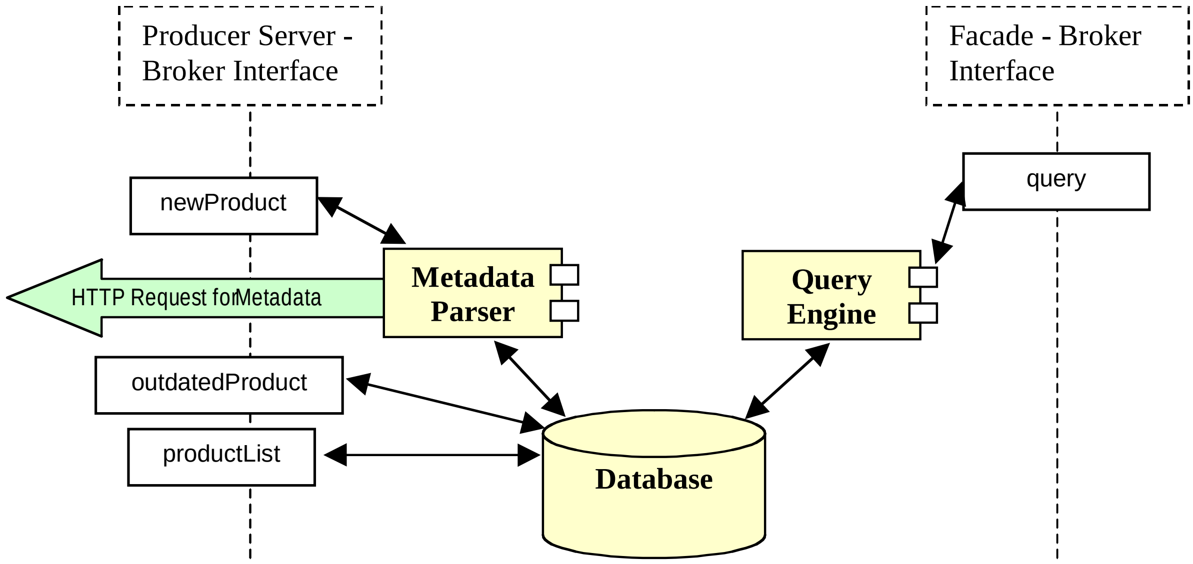


Figure 3.3 The Broker Internal Structure.

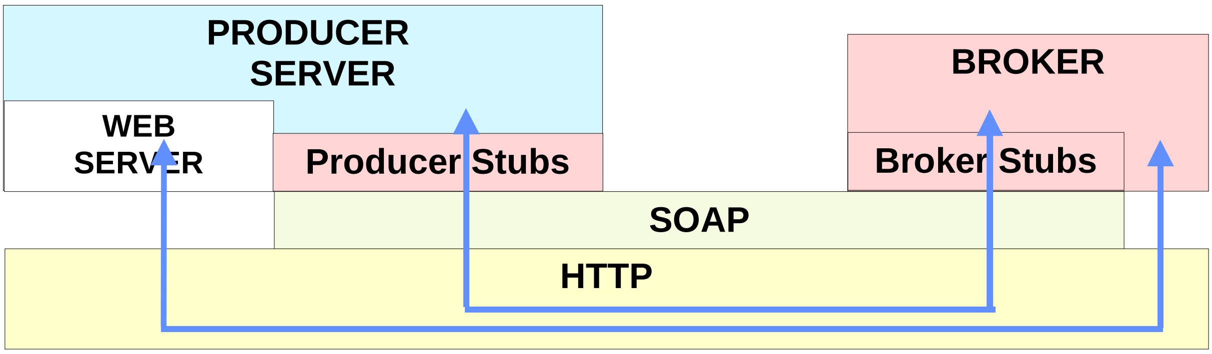


Figure 3.4 The IWICOS Producer Server and Broker Stubs.

3.3 Communication possibilities

Basically the requirements for IWICOS communication capabilities fall in to two categories. First category is the communication between the Producer Server, Broker, and Facade components that will occur in a stable high-band Internet environment. The second category is the communication within the End-User System (Client Software and Facade). This category is more complicated since the means and capability of the communication may vary a lot. The parties may communicate with a high-band Internet connection (a web-client), a costly high-band satellite connection, or narrow-band radio or cellular phone connection.

The first scenario is under a rapid change, although the communication capability is likely to remain at approximately the same level, but the way of using this capability is changing. New Internet technologies are developed with an aim to solve the problem of describing, discovering, selecting, and using the various services automatically. This trend known as the Semantic Web or Web Services is evolving rapidly.

In the second scenario there will not likely be any dramatic changes in the near future. The Satellite connections are likely to remain expensive and thus scarce. The cellular phone network coverage will be limited and out of scope for the sailors at high seas, although the GPRS and other new technologies may improve the bandwidth.

Considering these categories/scenarios our natural conclusion is to concentrate on the first category, with a preparational view for the future technologies. Our approach to implement an interoperable metadata service is to introduce the use of SOAP (Simple Object Access Protocol), SOAP RPC and extensive use of other XML related technologies where applicable (see Figure 3.5).

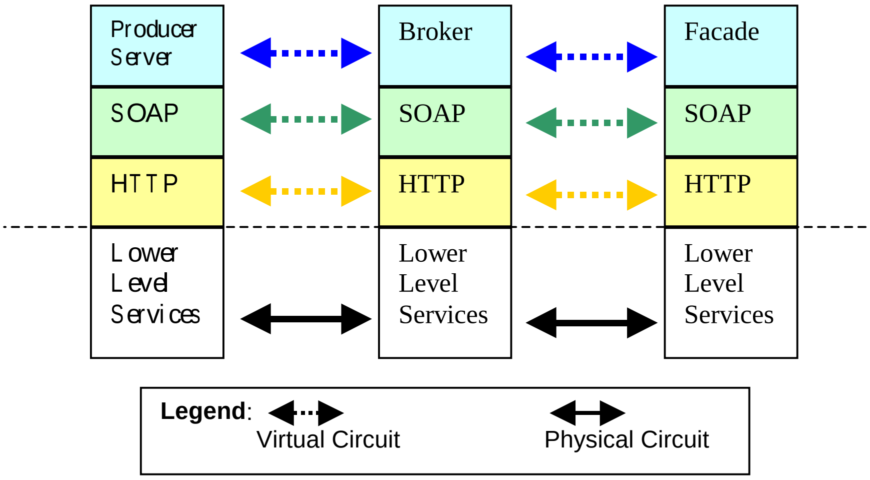


Figure 3.5 The SOAP Based Communication in the Broker Interfaces.

The Simple Object Access Protocol (SOAP) is an open standard that supports the interoperability of autonomous systems. Since it can be run over the Hypertext Transfer Protocol (HTTP), it helps to resolve the communication problems that occur when the applications have to operate through the firewalls of different organisations. Furthermore, SOAP supports RPC for invoking services on the service. SOAP messages can contain data packed in XML format, so they provide an ideal platform for implementing a tailored messaging service. Due to the XML approach the SOAP messages are easy to understand when compared to their binary correspondents such as CORBA, DCOM and RMI. The character-based nature of the messages introduces the requirement for encoding and decoding at the ends of communication, however this is relatively easy task when compared to the cost of the transmission itself. The SOAP will probably also be a fundamental building block of the yet to come Semantic Web technologies, which will probably significantly change the way we look at implementation of interoperability.

3.4 Client capabilities

Client Software visualises the weather and ocean information to the user. It retrieves the data from Façade, which has already tailored the data into a proper form (Figure 3.6)

Façade can be understood as a server for the Client Software. Façade and Client Software need not be located in the same physical location, and the communication link between Client and Façade varies from high-speed Internet connection to low bandwidth cellular phone link.

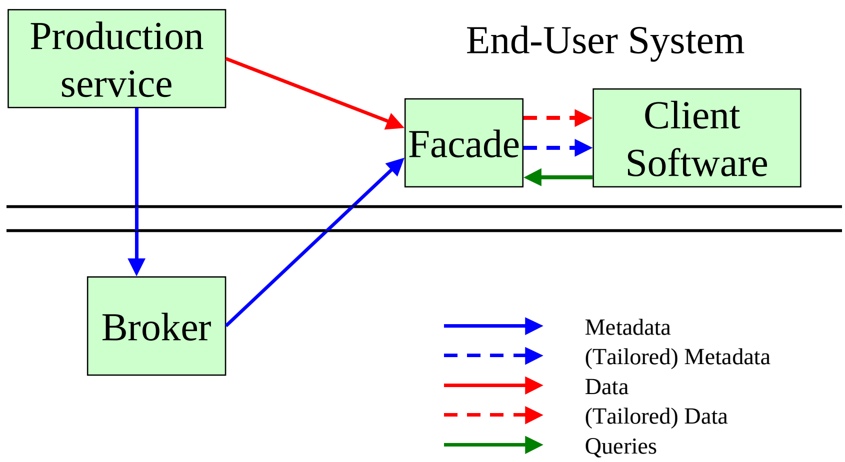


Figure 3.6 The data flows between Client Software and Façade.

Client Software includes the following functions:

A Receive/Retrieve data from Facade
Client Software has to be able to communicate with Façade. User queries are delivered to Façade, and metadata and weather-ocean data are received in return.

B. Display metadata
Client Software is responsible for presenting the metadata to the user and providing means for product selection. Predefined profiles may also be used to retrieve the purposeful data. In that case, some means for profile input are provided.

C Generate presentation (thick-clients)
As thin clients mainly present the image data received from the server as such, thick clients are able to generate a visualisation from raw data received.

D Allow customisation of the presentation (thick-clients)
Users typically want to combine some data and filter out some aspects of data. (E.g. User may want to see weather forecast and an ice-image combined on the screen, or want to view only the wind field instead of whole weather forecast).

3.4.1 Is the client thin or thick?

The users of the IWICOS system will have a variety of communication capabilities in use. There are several ways to distribute the load between server (Façade) and client in order to get the most out of the communication link's bandwidth. One way is to give all computational tasks to a *heavy server* and let a *thin client* only take care of the presentation. This *thin client model* needs a broad bandwidth connection as all the images are created on server side and delivered to the client.

The other way around is to have a *light server* delivering raw data to a *thick client*, which produces the images needed for presentation. The communication line is burdened only when the raw data files are transmitted to the client.

The third solution is the balanced model where a *semi-heavy server* performs all the demanding calculations and a *semi-thick client* takes care of the rest of the tasks. A Java-applet client can be considered as an example of the balanced model, as it may present ready-made images and generate customised views out of raw data.

Table 3.1 summarises the different ways of distributing the tasks between client and server. The tasks include creating map images out of raw GIS data, creating overlay composite images, displaying the images, browsing the map (pan and zoom) and executing spatial queries (E.g. give me wind data for Baltic Sea area! What forecast data are available for tomorrow? Etc.). According to the table a thin client retrieves images and presents them as such on the screen. In the balanced model a client retrieves raster and/or vector data and draws images according to user's setting (zoom level, geographical viewport etc.). A thick client draws the images out of the raw data, which the server delivers to the client as such.

Table 3.1 Possibilities to distribute the load between client and server.

	Thin client	**Balanced**	**Thick client**
Façade/Server tasks	Map drawing Overlay drawing Map browsing Query	Query Map drawing Overlay drawing	File serving
Data transferred	Raster images	Raster / vector	Raw GIS data
Client tasks	Display	Display Map browsing Query input	Display Map drawing Overlay drawing Map browsing Query

3.5 Facade specification

The Facade acts as a Server for the Client Software. It communicates with the Broker, the Producers and the Client Software. The range of functions that may be present in a Facade is very wide. It can be a mere tunnel doing practically nothing to the bypassing metadata and data or it may be a very complex entity that combines divergent AI and data filtering and conversion capabilities to a high level service component.

In Figure 3.7 the structure of the Facade is shown. This structure depicts an Interactive Facade, i.e. the product candidates are retrieved from the Broker and the list is displayed to the User, who then interactively selects the products to be processed for viewing.

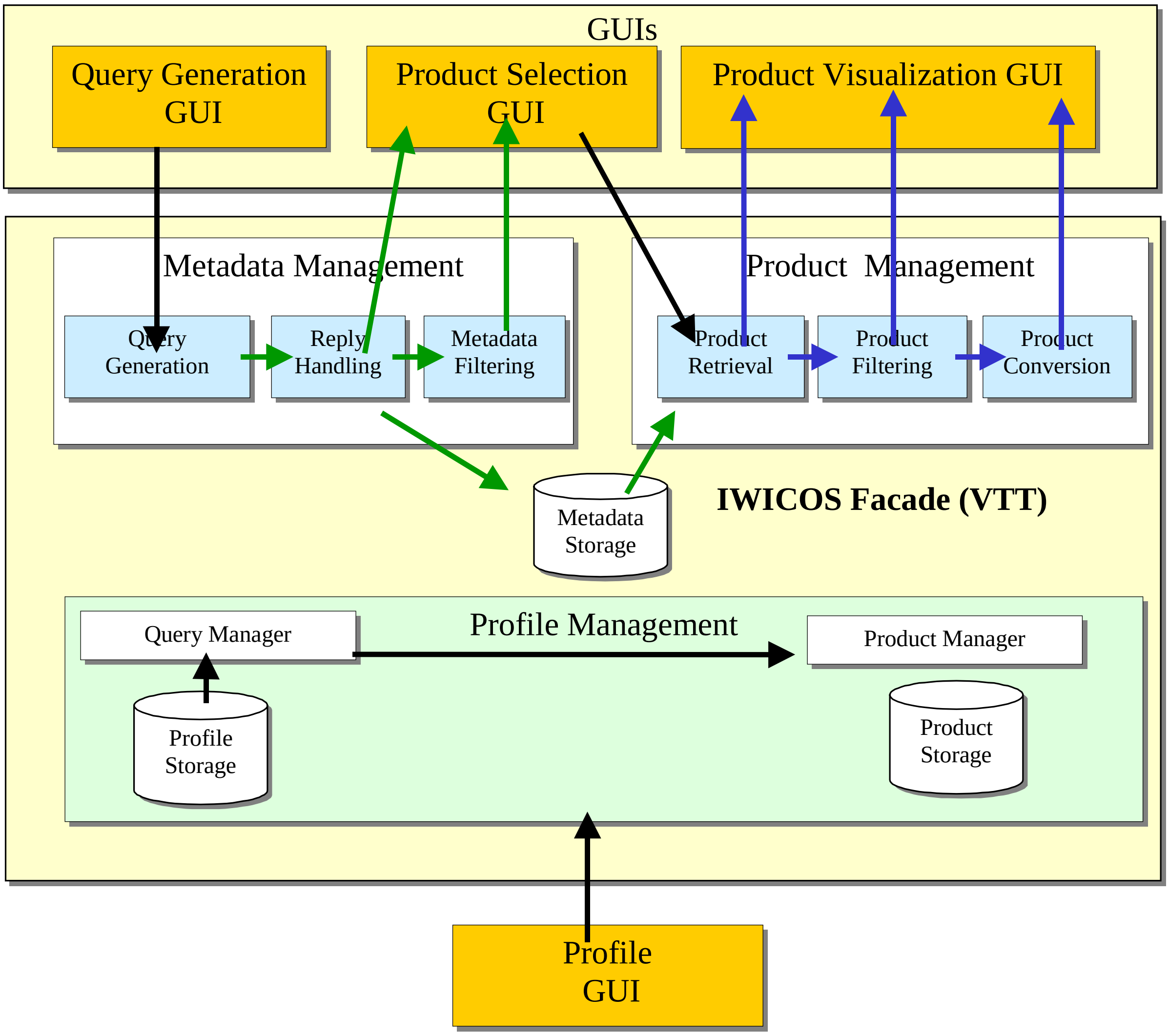


Figure 3.7 Structure of the Façade.

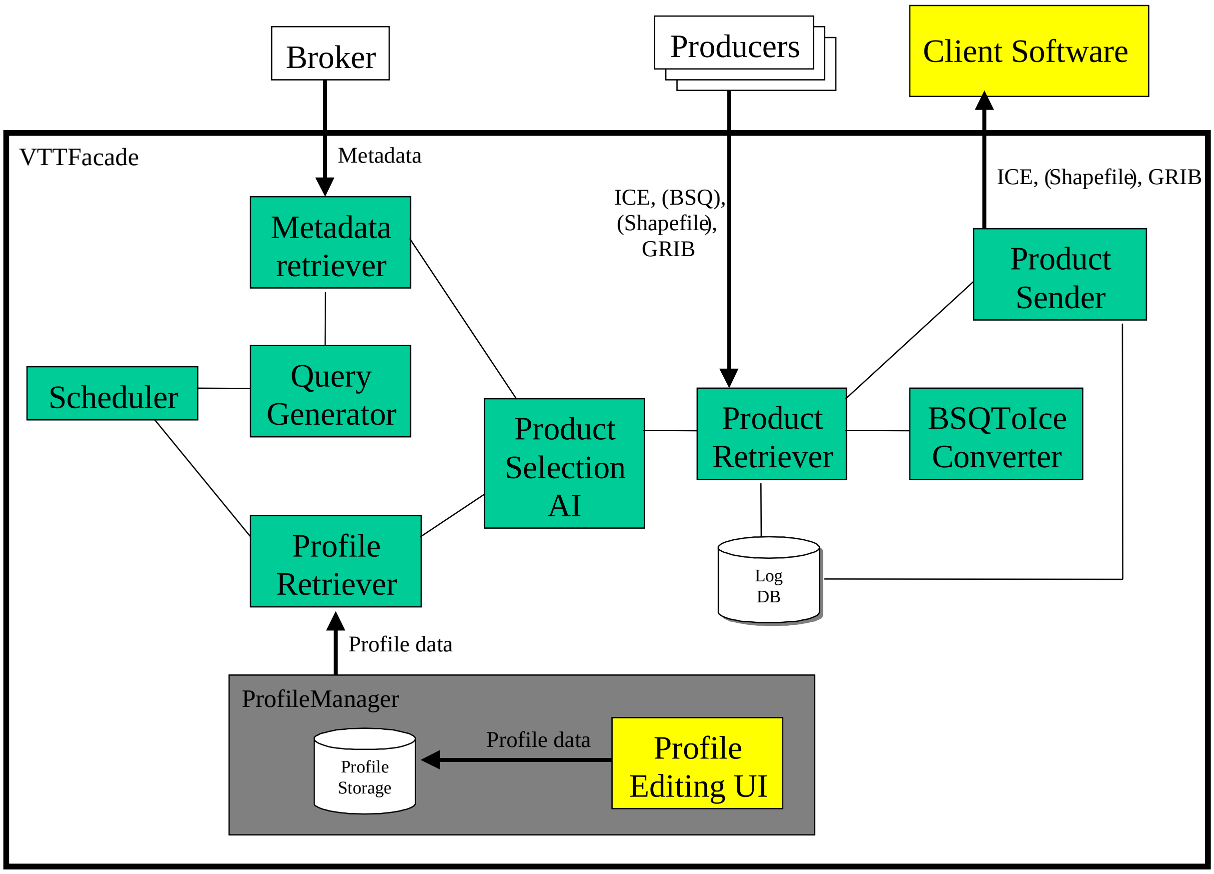


Figure 3.8 Detailed structure of the VTT implementation of the Façade.

In Figure 3.8 is shown the detailed structure of a Facade that is intended for automatic profile based processing of the products to be sent to the Client Software. This structure will be used by VTT when implementing the Facade for the demonstrations. The modules in the figure are as follows:

- *Scheduler:* This module controls the action of the submodules.
- *Query Generator:* This module is responsible for generating the XML queries to the Broker according to the parameters set in the profile.
- *Metadata retriever* - handles the communication with the Broker.
- *Product Selection AI* - this "Artificial Intelligence" module contains the logic to select which products are actually retrieved from the Producers and prepared for sending to the Client Software. It combines the parameters from the Profile with the capabilities of the Client Software and the communications channel to the Client.
- *Product Retriever* - performs the actual retrieval of the data and stores the data on a local disc.
- *BSQToIce Converter* - is responsible for performing the necessary format conversions from IWICOS format to Client format. The conversions may also contain remappings (projection conversions), resolution conversions and sub-area-selections.
- *Product Sender:* Handles outputting of the data for the Client by means of E-mail or putting the data on a web-site. It may also call a notification mechanism to make the Client user aware of new data availability.
- *Profile Manager:* This subsystem contains the storage and handling of the Profile, where the parameters for the production are stored. The contents of the Profile is changed using the Profile Editing UI.

4. IWICOS clients' design

The IWICOS clients (also called Client Software) are customised to the target end-users. After the baseline period ended, only minor changes to the design have been made, in the form of additions to or extensions of the existing design. These design issues are presented below, grouped under client categories *thin*, *thick* and *balanced*.

4.1 Revised system architecture of thin clients

The baseline system at IMO contains 2 product chains; forecasts in plain text written by meteorologists and model output wave forecasts for Icelandic waters. The target user group for IMO's baseline products will be fishermen on small boats. It is vital for them to receive detailed but still concise forecasts and warnings for their area. They will normally not have access to sophisticated communications systems onboard the boats and they will rely heavily on traditional communication, such as radio and telephone answering services. They will be able to approach graphical products on a specially designed web page, which they can study before they leave home.

Figure 4.1 shows the data flow for IMO's baseline products, which are described in Section 5.2.

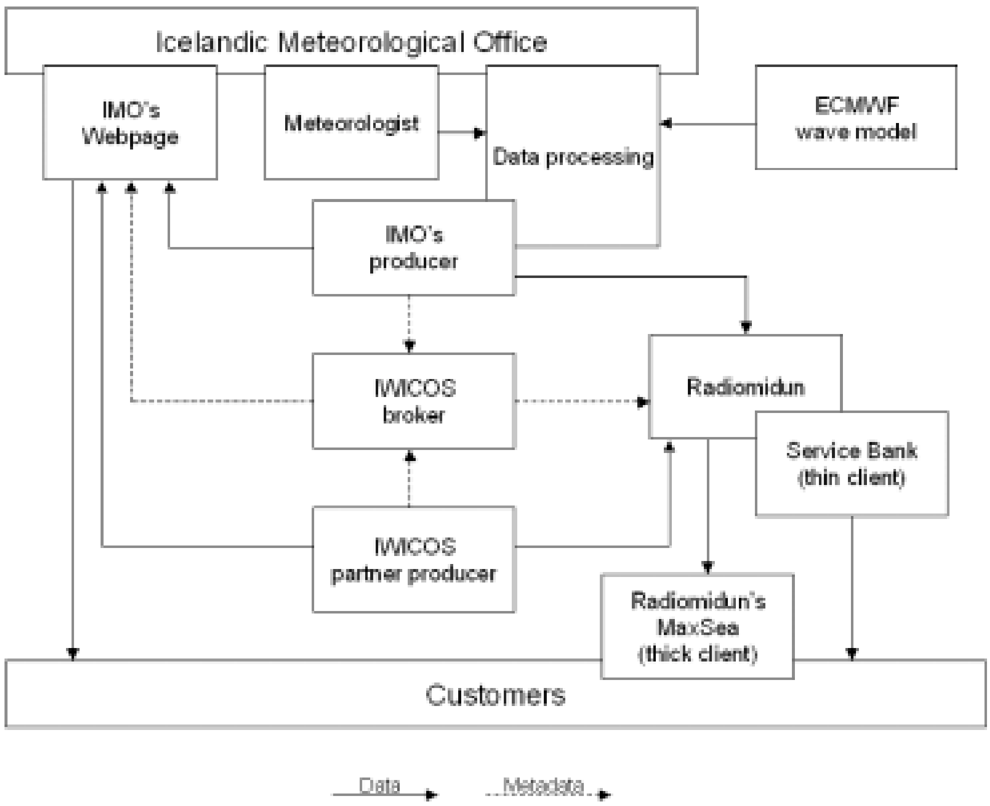


Figure 4.1 Data flow for IMO's baseline products.

4.2 Revised system architecture of thick clients

A thick client solution has been developed and named the 'Met-Ice-Ocean Viewer' or in short the MIO Viewer. The client has been tailored to handle and present digital meteorological, oceanographic, sea ice data and satellite imagery, primarily to users onboard ships. The thick client is foreseen to serve those users that are considered ‘off-line’ users, i.e. users who only have access to data through narrow bandwidth connections. Users need to carry out both tactical and strategic route planning which involves analysis of sea ice, weather and ocean information. Today this information is available, but almost entirely as separate information layers. Therefore, users are interested in integrating weather, ocean and sea ice information in a more user friendly way and consequently benefit from the synergy that often will emerge when combining these data. By integrating different met-ice-ocean products in the MIO Viewer and combining these in a common presentation environment the user has a valuable tool when interpreting surrounding weather, sea ice and ocean conditions. Thus, the application is intended as a decision support and route-planning tool.

The following generic features have been added to the design of the 'Met-Ice-Ocean Viewer' (MIO Viewer) developed by DMI:

- Fast display of satellite imagery and sea ice charts.
- Special facility for displaying sea ice attribute data.
- Multiple-format display of meteorological and oceanographic parameters for user selected prognoses, areas and models.
- On-screen digitising and editing of routes and automated calculation of distance and course between way points.
- Easy-to-use intuitive user interface.

The functionality of the MIO Viewer can be summarised as follows:

- A mix of the basic GIS functionality as provided by ArcView and the MIO Viewer specific functionality developed using the Avenue scripting language.
- The MIO Viewer specific functionality can be divided into two parts, i.e. a data functionality part and a navigation/route planning part.
- All functionality is available to the user through a customised graphical user interface.

Figure 4.2 illustrates this functionality.

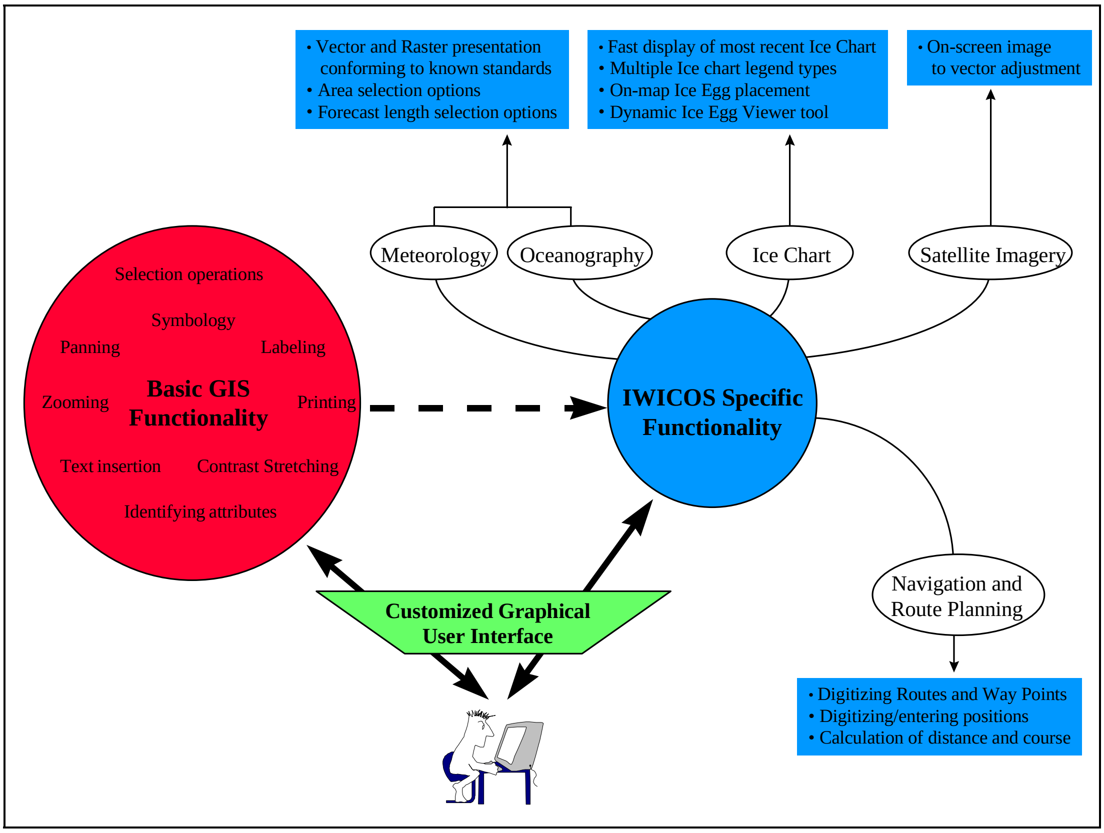


Figure 4.2 Met-Ice-Ocean Viewer functionality.

The Baltic Sea Baseline System, developed by FIMR and VTT, provides two products: (1) water level data and (2) PWM wave model forecasts, in the IWICOS metadata and data standard. Figure 4.3and Figure 4.4 show the respective processing chains for these two products. Ice products were not included in the Baseline System tests, because they are operational only during the Baltic Sea ice season (October - May).

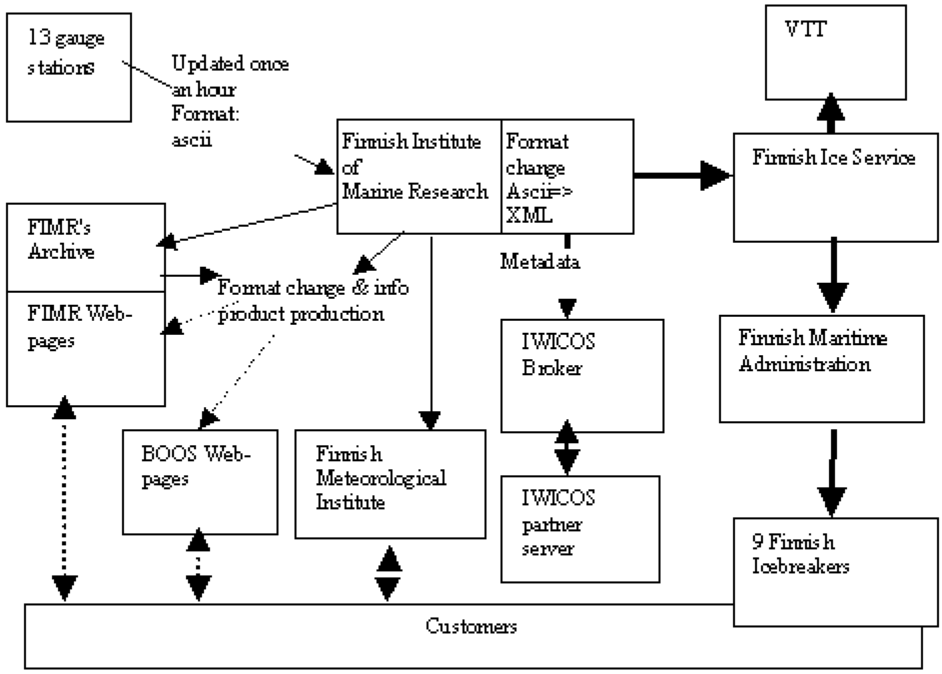


Figure 4.3 FIMR's water level data flow. Data is updated once a hour. Thin arrows: ascii format, thick arrows: XML format. Broken lines indicate various other formats.

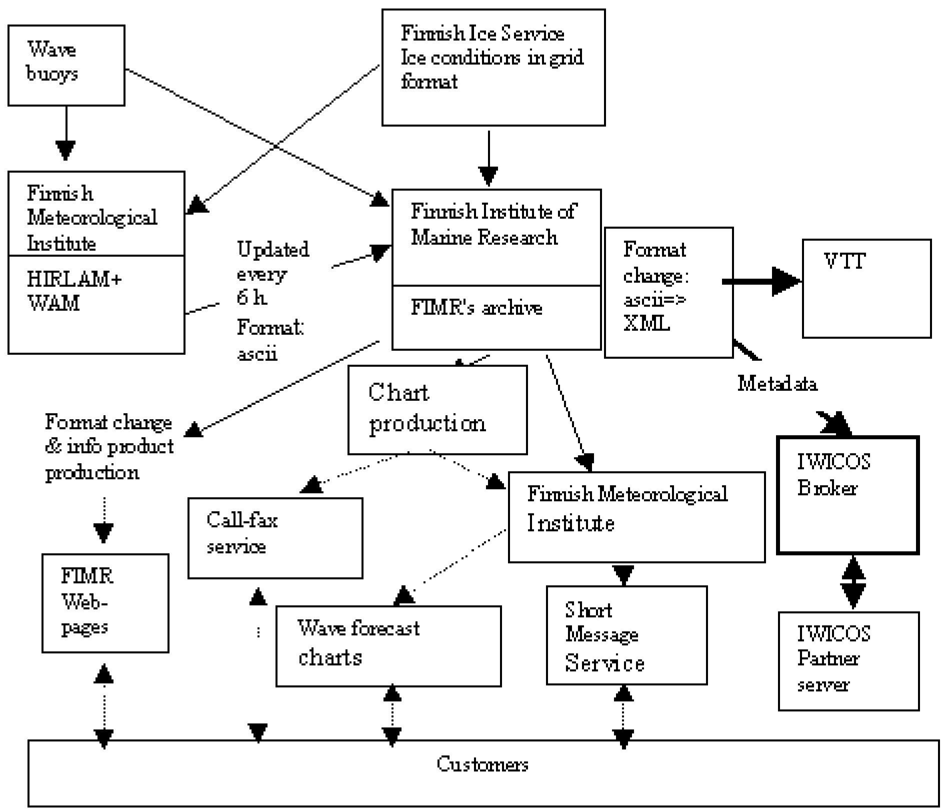


Figure 4.4 FIMR's WAM model forecast flow. Forecasts are updated once in 6 hours. Thin arrows: ascii format, thick arrows: XML format. Broken lines indicate various other formats.

4.3 Revised system architecture of balanced clients

The concept of a balanced client lies somewhere between the thin and the thick clients, i.e. it has some processing and analysis capabilities, which makes it more flexible than a thin client, but these capabilities are not as extensive as those of a thick client. The purpose of the development of balanced clients is to keep some of the capabilities of the thick client without having to install too much software. The Java programming language and the availability of standard web browsers with Java capability enables development of so-called *applets*, which are programs that can be downloaded via Internet or pre-installed if operated on a vessel. Applets are started from a web page, and run within the browser.

The DTU/DCRS Java browser is such an applet, which has been used extensively from both land-based and ship-borne users. The size of the code is in the order of 60 Kbytes, and it can be transferred over even very slow Internet connections in a very short time (seconds). The software is transferred automatically (if not cached) when the application web page is loaded. Despite the small amount of dedicated code, the application allows a number of capabilities that are otherwise only available in thick clients. Currently, these features include:

- Display of images, and colour-/grey-scale manipulation
- Overlay of vector graphics including
    - Coastlines
    - Lat/lon grids
    - Contours of bathymetry
    - Contours of ice concentration (same day and previous days)
    - Digital ice charts (ice eggs and polygons)
    - Wind forecasts
- Zoom in/out
- Georeference (lat/lon coordinates at the click of the mouse)
- Distance calculations

Figure 4.5 shows a screen shot of the DTU/DCRS Java browser, illustrating some of its capabilities.

NERSC is developing a mixed thin and thick client for retrieval of SAR ice images and retrieved ice parameters such as ice classification and ice drift. In the baseline system, focus has been on implementing thin client capabilities, with display of metadata, SAR images and derived parameters. Figure 4.6 shows an example of a map of the study area around Svalbard, which will show the location of selected SAR images. Also shown in Figure 4.6 is the data flow from "raw" satellite data to sea ice products delivered in IWICOS metadata and data format.

Ongoing design of the SeaIceViewer application will incorporate algorithms for SAR images, ice motion and classification (thick client), and streamline the metadata/data production line for ice type classification and ice motion (both thin and thick client). NERSC also plans to include NCEP/DMI wind/SST data in the extended version of the SeaIceViewer client, and foresee that this will require additional modules that can be plugged into the client when needed.

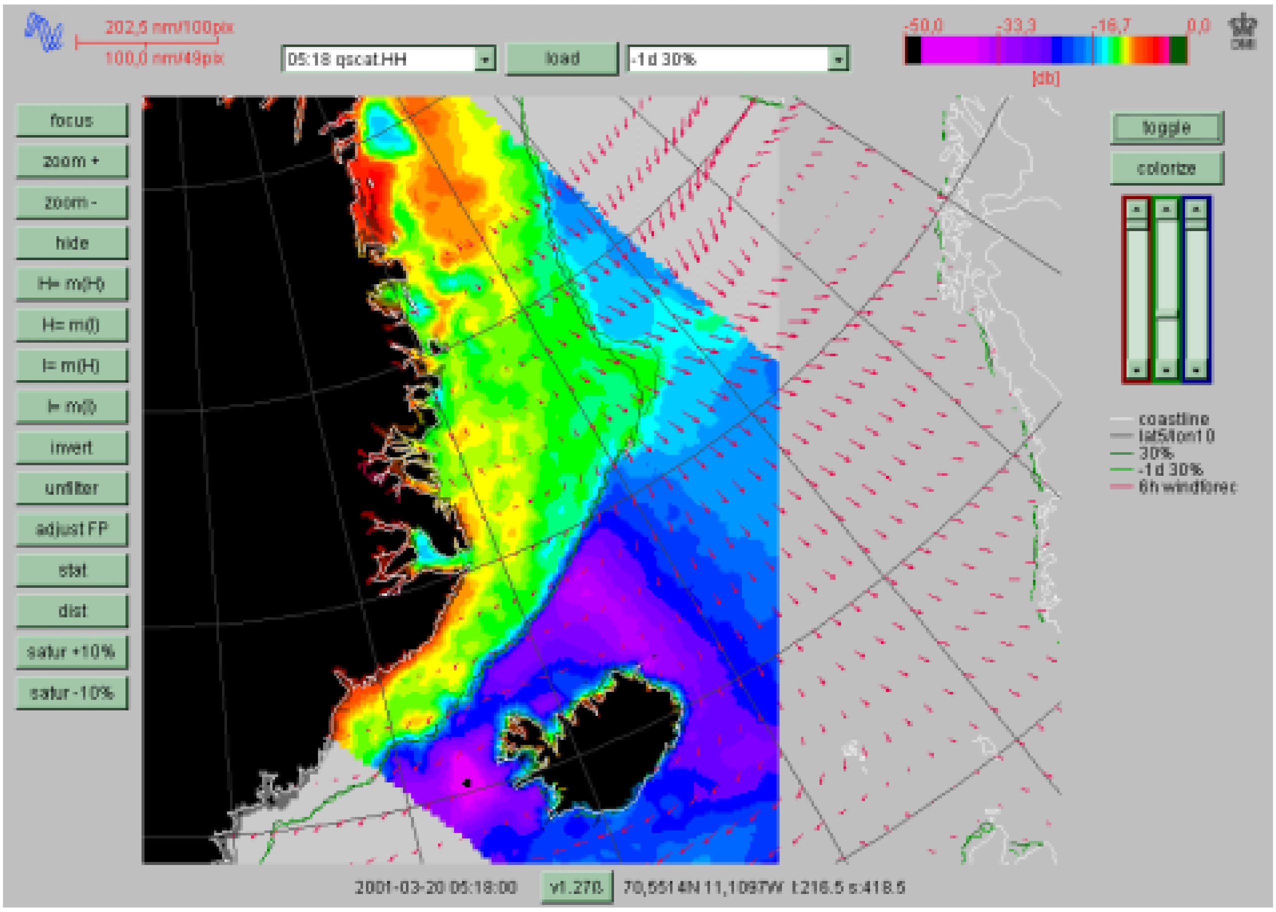


Figure 4.5 The baseline DTU/DCRS IWICOS met/ice/ocean browser. The imagery is from NASA's QuikSCAT scatterometer instrument 05:18 UTC on March 20, 2001. Overlays are coastline, lat/lon grid, 6 hour wind forecast valid at 06:00 and 30% ice concentration contours from March 19 and March 20.

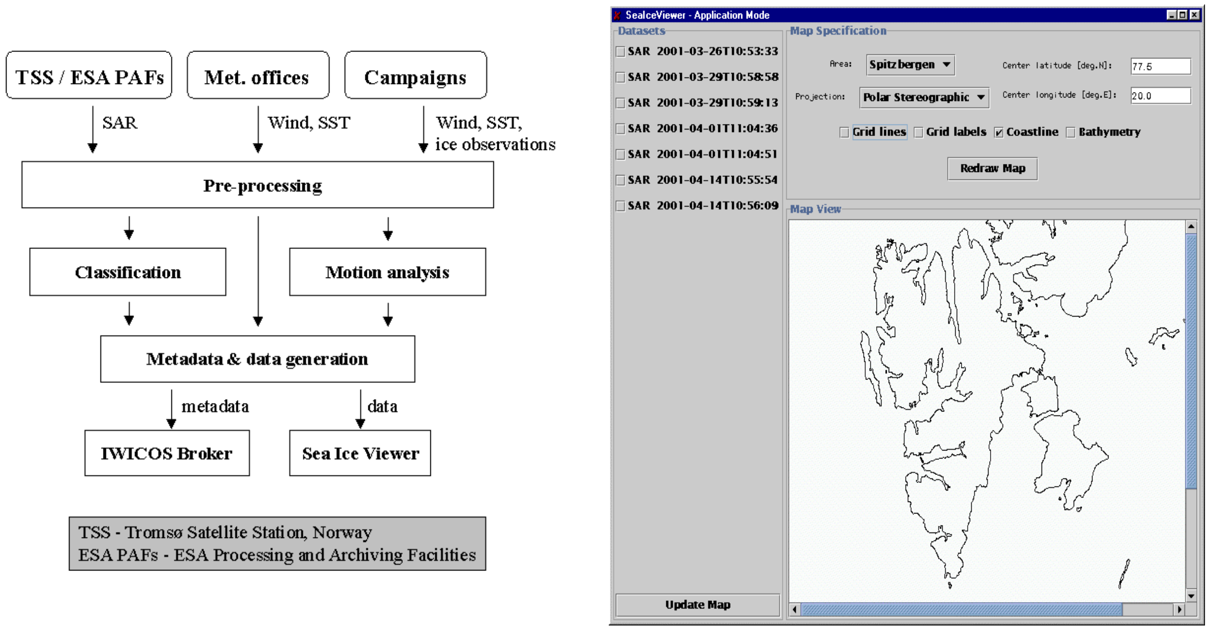


Figure 4.6 Data flow for baseline product generation at NERSC (left) and screen shot of the Java client developed for sea ice products (right).

5. Products delivered through the IWICOS Service Chain

All data sets go through a set of processing steps, called the Service Chain, before being delivered as met-ice-ocean products to the end-users (Figure 5.1). The initial data products are transformed into client products through different processing in production and brokering servers, and client software. In this chain, the data that the user needs are produced, processed for delivery, selected and presented to the user in the form of client products.

The base for identifying useful data and the processing it requires, is the metadata 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 metadata presentation (Karttunen 1999, Lassila 1999). The main components in the service chain are the subsystems of the reference architecture described in Section 3.

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.

All data products have metadata according to the IWICOS metadata standard (IMS-001-2001), and data in one of the selected industry standard formats (BSQ, GRIB, Shapefiles and XML). In addition, the data may also be available in other formats, specialised for a particular client.

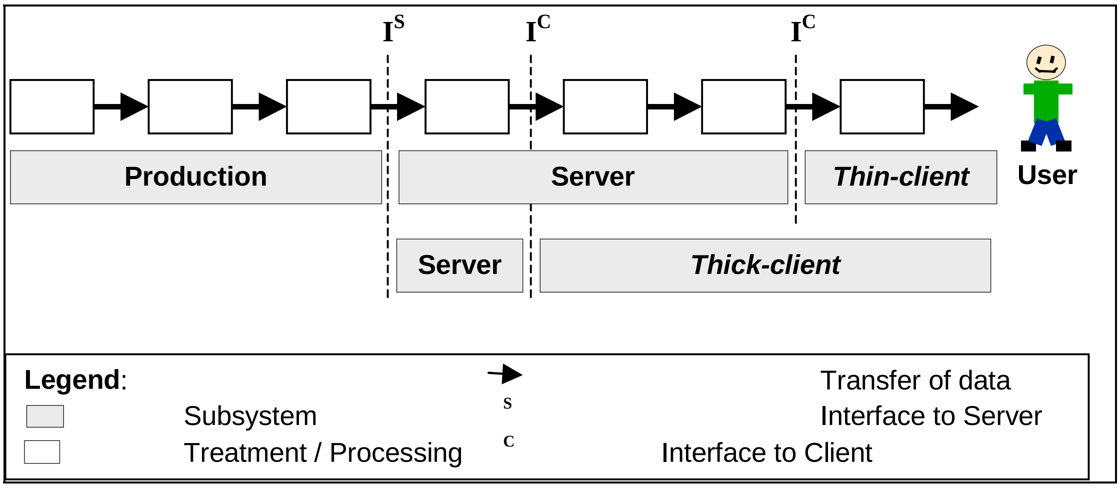


Figure 5.1 Processing steps in the IWICOS Service Chain.

5.1 Greenland Sea products

The service chain and data flow for DMI's products are the following:

- Ice Charts, satellite data and weather model output are stored on a partner specific product server.
- Metadata are generated to match products and validated against the IWICOS Schema Definition.
- The broker is informed every time a new product is available on the product server and then fetches the product metadata from the product server and stores it in a metadata database.
- Facade handles data conversion from IWICOS Exchange formats to client specific formats.
- Data is sent to MIO Viewer through narrow bandwidth connections.
- Data provision is based on a data product profile as predefined by the user and the provider in collaboration. The data product profile is then adjusted from time to time according to sail routes, weather, ocean and sea ice conditions and data availability.

Figure 5.2 shows the service chain for DMI baseline products.

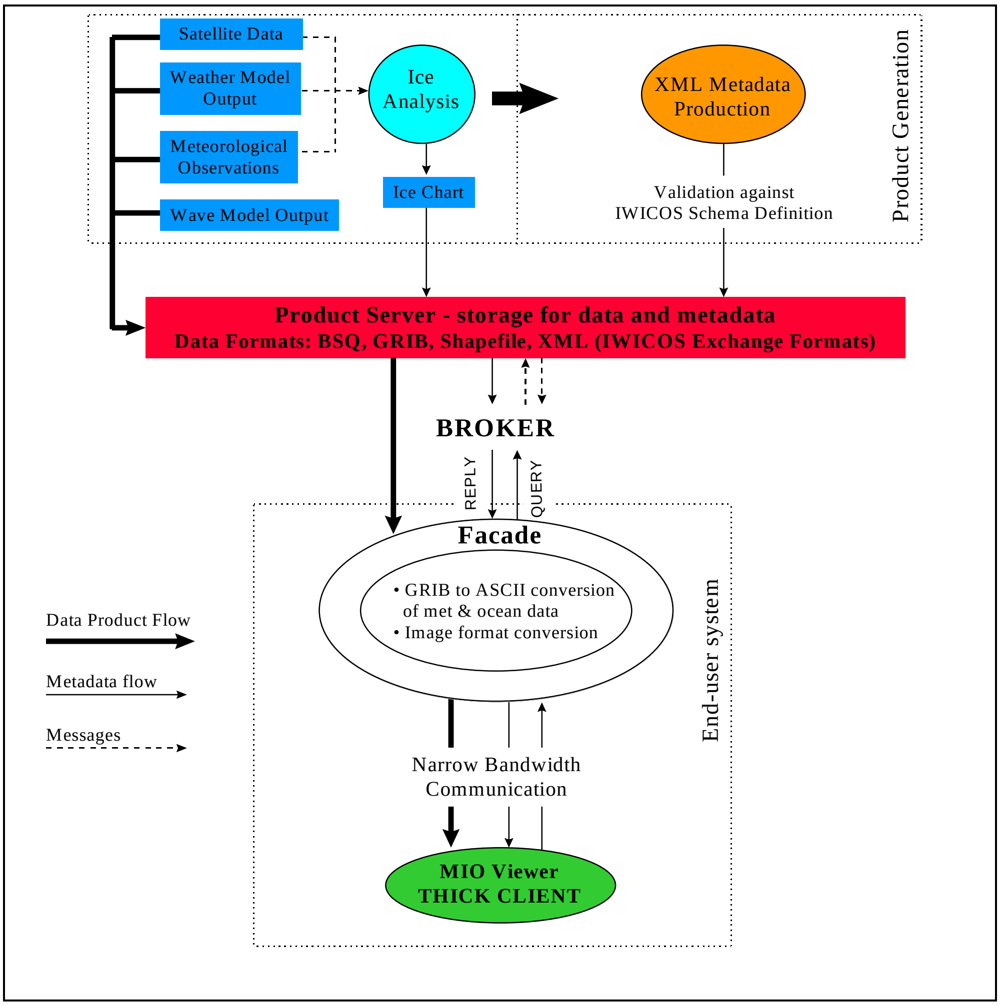


Figure 5.2 Service chain and data flow at DMI.

Currently supported products are shown in Table 5.1.'

Table 5.1 Currently supported products at DMI.

CATEGORY	PRODUCT/PARAMETER	INPUT FORMAT
Satellite Image	RADARSAT	ERDAS, MrSID, BSQ
Satellite Image	NOAA AVHRR	ERDAS, MrSID, BSQ
Satellite Image	DMSP	ERDAS, MrSID, BSQ
Sea Ice Data	Ice Chart	Shapefile
Meteorology	Mean Sea Level Pressure	ASCII
Meteorology	Air Temperature (2 meter)	ASCII
Meteorology	Wind Speed/Direction (10 m)	ASCII
Oceanography	Significant Wave Height	ASCII
Oceanography	Mean Wave Direction	ASCII

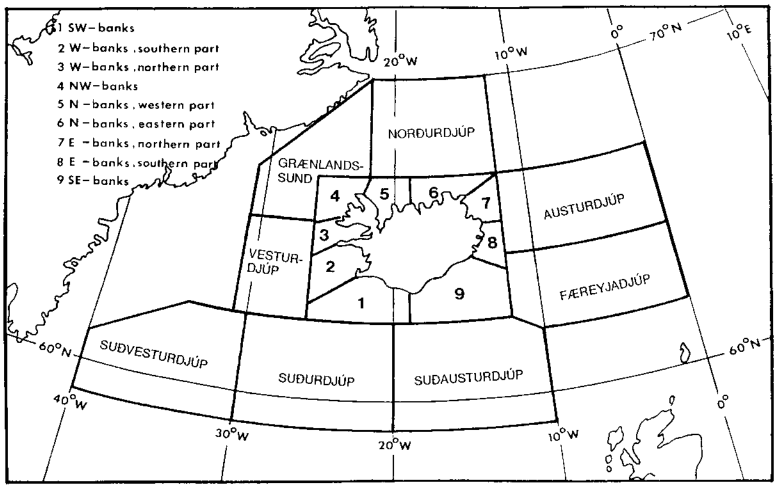
The presentation of products seeks to follow known standards for presenting sea ice, meteorological and oceanographic data as defined in World Meteorological Organisation, 1970, World Meteorological Organisation, 1992 and World Meteorological Organisation, 1994.

5.2 Icelandic waters products

5.2.1 Baseline 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.

- Text forecasts, written for up to 17 areas (Figure 5.3) and issued up to 8 times a day. Strong gale warnings are issued if wind speed is expected to exceed 20 m/s. The forecast is stored in XML-format.
- Wave forecasts updated once a day. They contain forecasts for significant wave height, mean wave direction and mean wave period. The forecasts will be delivered to the baseline system in GRIB-format.



1 Sudvesturmid
2 Faxaflóamid
3 Breidafjardarmid
4 Vestfjardamid
5 Nordvesturmid
6 Nordausturmid
7 Austurmid
8 Austfjardamid
9 Sudausturmid

Figure 5.3 Areas used in Icelandic maritime forecasts.

5.2.2 Planned products

In addition to the two baseline products which are very essential to seafarers, particularly for those on smaller boats which are the main target group of IMO, the following products are planned:

- Enhancement and increased flexibility of presentations of text forecasts and warnings for strong wind, high waves, ice accretion etc.
- Point forecasts for selected stations at the coast.
- Sea ice charts for the area north and west of Iceland, based on satellite images. The work will include investigation of the quality and other properties of the available satellite images and how different images may be combined.
- Methods for plotting ice charts based on observations will be improved, both at IMO and at Radiomidun (MaxSea).
- QuickScat winds will be presented on maps. Furthermore they will be used to monitor the reliability of wind forecasts calculated by numerical prediction models and should be helpful to indicate how the actual winds follow the model output. Warnings may be issued when model and observations start to diverge.
- Dangerous wave forecasts, based not only on the sea state but also on accident frequency and acceptable risk level. The likelyhood of dangerous breaking waves is considered.
- Warnings for risk of heavy ice accretion on ships, based on fields from numerical prediction models

5.2.3 Data Presentation

A new example of presenting weather parameters, colors indicate maximum wind speed, expected in each forecast area is shown in Figure 5.4.

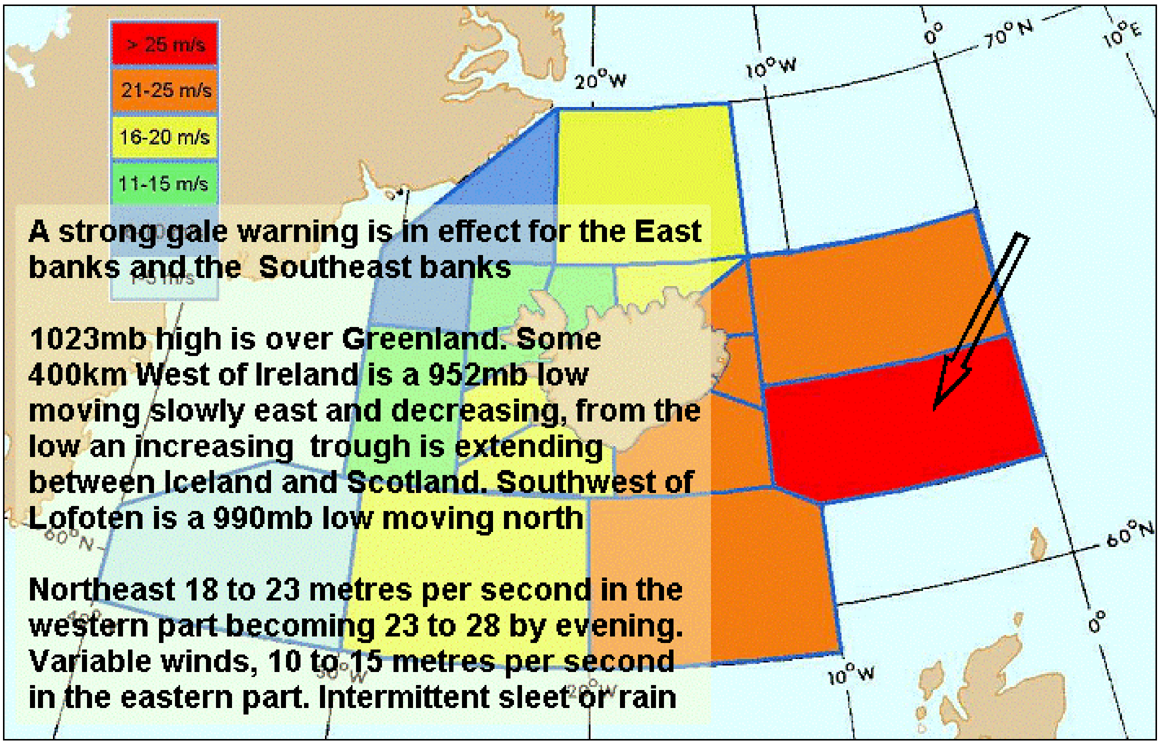


Figure 5.4 Example of text forecast combined with map information.

5.2.4 Currently used formats and information content of data

A new format, XML, has been introduced for text forecasts at IMO (see Figure 5.5). An example of a metadata file for the forecast in XML, shown in Figure 5.5, is shown in Figure 5.6.

```
<?xml version="1.0" encoding="UTF-8" ?>
<!-- edited with XML Spy v3.5 (http://www.xmlspy.com) by Annska (VÍ) --
>
- <Forecast xmlns:xsi="http://www.w3.org/2000/10/XMLSchema-instance"
   xsi:noNamespaceSchemaLocation="C:\iwicos\metadata\ForecastV1.xsd">
   <ProcessInfo Characterset="OSP88591" />
 - <Data>
     <Warning inEffect="false" />
     <Synopsis>Just east off The Shetland Isles is a 1004mb low drifting
       east. 1020mb high pressure ridge over west Iceland is also moving
       east. Just north off Cape Farewell is a filling 1006mb
       low.</Synopsis>
     <ForecastArea>The Southwest banks</ForecastArea>
     <Forecast>Variable winds 5 to 8 metres per second at first, then
       southerly 5 to 8. Partly cloudy.</Forecast>
     <MaxWind>8</MaxWind>
   </Data>
</Forecast>
```

Figure 5.5 IMO's text weather forecast in XML format.

```
<?xml version="1.0" encoding="UTF-8" ?>
<!-- edited with XML Spy v3.5 (http://www.xmlspy.com) by Annska (VÍ) -->
- <Product xmlns="http://www.dmi.dk/pub/IWICOS/metadata/xsd/IWICOSSchema"
    xmlns:xsi="http://www.w3.org/2000/10/XMLSchema-instance"
    xsi:schemaLocation="http://www.dmi.dk/pub/IWICOS/metadata/xsd/IWICOSSchema
    C:\iwicos\metadata\ProductV1_0.xsd" Category="Meteorology" ProductType="Forecast"
    HeaderVersion="1.0">
  - <Extent AreaName="Southwest Banks">
      <UL Lon="-27" Lat="63.8" />
      <UR Lon="-19" Lat="63.8" />
      <LR Lon="-19" Lat="62.5" />
      <LL Lon="-27" Lat="62.5" />
    </Extent>
  - <ReferenceTime>
      <Instant Time="2001-06-21T04:30:00.000" />
    </ReferenceTime>
  - <ValidTime>
    - <Interval>
        <min Time="2001-06-21T04:30:00.000" />
        <max Time="2001-06-22T18:00:00.000" />
      </Interval>
    </ValidTime>
    <ProcessInfo Generator="IMO" ProducerLocator="www.vedur.is" />
  - <Data Availability="true"
      FileLocator="www.vedur.is/iwicos/.DATA/sjospa/ens/forecast_for_the_Southwest_banks.xml"
      FileSizeInBytes="2000">
    - <XML Language="English">
        <Parameter>2MT</Parameter>
        <Parameter>10WN</Parameter>
        <Parameter>LSP</Parameter>
      </XML>
    </Data>
</Product>
```


Figure 5.6 Example metadata file for a text weather forecast.

5.3 Baltic Sea products

The FIMR Baltic Sea products include water level data and forecasted wave data, as described in Section 4.2. Figure 5.7 is an example of presenting pressure and water level parameters in the Client Software. Isobars are calculated locally on client side.

5.4 Arctic Ocean products

Current SAR-based products for the Arctic Ocean include:

1. SAR quick-looks
2. Ice motion derived from SAR images
3. Ice type classifications extracted from SAR data

Figure 5.8 shows an example of the ice motion and ice type classification product.

In addition, sensors with global coverage, such as SSM/I, can be used to derive products for the Arctic Ocean. For instance, ice concentration maps similar to the QuikSCAT image shown in Figure 4.5, i.e. overlaid with coastline, geographic grid and wind forecast, can be generated for the Arctic Ocean as well.

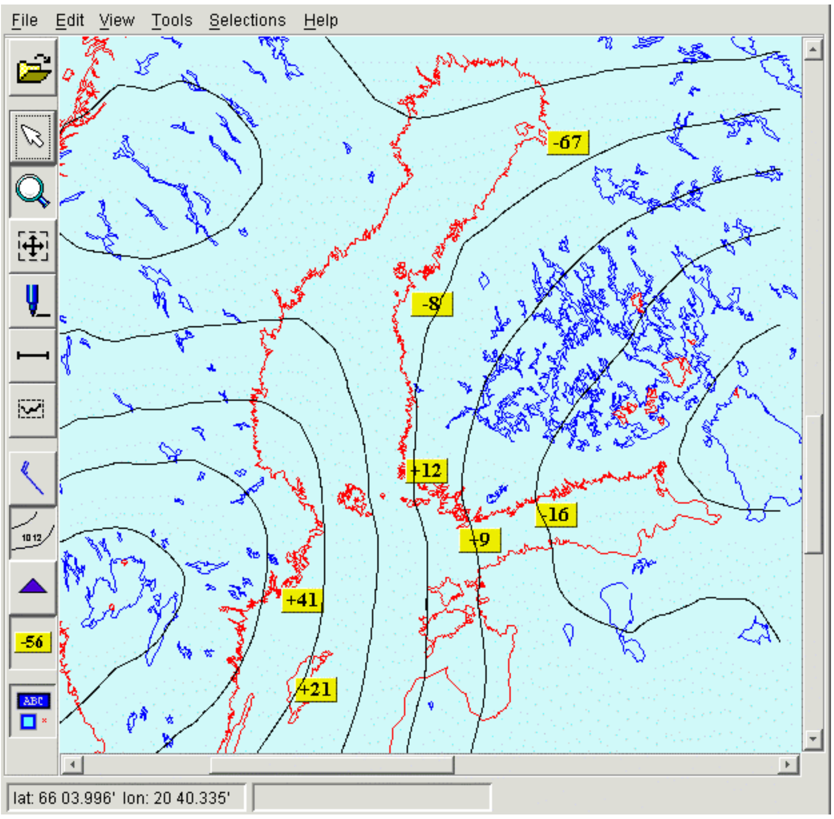
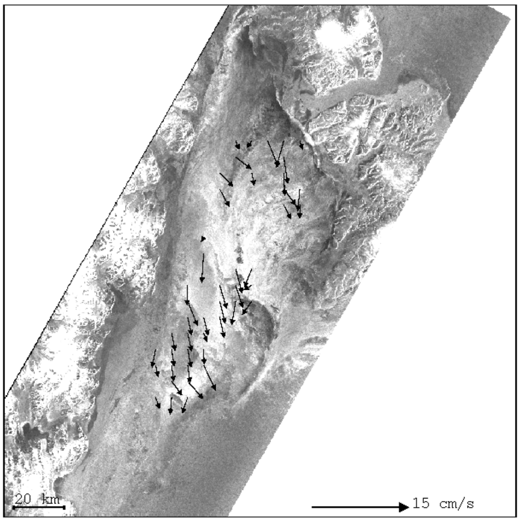


Figure 5.7 Water level and isobars.



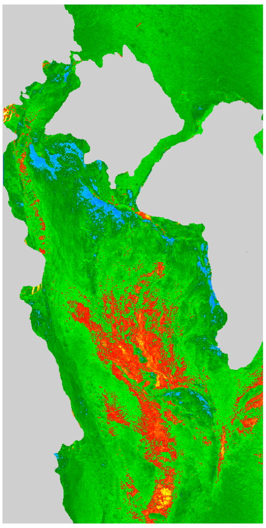


Figure 5.8 Ice motion vectors overlaid on georeferenced SAR image and ice type classification of the same image. Colour coding of ice classification: blue=open water or thin ice; green=first-year ice; red-yellow=rough first-year ice.

6. Summary and conclusions

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 that determines which product or service a user selects in a given situation.

The meteorological information needed by users at sea can basically 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 that integrate or display 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.

The IWICOS 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 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. The presentation subsystem (also called End-User System) was further divided into two subsystems: the Façade and the Client Software. The Façade is a communication link between Producer subsystems, the Broker and the Client Software, which is the program running on the end-user's computer giving access to the IWICOS products. Design for all subsystem has been developed during the baseline period, and will form the basis for the Extended System in the second half of the project.

Communication issues

The server and broker subsystems will both be installed on powerful land based 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.

Metadata and data standards

The IWICOS metadata standard (IMS-001-2001) was defined based on domain expertise and review of existing standards for geographic data sets, including the ‘Standard for Digital Geospatial Metadata’ (FDGC-STD-001-1998). XML and XML Schema were chosen as the methodologies for specifying the IWICOS metadata standard, and the schema definition was built around a core element named ‘Product’. Generic child elements of the root element included: 'Extent', 'Reference Time', 'Valid Time', 'Scheduled Time', 'ProcessInfo', 'Data' and 'Projection'.

For data files, the following industry standard formats were selected: BSQ (for raster data), GRIB (for meteorological data), Shapefiles (for vector data) and XML (for text messages and client-specific data).

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