CryoLand

GMES Service Snow and Land Ice

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User Requirements Document – Final Version

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Prepared by

Eirik Malnes and Arild Buanes, Norut, Norway

Thomas Nagler and Gabriele Bippus, ENVEO, Austria

Sari Metsämäki, Ritta Teiniranta, Yki Laine, Kaisu Harju, and Kristin Böttcher, SYKE, Finland

Gerhard Triebnig and Christian Schiller, EOX, Austria

Jouni Pulliainen and Kari Luojus, FMI, Finland

David Gustafsson, SMHI

Rune Solberg, NR

Andrei Diamandi and Vasile Craciunescu, NMA, Romania

Andreas Wiesmann, GAMMA, Switzerland

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Document controlled by: E. Malnes, NORUT (Lead Beneficiary)

CryoLand Report

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This is the final version of the User Requirement Document (URD), specifying the requirements for CryoLand snow, glacier and lake/river ice products, as well as for services and service interfaces to match the user needs. As starting point for defining the requirements relevant documents and publications of international working groups and organisations and of international and national projects (EC, ESA, national, etc.) have been reviewed. User Requirement Workshops with participants from various organisations and enterprises were held in Vienna, Oslo, Saariselka and Bucharest in May and June 2011 for collecting requirements for snow and land ice products and services in different application fields. Additionally, relevant governmental organisations and companies in Europe were contacted and invited to complete a questionnaire on snow, glacier and lake / river ice products requirements. A User Coordination Meeting with key users was held in Stockholm in May 2012 for reviewing and consolidating the product and service requirements and for discussing the implementation priority for products. Based on these information sources, the user requirements on snow, glacier and lake ice products, services and service interfaces are discussed and reviewed in this report, providing the basis for development of products and services in the project.

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AUTHORS: E. MALNES, A. BUANES, T. Nagler, G. Bippus, C. Schiller, G. Triebnig, S. Metsämäki, R. Teiniranta, K. Harju, K. Böttcher, J. Pulliainen, Y. Laine, K. Luojus, D. Gustafsson, R. Solberg, J.P. Pedersen, A. Diamandi, V. Craciunescu, A. Wiesmann

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1. INTRODUCTION

1.1 Purpose of the document

The CryoLand project aims to develop, implement and validate a standardized and sustainable service on snow and land ice monitoring as a Downstream Service within GMES. One objective in CryoLand is to define a framework and specifications for the snow and land ice monitoring system that is based on requirements of users from different application fields. This provides the guidance for the development of geospatial infrastructure, of snow and land ice products and of related services in the project.

Users play a key role in the definition of product and service requirements. Based on the baseline product portfolio of CryoLand – consisting of various products on snow, glacier and lake and rive ice – requirements on snow and land ice products and services are collected and discussed with organisations operating in different working fields for which snow and land ice products are relevant. As a result, the baseline portfolio of snow and ice products will be improved and augmented to better match the user requirements. An important part of the project is also the design, development and implementation of a distributed system for CryoLand services that will ensure interoperability of infrastructure in compliance with INSPIRE and GEOSS, and by integration with the Land Monitoring Services, the GMES Space Component Data Access service, and the required in-situ and reference data access. This includes also technical requirements and specification of service interfaces. These issues are covered by CryoLand user requirement workshops and the survey on product and service requirements initiated by CryoLand. These activities provide the basis for specifying the CryoLand services tailored to user needs, but also keeping in mind the current technical possibilities and feasible solutions. The Cryoland user group was formed and by May 2012 consists of 60 organisations from 11 countries in Europe incl. Greenland operating in different application fields.

This document is the final version of the User Requirement Document, which represents the requirements for snow and land ice products, services and service interfaces. The requirements are defined in discussion with the members of the CryoLand User Group.

1.2 Outline

The collection on user requirements takes place in two stages. The starting point is a review of user requirement studies on snow and land ice products and services performed by international working groups and organisations as well as and requirement studies carried out by previous projects (e.g. EC, ESA, national projects, etc). The second stage is the collection of requirements within user requirement workshops, organized by the CryoLand consortium, where relevant organisations from different working fields participated. Additionally the results of a questionnaire on snow, glaciers and lake/ river ice products and services and service interfaces send out to relevant organisations are presented.

Section 2 provides the review of products and service requirements as specified by international working groups and organisations as well as collected by previous projects. Section 3 describes the design and implementation of the questionnaire on Snow and Land Ice Product and Service Requirements, which was sent to organisations, companies, national authorities etc. Section 4 reports on the analysis of the requirements and ranking of products according to user requests, as responded in the online questionnaire and discussed at CryoLand User Requirements Meetings held in Vienna, Oslo, Saariselka and Bucharest in May and June 2011, and at the User Coordination Meeting held in Stockholm in May 2012. Section 5 lists relevant references. The Appendix includes the detailed results of the user responses on the questionnaire (Section 6; Appendix A).

1.3 Acronyms

ASAR	Advanced Synthetic Aperture Radar
ATD	Acceptance Test Document
AVHRR	Advanced Very High Resolution Radiometer
BUFR	Binary Universal Form for the Representation of meteorological data
CliC	WCRP Climate and Cryosphere Project
CEOS-IDN	CEOS (Committee of Earth Observation) International Directory Network
CCRS	Canada Centre for Remote Sensing
CryOS	Cryosphere Observing System
CVB	Cryospheric Variable Baseline
DISC	Data and Information Service for CliC
DDF	Design Definition File
EC	European Commission

ECV	Essential Climate Variable
EEA	European Environment Agency
EO	Earth Observation
ESA	European Space Agency
ESRIN	ESA Centre for Earth Observation
ETC/ACC	European Topic Centre on Air and Climate Change
ETM+	Enhanced Thematic Mapper Plus, sensor on-board of Landsat 7
FCDR	Fundamental Climate Data Record
FMI	Finnish Meteorological Institute
FP5	Fifth Framework Programme
GCOS	Global Climate Observing System
GAC	Global Area Coverage
GCW	Global Cryosphere Watch
GEO	Group on Earth Observations
GEOSS	Global Earth Observation System of Systems
GIP	GCOS (Global Climate Observing System) Implementation Plan
GIS	Geographic Information System
GMES	Global Monitoring for Environment and Security
HDF	Hierarchical Data Format
HH	Horizontal polarisation: transmit and receive
ICC	Indicators of Climate Change
ICIMOD	International Centre for Integrated Mountain Development
IGOS	Integrated Global Observing Strategy
IPY	International Polar Year
INHGA	National Institute for Hydrology and Water Management (Romanian)
INSPIRE	Infrastructure for Spatial Information in Europe

IFOV	Instantaneous field of view
IGOS	Integrated Global Observing Strategy
ISO	International Standardization Organization
ME	Ministry of Environment and Sustainable Development (Romanian)
MERIS	Medium Resolution Imaging Spectrometer
METNO	Norwegian Meteorological Institute
MODIS	Moderate Resolution Imaging Spectrometer
netCDF	Network Common Data Form
NIR	Near Infrared part of electromagnetic spectrum
NOAA	National Oceanic and Atmospheric Administration
NPI	Norwegian Polar Institute
NR	Norwegian Computing Centre
NRT	Near Real Time
NVE	Norwegian Water Resources and Energy Directorate
QPR	Qualification Review Report
R&D	Research and Development
RCM	Regional Climate Modelling
SAR	Synthetic Aperture Radar
SCA	Snow Covered Area
SCAR	Scientific Committee on Antarctic Research
SEVIRI	Spinning Enhanced Visible Infra-Red Imager
SoW	Statement of Work
SST	Snow Surface Temperature
SWE	Snow Water Equivalent
SWIR	Shortwave Infrared
SYKE	Finnish Environment Institute

TM	Thematic Mapper, sensor on-board of Landsat 5
VIS	Visible part of electromagnetic spectrum
VV	Vertical polarization (both transmit and receive)
WCS	Web Coverage Service
WMO	World Meteorological Organization
WMS	Web Map Service
WCRP	World Climate Research Programme
UNFCCC	United Nations Framework Convention on Climate Change

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2. REVIEW OF USER REQUIREMENTS FROM PREVIOUS PROJECTS

2.1 Introduction

This section gives a review of the user requirements for snow, glacier and lake / rivers ice products and services as specified by international working groups and organisations as well as from previous projects.

2.2 Snow and land ice product requirements assessed by international working groups and previous projects

In this section a review of the user requirements collected in various international cryosphere-related projects carried out within last ten years is carried out. This time-span is appropriate considering the recent advances in remote sensing techniques as well as in data interfaces and services. This chapter gives a short presentation of the projects in concern as well as lists the outcome of user requirements for CryoLand-related products.

The Implementation Plan for the Global Observing System for Climate in Support of the UNFCCC (United Nations Framework Convention on Climate Change) (GCOS, 2010) serves as the basic document on observations of climate variables including parameters from the seasonal snow pack, glaciers and lake / river ice. It is compiled under the guidance of GCOS Steering Committee, with feedback from several hundreds of international experts. The current version of the report was published in August 2010.

2.2.1 *The requirements from IGOS Cryosphere Theme Report*

The Integrated Global Observing Strategy (IGOS) Cryosphere Theme is a joined initiative of the World Climate Research Programme (WCRP), the Climate and Cryosphere (CliC) Project and the Scientific Committee on Antarctic Research (SCAR) and is part of the IGOS Partnership. The aim of the Cryosphere Theme is to determine requirements for cryospheric observations and to prepare recommendations on the comprehensive and efficient ways of developing, coordinating and maintaining those observations and related data. Recommendations and requirements for cryospheric observations were published in the IGOS Cryosphere Theme report (IGOS, 2007), which was approved and accepted as new IGOS Theme by IGOS partners in May 2007. Hereafter, the IGOS Cryosphere Theme will be referred to as CryOS, the Cryosphere Observing System. Many recommendations for CryOS will be implemented as part of the work plan of the Group on Earth Observations (GEO), coordinating the development of a Global Earth Observation System of Systems, or GEOSS.

The **Cryosphere Theme Report of the Integrated Global Observing Strategy** (IGOS 2007) is the only document providing detailed specifications on the observational requirements for all elements of the global cryosphere, based on broad consultation of the scientific community.

It emphasizes the need for sharing cryospheric observations and data products due to the high costs for observation especially in this region. Furthermore, the importance of satellite instruments for the delivery of consistent observations of the global cryosphere is highlighted, at which a combination and synthesis of data from different complementary sensors is essential. In addition to satellite observations and with the same importance, surface and airborne observations are needed in order to provide data currently not measured from space, detailed information for critical areas and calibration and validation data for satellite retrievals. Another important issue for the CryOS is the fostering of the evaluation of the cryosphere in models.

CryOS minimum (threshold) and goal (target) requirements for satellite observations of terrestrial snow, lake and river ice and glaciers, relevant to the CryoLand product portfolio, are given in the Table 2.1.

Table 2.1:
Requirements from IGOS Cryosphere Theme Report (2007).
G – Goal (target) requirements; T – threshold (minimum) requirements.

Product	***Measurement range***	***Thematic accuracy***	***Temporal resolution***	***Spatial resolution***
SNOW				
Snow Water Equivalent (shallow)	T: 0 – 0.3 m G: 0 – 0.3 m	T: 3 cm G: 2 cm	T: 6 days G: 12 hr	T: 0.5 km G: 0.1 km
Snow Water Equivalent (deep)	T: 0.3 – 3 m G: 0.3 – 3 m	T: 10 % G: 7 %	T: 6 days G: 12 hr	T: 0.5 km G: 0.1 km
Fractional Snow Cover	T: 0 – 100 % G: 0 – 100 %	T: 10 % G: 5 %	T: 1 day G: 12 hr	T: 0.5 km G: 0.1 km

Product	***Measurement range***	***Thematic accuracy***	***Temporal resolution***	***Spatial resolution***
Snow Surface Temperature	T: 200 – 275 K G: 200 – 275 K	T: 1 K G: 0.1 K	T: 1 hr G: 30 min	T: 1 km G: 0.1 km
Snow Albedo (broadband)	T: 0 – 100% G: 0 – 100 %	T: 1 % G: 0.5 %	T: 1 hr G: 30 min	T: 8 km G: 5 km
GLACIERS AND ICECAPS				
Glacier area (based on Landsat etc.)	T: G: 0.01 km^2	T: G: 3 %	T: G: 5 yr	T: G: 30 m
Glacier area (based on Hi-res optical)	T: 0.01 km^2 G: 0.01 km^2	T: 3 % G: 1 %	T: 5 yr G: 1 yr	T: 50 m G: 15 m
Glacier facies, snowline	classes	T: 200 m G: 30 m	T: 1 month G: 10 days	T: 100 m G: 30 m
Glacier velocity[1]	T: 0 – 10 km / yr	T: 1 %	T: 1 month	T: 20 m
Glacier dammed lakes [km^2][1]	T: 0.05 – 10 km^2 G: 0.01 – 10 km^2	T: 3 % G: 1 %	T: 1 month G: 5 day	T: 50 m G: 15 m
LAKE / RIVER ICE				
Ice Areal extent (and open water areas)	T: 250 m – 1000 m G: 100 m (SAR)	T: 10 % G: 5 %	T: 1 day G: 1 day	T: 100 m G: 30 m
Snow Depth on Ice	T: 0 - 0.8 m G: 0 – 1 m	T: 5 cm G: 2 cm	T: 1 week G: 1 day	T: 100 m G: 10 m

2.2.2 *Requirements from IGOS Water Cycle Report*

The IGOS Water Cycle Report is available as draft version only. Only numbers for snow cover extent (1-10 km spatial resolution, 1-3 day repeat) and SWE (10 km spatial resolution, 1-3 day repeat) are listed (IGOS-Water, 2003).

2.2.3 *The requirements from GCOS*

The **Global Climate Observing System** (GCOS) was established in 1992 and focuses on satellite and in-situ observations for climate in the atmospheric, oceanic, and terrestrial domain. Global monitoring of climate requires products derived from satellite data records, as recognized by the *Implementation Plan for the Global Observing System for Climate in Support of the UNFCCC* (GCOS-92, October 2004; the 'GIP'). These needs are documented in Systematic Observation Requirements for Satellite-based products for Climate (GCOS-107, September 2006). Note is also made of needs for data access and archiving, and issues related to calibration and validation. Snow cover, lakes and Glaciers are listed in the table of essential Climate variables (ECV), which are highly dependent upon satellite observations.

Concerning snow, the primary monitoring product is a continuous data record of snow areal extent in global scale. Snow water equivalent is mentioned as a highly desirable supplementary information, as well as snow depth and information on the presence of water in the liquid phase (i.e. wet snow).

Although lake/river ice is not directly mentioned in the ECV list, it is relevant through lake temperature which linked to the lake freeze-up and break-up dates, serving as an indicator for regional climate modelling purposes.

GCOS-107 also lists requirement (as an example) for earth observation instruments

- Glaciers: VIS/NIR/SWIR multispectral imagery, e.g. like Landsat TM/ETM+ type instruments
- Snow extent: Current and planned moderate-resolution, multispectral optical sensors in polar-orbiting (e.g., MODIS) and geostationary (e.g., SEVIRI) mode, continuation of their capability should be ensured
- Snow water equivalent: current and planned low-resolution passive microwave sensors are adequate to provide an estimate of snow-water equivalent for shallow snow packs in simple terrain, and their continuation is desirable
- Multi-sensor (optical, microwave, *in situ*) observations should be integrated to ensure spatial and temporal consistency for the snow areal extent product and the supplemental snow variable datasets
- Instrument and algorithm calibration is required, to account for changes in sensor characteristics.
- Improvements in spectral resolution, calibration and dynamic range, which are important considerations for future sensors. More, narrower, and better-calibrated bands would help

improve observation accuracy and improve snow-cloud discrimination. Greater dynamic range is needed to avoid sensor saturation

- The document also emphasizes the importance of the near-real-time accessibility of *in situ* observations of snow, as well as need of protocols for comparing *in situ* observations with satellite derived information.

Table 2.2:
Observational requirements for cryospheric parameters from GCOS-107.

Product	***Thematic accuracy***	***Location accuracy***	***temporal resolution***	***Spatial resolution***	***Coverage***
Snow areal extent	5 % (max. error of omission and commission)	1/3 IFOV, target IFOV 1km (100m in complex terrain)	12 h (24h)	1 km (100 m in complex terrain)	global
Glacier outlines, Snow/Ice Area map	5 % (max. error of omission and commission)	1/3 IFOV, target IFOV 30m	1 year observing cycle	30 m	regional
Lake/River Ice (freeze up, brake up)			daily	1 km	regional

2.2.4 *EC FP5 EnviSnow-project*

The EnviSnow project (2002-2005) was a research project supported by the EC under the FP5 and contributing to the implementation of the Key Action Research and Technological Development Activities of a Generic Nature within the Energy, Environment and Sustainable Development, contract n°: EVG1-2001-00052. The overall goal was to develop and validate new and improved multi-sensor algorithms for retrieving snow and soil parameters from Earth Observation (EO) data. Improved EO-based snow and soil information were to be used in global climate study and hydrology, in particular for runoff and flood prediction. Assessment of the user requirements was an important step in the EnviSnow project. Collecting and analysing the various user requirements in relation to the products developed highlighted the adaptations needed for commercialization of the products and to make them accessible and useful for the customers.

The user requirement assessment documented that in general, the operational use of EO based snow information was limited, even though there had been several R&D project focusing on operational EO-based snow product development.

In particular the users requested regularly available accurate information on Snow Water Equivalent (SWE) and Snow Covered Areas (SCA). The main application is improved runoff forecast by assimilation of snow products into hydrological models. Snow Surface Temperature (SST) is also important for the hydrological models as it indicates when the snow starts to melt.

To fulfil the requirements from the northern part of Europe accurate information on SWE and SCA within their region of interest should be provided daily during melt season and early winter transition season, and less frequent, i.e. weekly, during winter. Information should be available within 12 - 24 hours in the melt season. The estimation error should be less than 10% and the spatial resolution should be around 0.2-1.0 km. Temporal resolution and thematic accuracy are identified as the most important requirements, and spatial resolution is the third most important requirement. In general, absolute geometric accuracy is considered as less important than the other three. It should also be noted that the thematic and temporal requirements vary among the users. It is therefore difficult to provide a unified set of requirements applicable to all users. The more detailed presentations in the following sections are therefore tailored to the various user categories.

Table 2.3:
Observational Requirements for EnviSnow FP6 Project.

Product	***Thematic accuracy***	***Location accuracy***	***Temporal resolution***	***Spatial resolution***	***Turnaround time***	***Coverage***
Snow Water Equivalent	< 10%	< footprint	daily (melting season) weekly (winter season)	0.2 – 1.0 km	3 h – 48 h	Northern Europe, Alps
Fractional Snow Cover, regional	< 10%	< footprint	daily (melting season) weekly (winter season)	0.2 – 1.0 km	12 h – 48 h	Northern Europe, Alps
Snow Surface temperature	1° C		Daily - weekly	1 km	hours	Northern Europe, Alps

2.2.5 *Organisations related to water and energy management*

For water and energy management user organisations snow information is important to improve the run-off prediction where flood forecasting is the most important application, but they are also providers of data to the power producers and traders. Snow information is also important for avalanche forecast and for monitoring of water level and discharge. For organisations responsible for energy resource management snow information is used for monitoring of energy potential. Conventionally, these organisations get snow information based on point measurements from national meteorological agencies and from others having ground observing stations i.e. avalanches services and hydropower producers. The experience on the use of EO-data varies, from producing SCA maps from NOAA/AVHRR data, and use the information to correct the snow cover simulations, into limited experience from research projects only using optical data. None of the interviewed users were satisfied with their existing solution for gathering of snow information, and were interested in exploring the contribution from an EO based service.

The runoff forecast is overall the most important product and if snow information could be assimilated into hydrological models it could improve the performance of these models and better runoff forecast could be produced. The snow parameters of highest priority are SWE and SCA. SST is also useful for the hydrological models as it indicates when the snow starts to melt, and it is an important parameter for avalanche warning in the Alpine region. SWE and SCA are also assessed as useful stand-alone products. In areas where snow melts is an important factor for runoff, SWE is considered as the most important parameter. SCA is used for visual validation of snow extent, and it is applied as auxiliary information to validate runoff forecasts.

In the Alpine region the requirements for SCA and SWE information varies. The required periods include May to October, one weekly (daily in high risk situations) delivery and the other every 12 day. Others are interested in snow information in the winter and spring time (November/December to May/July). In the northern part of Europe the SCA and SWE products are needed during the winter season. The majority would prefer the SWE on a daily from basis, while the temporal requirement for SCA varies from daily to every 14th day in this period. Information should be accessible within 24 hours after data acquisition for most of the organizations; one organization has requirements as low as 3 hours. For both regions the spatial resolution requirements of SCA and SWE varies from 4 – 5 km down to 50 m, with 250 m – 1000 m as the most frequent requirement. The spatial accuracy requirement varies from a pixel down to half a pixel. The acceptable classification error rate shall be within 10 % for a sub catchment area.

Thematic accuracy is assessed as the most important requirement but temporal and spatial resolution is almost assessed as equally important product requirement for SCA and SWE. The geometric accuracy is also rated as a very important requirement especially in areas with steep topography.

2.2.5.1 Hydropower industry

For the hydropower industry snow information is important for two main purposes, production management and energy trading. Information on available amount of water within a catchment, runoff forecasts, and melting conditions is important for production planning. For energy trading the same information is important as the electricity price varies with the availability of hydropower energy. Thus the amount of snow in a region affects the expected energy prices. Some of these users acquired information about the snow from manual point measurements of water content and snow depth, while others were using SCA maps derived e.g. from NOAA/AVHRR or MERIS/MODIS type of data. In general, this user group was interested in using a temporally and spatially improved snow information service, and saw the utilisation of EO data as an important development. Run-off information was described as a base product and the most important for production planning. *SWE is the most important snow product as it gives information on available amount of water within a catchment. SCA is also important for visual inspection of the catchment and can help them to validate the runoff forecasts* as remarkable errors can easily be seen.

The hydropower industry needs for SCA and SWE varies from monthly from January to mid-March, weekly from mid-March to mid-May, daily during September and October, or daily delivery of SCA and SWE every 14 days from February to June. Information must be available within 1-2 days after data acquisition. The required spatial resolution varies from 200 m to 1 km and the acceptable classification error rate shall be within 10 %. In autumn (September and October) updated snow information is important as wet snow in the mountain areas may melt within a few days. Updated runoff forecast is necessary to avoid flooding, as the basins are full at this time of the year. In the spring the snow melt is slower and weekly coverage of snow area is enough to monitor the melt outflow of the following days.

2.2.5.2 Meteorological offices

For meteorological offices accurate estimates of SCA is an important parameter needed in the numerical weather prediction models. Accuracy improvement of runoff forecast is another important application for EO-based snow information for meteorological organisation as the power industry has become important customers of specialized services provided by these organizations. At the time of EnviSnow, they used ground observations and AVHRR derived data, which was not considered to be good enough. Particularly in the mountainous regions in Northern Scandinavia, there were problems in assessing the actual snow cover only from ground and AVHRR observations. The area is sparsely populated and there are few meteorological stations. At the same time, the area is very important for hydropower production. Better information on the snow pack should improve runoff forecasts and thus enable a more efficient use of hydropower reservoirs. The SWE with a complete spatial coverage, particularly in the mountain regions is important. High temporal resolution during the melt season, less frequent during winter. The error in the estimation of SWE should be less than 5% for a catchment area of 500 km2 (i.e. it must be considerably better than present models). Temporal resolution and thematic accuracy are assessed as the most important requirements.

2.2.5.3 Energy brokers

User group *Energy Brokers* had yet no experience from using EO based information. They did, however, express an interest in exploring the use of EO based information in particular if snow information like SCA and SWE distribution across the different elevation zones in the model catchment areas could be provided for direct incorporation into the models. The final products for the users that have been interviewed here are runoff forecasts, short term (1 day) and longer term (7-10 days) based on their operational models. 40 years of climatology data is also used to assess different scenarios based on today's situation. Today, these users rely on data from national meteorological and hydrological services in the countries which they assess.

For this user category snow products are needed for the period October until July. The temporal resolution requirements vary from one until two weeks, and the information needs to be provided in less than 48 hours after data acquisition. The requirement for thematic accuracy is high, 2-5 %. The contributing users were quite satisfied with their current systems, and the high thematic accuracy requirement reflects this. If this category shall utilise the EO based information, it must represent a significant improvement compared to current solution.

Thematic accuracy is assessed as the most important requirement. Though, all accuracy requirements are assessed as very important.

2.2.6 *ESA DUE GlobSnow-project*

The requirements for the GlobSnow products are derived from the ESA Statement of Work (SoW), and the Requirements Engineering Review (RER) Meeting held on 3 February 2009, Geneva, GCOS-107 (2006), and the IGOS Cryosphere Theme Report (2007). The latter two are addressed in section 2.3 and section 2.4. Below we shortly summarize the requirements from the GlobSnow Statement of

Work (SoW) and RER-meeting, where representatives from European Environment Agency EEA, CCRS, MeteoSwiss and UK MetOffice were present.

According to the GlobSnow SoW, the snow monitoring products shall represent harmonized and globally consistent observations (including information on uncertainty) of the snow cover independent of sensor, landscape or algorithm. The requirement are summarized in All provided products are requested to be validated against in-situ data and quality controlled. Uncertainties of the products shall be specified and quality flags provided as part of the metadata. The documentation of the data production and validation shall be publicly available.

The users emphasized the product consistency particularly with respect to time series generation, as well as product validation.

Considering the requirements from the users, the IGOS and GCOS reports and the state-of-the-art, GlobSnow consortium proposed a daily, weekly and monthly snow water equivalent (SWE) product starting from 1978 and extending to 2010 with a spatial resolution of 25km and a thematic accuracy of 25-40 mm. This was already deemed to surpass the then available state-of-the-art and was considered attainable for the GlobSnow consortium and agreed as a challenging goal for the project. For the snow extent (SE) product a daily, weekly and monthly product ranging from 1995 to 2010 with a spatial resolution of 0.01 degrees in a latitude longitude grid and a total (pooled) error of less than 5% was proposed and agreed on the Requirements Baseline document.

Table 2.4:
Observational Requirements for GlobSnow Statement of Work, ESA.

Product	***Thematic accuracy***	***Location accuracy***	***Temporal resolution***	***Spatial resolution***	***Coverage***
Snow Water Equivalent, global	15 mm	sub pixel	Daily, weekly, monthly	10 km	Global, excluding mountainous areas
Fractional Snow Cover, global	5 %	sub pixel	daily-weekly	0.3 – 1 km	Global

Table 2.5:
Requirements by Requirements Engineering Review (RER) Meeting 2009, Due GlobSnow Project.

Product	*Thematic accuracy*	*Location accuracy*	*Temporal resolution*	*Spatial resolution*	*Coverage*
Snow Water Equivalent	15 %		Daily	12 – 25 km	Northern Hemisphere
Fractional Snow Cover, regional	10 %	1/3 IFOV maximum	daily – weekly – monthly	100 m – 25 km	Europe, Alps, parts of Asia
Fractional Snow Cover, global			daily	4 km	Northern hemisphere

2.2.7 *ESA DUE GlobGlacier project*

The ESA project GlobGlacier aimed at the observations for glaciers and ice caps generating the products glacier outlines (area), glacier terminus position (which is a subset of glacier outlines, but was treated as separate parameter in GlobGlacier), late summer snow / ice area and snowline (which are interrelated), surface topography, surface elevation change, and surface velocity.

Regarding the various applications of the generated products meeting the accuracy standards defined in the IGOS Cryosphere Theme Report (IGOS, 2007) was essential.

Some generic guidelines on product requirements are provided based on input of the user groups. However, clearly defined quantitative specifications for observational variables are missing. The processing lines and validation of products are described in detail in project reports.

Glacier outlines, terminus positions, late summer snow/ice areas and snowlines were derived from Landsat data with 30 m pixel size. Based on the requirements of the global glacier inventory services WGMS (World Glacier Monitoring Service), WGI (World Glacier Inventory), and GLIMS (Global Land Ice Measurements from Space), the mapping of glacier outlines was focused on regions with still missing glacier inventories. Late summer snow/ice areas of selected glaciers in regions worldwide were derived not only for single, but also for multiple years since the mid 1980's, depending on the availability of clear sky Landsat imagery acquired as close as possible to the date with the maximum extent of the ablation area. The retrieval of glacier elevation changes was based on digital elevation models (DEMs) from two epochs in time (e.g. INSAR, and stereo-photogrammetry) and from time series of satellite altimetry data (LiDAR, RADAR). The spatial resolution of the DEMs varies between

10 – 100 m, depending on the sensor type (optical or microwave) and source (aerial or satellite). A typical time scale for measuring glacier elevation changes is about 10 to 20 years. Glacier surface velocity fields were derived from optical and from microwave repeat satellite data. The temporal scale of this product mainly depends on the availability of appropriate satellite data. In the GlobGlacier project, velocity fields were generated considering temporal resolutions of a few days up to an annual scale.

Reports of the GlobGlacier project, including guidelines for the retrieval of the products from optical and radar data, as well as validation documentations, are publicly available at the project homepage (http://www.globglacier.ch).

2.2.8 *ESA glaciers_cci project*

The ESA initialized and supports the Climate Change Initiative (CCI) program aiming at the long-term investigation of variable essential climate variables (ECV). The ECV Glaciers and icecaps addresses three products, namely: glacier outlines (area), glacier surface elevation change, glacier surface velocity. All products shall meet the quality recommendations defined in the IGOS Cryosphere Theme Report (IGOS, 2007).

2.2.9 *ESA DUE Permafrost project*

The ESA project DUE Permafrost has the objective to define and establish a monitoring system of permafrost research based on satellite data as support to the GCOS implementation plan (2006). Because permafrost is a subsurface phenomenon it cannot be observed directly with satellite data. Satellite observations can supply permafrost indicators and provide input to permafrost models. In the project thermokarst, lake dynamics and surface elevation changes were identified as indicators, to be observed on local scale. Regional to circumpolar monitoring requires the use of permafrost models, where relevant satellite observed parameters are land surface temperature (LST), snow extent, snow water equivalent (SWE), vegetation, and soil moisture.

2.2.10 *ESA DUE INNOVATOR2 GLOF project*

Table 2.6 summarizes the User Requirements of the DUE INNOVATOR2 GLOF (Glacial Lake Outburst Floods) Project led by GAMMA Remote Sensing AG. The aim of the GLOF project was to develop a glacier lake mapping service based on very high resolution satellite SAR data. Two users drove the development, (i) the FOCUS Humanitarian base in Tajikistan and (ii) ICIMOD based in Kathmandu, Nepal.

Table 2.6:
Observational requirements for glacier lakes by ESA Innovator project GLOF.

Product	***Thematic accuracy***	***Location accuracy***	***Temporal resolution***	***Spatial resolution***	***Map projection***	***Coverage***
Glacier Lake Outline "FOCUS"	10.00%	10m	2x year	10m	UTM	Hot spots in Pamir
Glacier Lake Outline "ICIMOD"	10.00%	1m	2x year	10m	UTM	Hot Spots Himalaya
Historical Glacier Lake Outline "FOCUS	10.00%	10m	2x year	10m	UTM	Hot spots in Pamir
Historical Glacier Lake Outline "ICIMOD"	10.00%	1m	2x year	10m	UTM	Hot Spots Himalaya

2.2.11 *GLIMS project*

A main international initiative for world-wide observation of glaciers is the *Global Land Ice Measurement from Space (GLIMS*) project (Bishop et al., 2004; Raup et al., 2007). GLIMS is a cooperative effort of over sixty institutions world-wide with the goal of inventorying a majority of the world's estimated >160000 glaciers. The GLIMS Glacier Database is accessible on the World Wide Web at http://nsidc.org/glims/. GLIMS lists basic glacier parameters such as glacier outlines, centrelines, snowlines, etc., to be derived from the satellite data, but does not define a quantitative list of requirements.

2.2.12 *PolarView project*

Polar View is an earth observation or satellite remote-sensing program, focused on both the Arctic and the Antarctic. Polar View is supported by the European Space Agency (ESA) and the European Commission with participation from the Canadian Space Agency. The Polar View Team consists of companies, government agencies and research institutes across Europe and Canada. Each organization brings diverse and complementary skills to the Polar View program and is committed to establishing a dedicated service for addressing polar issues using Earth observation technologies. Polar View has participants from Belgium, Canada, Denmark, Estonia, Finland, France, Germany, Italy, Norway, Sweden, and the United Kingdom. Polar View offers integrated monitoring and forecasting services in the Polar Regions, as well as selected mid-latitude areas affected by ice and snow. Polar View utilizes satellite earth observation data from multiple satellites, in combination with ground truth, sophisticated models and automatic tools, to deliver products that accurately illustrate the characteristics of the ice and snow on any given day. More specifically, services take the form of enhanced sea ice information as well as ice-edge and iceberg monitoring data. Polar View also provides monitoring services for lake and river ice, snow cover maps and glaciers. Services are delivered in near real time and are readily accessible via the Internet (http://www.polarview.org).

The requirements shown in Table 2.7are derived from the reports (C-Core 2008 and C-Core 2011).

Table 2.7:
Observational requirements for snow, glacier and lake ice parameters, Polarview Project.

Product	*Thematic accuracy*	*Temporal resolution*	*Turnaround time*	*Spatial resolution*	*Coverage*
Fractional Snow Cover SCA percentage, snow line)	-	ideal: daily acceptable: 2–3 per week	3–4 h 1–3 h	5 km x 5km	Finland, Germany, Baltic sea drainage
Lake/River Ice (Ice type, Ice front, ice stability)	-	ideal: daily acceptable: 2–3 per week	4–6 h	-	Athabasca river, Lena river, Badget river, Yukon river
Glacier (Velocity, water equivalent, melting)	-	once a year	< 1 week	-	Hofjökull, Svartisen

2.2.13 *ESA STSE-North Hydrology project*

The ESA project STSE North Hydrology (ESA ESRIN contract No. 4000101296/10/I-LG) has documented user requirements related to lake / river ice observations (Deliverable 4. C. Duguay, 27.10.2010). The document contains the scientific and operational requirements associated with the major themes of the North Hydrology project. The users include CliC scientific community, the users of lake and river ice products identified by ESA Polar View, the weather prediction (NWP) and regional climate modelling (RCM) community, the hydrology community, and national and regional operational authorities. The main findings in the North Hydrology project are that the main user groups highly desires to acquire satellite products from surface temperature and ice cover (fractional coverage) to be used in assimilation in climate models. Also within hydrological modelling the North hydrology-project identified a growing interest in river and lake ice products.

Table 2.8:
Observational requirements for lake / river ice, North Hydrology Project.

Product	***Thematic accuracy***	***Location accuracy***	***Temporal resolution***	***Spatial resolution***	***Map projection***	***Coverage***
Lake/ Ice coverage, global scale	< 5%	< 1 pixel	Weekly, Daily*	150/300*	TBD	Large lakes, Global scale
Lake ice coverage, basin scale	< 5 %	< 1 pixel	Daily	150/300*	TBD	Basin scale
River ice coverage, global	< 5%	< 1 pixel	Daily	150/300*	TBD	Large rivers global
River ice, global	< 5%	< 1 pixel	Daily	150/300*	TBD	Large rivers global
Lake surface temperature	0.5 Kelvin	< 1 pixel	Daily**	1km	TBD	Large lakes, global scale

* Optical, SAR
** Temporal resolution depends on optical sensors, cloud-free and daylight conditions are required.

2.2.14 *ESA CryoClim project*

The vision of the CryoClim project is to develop a novel operational and permanent service for long-term systematic climate monitoring of the cryosphere (Solberg et al. 2010). The product production system and the product repositories are hosted by mandated Norwegian organisations, and the service is to be delivered through a state-of-the-art web service. The service is to be free of charge. The system and service is a contribution to the Global Earth Observation System of Systems (GEOSS) and the Global Cryosphere Watch (GCW) according to the climate monitoring principles recommended by the Global Climate Observing System (GEOS). The project runs in 4 phases from 2008 to 2012. The project currently develops sub-services for sea ice and snow products of global coverage and glacier products covering Norway (mainland and Svalbard). The current project partners are the Norwegian Computing Center (NR; project coordinator), Norwegian Meteorological Institute (METNO), Norwegian Water Resources and Energy Directorate (NVE) and Norwegian Polar Institute (NPI). The project is now close to the end of the third phase out of four phases.

There are two main product types provided by CryoClim:

- Cryospheric Variable Baseline (CVB) products: Spatial products, maps, of climate variables
- Indicators of Climate Change (ICC) products: Analysis result of a time series of observations (usually from baseline products) suitable to assess changes over time.

A CVB product is characterised by an aggregation period and a set of layers. The aggregation periods may typically be day, week, month, season (December-January-February; March- etc.) and year. Observations are collected and averaged for the given period of time. The typical layers of a baseline product are average, minimum, maximum, standard deviation, number of observations, uncertainty and flags (warnings, etc). There might be more or less layers depending on the characteristics of the actual cryospheric variable and the means of observing it by remote sensing. Most baseline products are provided in the netCDF CF file format.

The ICC product model is not as strict as the CVB model. A climate change indicator product is typically a result of an analysis of a time series of CVB products where the result might be plotted as a graph easily visualising potential changes over time. Typical examples are glacier area or length plotted as a function of time. Another example is the maximum or minimum Arctic sea ice area plotted as a function of time. These products are provided in Microsoft Excel format or in plain text (ASCII) with comma-separated values. In some cases a climate change indicator product is more suitable represented as a spatial (map) product. An example is the change of the length of the snow season per grid cell as they are defined by the baseline product for snow cover extent.

Table 2.9:
CryoClim variable baseline products (relevant for CryoLand) as they have been specified from user requirements.

	Current Cryospheric Variable Baseline (CVB) products						
ECV	***Name***	***Region***	***Frequency***	***Sensor***	***Grid size***	***Time span***	***Provision***
	Snow						
T.3	Snow Cover Extent (SCE), PMR	Global	Daily	SSM/I	12.5 km	1987-present	METNO
T.3	Snow Cover Extent (SCE), optical	Global	Daily	AVHRR GAC/APP	5 km	1982-present	METNO
T.3	Snow Cover Extent (SCE), multi-sensor	Global	Daily	SSM/I + AVHRR	5 km	1978-present	METNO
	Glaciers Mainland Norway						
T.2.1	Glacier Area Outline (GAO)	Norway	1-30 years	Landsat TM/ETM+	N/A	1930[2]/1982-present	NVE
	Glacier-dammed Lake Outline (GLO)	Norway	1-30 years	Landsat TM/ETM+	30 m	1930[2]/1982-present	NVE
T.2.1	Glacier Periodic Photo (GPP)	Norway	Annual[3]	in situ	N/A	1980-present	NVE
	Glaciers Svalbard						
T.2.1	Glacier Area Outline (GAO)	Svalbard	TBD	SPOT	N/A	2007/2008	NPI
T.2.1	Glacier Surface Type (GST)	Svalbard	Annual	ERS, ASAR, Radarsat	30 m	1992-present	NPI
T.2.2	Glacier Balance Area (GBA)	Svalbard	Annual	ERS, ASAR, Radarsat	30 m	1992-present	NPI

1 Data from 1978 to 2007 is based on daily data from the EUMETSAT OSI SAF reprocessing project.
2 Time span depends on availability of maps and mapping dates, and will also vary for each region.
3 Frequency will be dependent on the available imagery for each glacier. Only for selected glaciers and in recent years series of annual photos are available. It will also be dependent on copyrights.

Table 2.9 shows the current CVB product portfolio as they have been specified by user requirements. The column ECV refers to the Essential Climate Variables (ECVs) code as defined by GCOS. Table 2.10 shows the current and currently envisioned ICC product portfolio. The actual product portfolio will be further discussed with potential users and tailored according to the feedback. The product portfolio will be available through a portal and a machine-readable interface. Various documents directly related to the products are also available for downloading in PDF, such as user manuals, validation reports and GCOS compliance statements. A "helpdesk" is also available, where the product producer or service provider can be contacted.

Table 2.10:
CryoClim Indicator of Climate Change products as they have been specified from user requirements (only relevant products for CryoLand). The products are subject to further refinements with the users.

Current and potential Indicator of Climate Change (ICC) products					
ECV	***Name***	***Region***	***Presentation***	***Time span***	***Provision***
	Snow				
T.3	Length of snow season	Global	Map/graph	1982-present	METNO
T.3	First day of sustained snow cover	Global	Map/graph	1982-present	METNO
T.3	Last day of sustained snow cover	Global	Map/graph	1982-present	METNO
	Glaciers Mainland Norway				
T.2.1	Glacier area change	Norway	Graph	1930[2]/1982-present	NVE
	Glacier length change	Norway	Graph	1930[2]/1982-present	NVE
T.2.1	Glacier mass balance change	Norway	Graph	1930[2]/1982-present	NVE
	Glaciers Svalbard				
T.2.1	Glacier area change	Svalbard	Graph	TBD	NPI
T.2.2	Glacier length change	Svalbard	Graph	TBD	NPI
T.2.2	Glacier mass balance change	Svalbard	Graph	TBD	NPI

2.2.15 *NAM internal project A.III.1 of NMA, Romania*

A.III.1 is an internal project of the Romanian National Meteorological Administration aiming to create snow related products (mainly snow extend maps and calculate snow water equivalent) using data from three major sources: (1) satellite data; (2) observations from the Romanian meteorological station network; (3) field surveys. Currently, the products are created for the upstream areas of five Carpathian watersheds. The project end-users are the National Institute for Hydrology and Water Management (INHGA) and the Ministry of Environment and Sustainable Development (ME). The end-users are interested in snow and ice related products for:

- Integration with existing hydrological numerical models for a better hydrological forecast (especially flood forecast in the spring season when sudden increases in the air temperature leads to fast snow melting rates);
- Improving water forecasting for better hydropower production (the share of Romanian power plant production in 2009 was 27,25 % of the total amount of energy produced);
- Agro-meteorological applications (especially to detect early signs of drought)
- Table 2.11 lists the requirements of snow and river ice products as reported in the A.III.1 project.

Table 2.11:
Observational requirements for snow and lake / river ice products, NAM internal project A.III.1 of NMA.

Product	*Spatial resolution*	*Temporal resolution*	*Format*	*Projection*
Snow Cover Extent	500 – 1000m	1 – 5d	NetCdf, HDF, ASCII, GeoTiff	Stereo70, GCS_WGS84
Fractional Snow Cover	500 – 1000m	1 – 5d	NetCdf, HDF, ASCII, GeoTiff	Stereo70, GCS_WGS84
Snow Water Equivalent	1000m	1 – 5d	NetCdf, HDF, ASCII, GeoTiff	Stereo70, GCS_WGS84
Snow Depth	1000m	1 – 5d	NetCdf, HDF, ASCII, GeoTiff	Stereo70, GCS_WGS84
Snow Surface Temperature	1000m	1 – 5d	NetCdf, HDF, ASCII, GeoTiff	Stereo70, GCS_WGS84
Snow Surface Wetness	1 – 5km	1 – 8d	NetCdf, HDF, ASCII, GeoTiff	Stereo70, GCS_WGS84
Lake/River Ice	5 – 10m	24h	NetCdf, HDF, ASCII, GeoTiff	Stereo70, GCS_WGS84

The following items were identified in the project:

- A light web interface for product visualization and analysis is welcome. Some of the users are not trained to use advanced scientific/GIS applications.
- Data access should be performed through classical FTP protocol as well as standard geospatial services (WMS/WCS).
- At least some of the products (Snow Cover Extent, Snow Water Equivalent) should be available for the entire area of the transnational river basins (e.g. Danube)
- The Snow Cover Extent should be corrected in forested areas (in the low/medium resolution products, derived from satellite images, the snow on the ground is sometimes hidden by the coniferous leafs).

2.3 Major considerations

In this section a summary on requirements for snow, glacier and lake / ice products from the view of thematic, geometrical and temporal aspects is given, based on Section 2.2.

2.3.1 *Snow products*

For water and energy management authorities, snow information is important to improve the accuracy of their runoff forecasts. Flood forecasting and management of energy potential are the most important applications. For hydropower industries snow information is important for production planning and energy trading. EO-based snow parameters are most important if they could be assimilated into hydrological models and improve the runoff forecast. For energy brokers and consultants snow information is important in assessing the availability of energy on short and long term to correctly assess the energy market. In general, organisations with EO experience recognise the weather dependency as a limiting factor with current optical satellites. They therefore in practice would like to have an improved spatial and temporal coverage.

In global scale, climate (climate change) studies and weather prediction are the most important application to EO-derived snow information. Climate and weather prediction models typically include snow among other variables, often linked to the soil moisture, evaporation and most of all, albedo, which plays a important role in the models. Although albedo can be related to Snow extent, the disadvantageous discontinuities in spatial data field - when based on optical data - is recognized. The microwave data-based products (or multi-sensor products) are therefore appreciated. Some users also emphasise the importance of having snow information also for forested areas.

2.3.1.1 *Thematic aspects*

Regionally, in areas where snow melt is an important factor for runoff, *SWE is considered as the most important parameter for runoff forecasts* as it gives information on available water within a catchment. In the alpine and mountainous areas SCA and SWE combined with elevation data is the most requested snow parameter. Thematic accuracy is assessed as the most important requirement but temporal and spatial resolution is almost assessed as equally important product requirement for SCA and SWE. The geometric accuracy is also rated as a very important requirement especially in areas with steep topography. Typically, SWE accuracy less than 10% is requested, while the targeted/accepted SCA accuracy is 5-10%.

In global scale, snow extent and SCA are considered as the most important parameters, although SWE is also highly rated. The required accuracy for SCA is typically 10-15% (out of 0-100%), or even 5%. SWE accuracy of 15mm or 15% is required.

For snow surface temperature, accuracy of 0.5-1 K is typically required. Snow albedo's accuracy should be 1% or less.

2.3.1.2 *Geometrical aspects*

The user requirement varied clearly according to whether a regional or global application was in concern. In global scale, typical SWE spatial resolution was 10-25 km, while regional applications required a resolution of 1km or even more, depending on terrain steepness. For SCA, the required resolution in both regional and global scale is smaller, clearly based on the current state-of-the-art of optical and microwave instruments and methodologies. The prevailing resolution requirement is 1-5 km in both global and regional scale, with the exception of very steep terrain where even 200m resolution was needed. For Snow Surface Temperature, most common requirement for resolution is 1 km, while for Snow albedo 5-8 km is required. The prospective location accuracy was typically less than the satellite footprint.

2.3.1.3 *Temporal aspects*

The temporal requirements for SWE and SCA depend on application, season and scale. Typically, when changes in snow cover occur, daily information within 3-24 hours after acquisition is needed;

outside the melting season, even weekly temporal resolution is adequate. Snow surface temperature as an indicator of snow melting is required most frequently, e.g. with 1 to a few hours intervals.

2.3.2 *Glacier products*

The overview of requirements related to glacier products is based on IGOS 2007 (and accordingly, on ESA DUE GlobGlacier), GCOS-107, ESA DUE INNOVATOR2 GLOF, PolarView and ESA CryoClim.

2.3.2.1 Thematic aspects

With glacier products, the measured parameter is typically related to area extent and its annual changes. Therefore, the thematic accuracy requirement is expressed as a percentage the estimated area (measurement range is e.g. 0.01-10 km^2): 1-5% error is generally accepted. Glacier velocity is expressed as [km/year], needed with an accuracy of 1%.

2.3.2.2 Geometrical aspects

The glaciers are mostly observed with high resolution VIS/NIR/SWIR (e.g. Landsat TM/ETM+, SPOT-5) or high resolution imaging active microwave instruments (SAR). The data provided by present and near-future instruments is in line with the typically requirement of 5-30 m spatial resolution. Applications are regional scale, or focusing e.g. on specific glacier lakes, which enables also the use of specific instrumentation with limited data availability and with relatively small spatial coverage.

2.3.2.3 Temporal aspects

The temporal requirements are strongly driven by applications, i.e. climate change studies or water management. The typical demand on monitoring glacier lakes is typically 6 months, however, in certain cases of possible hazards the frequency of monitoring glacier lakes might be several days to a few weeks. For Glacier area (outline) the time interval is typically 1-5 years. Glacier velocity is typically needed once or 4 times (quarterly) a year. In certain cases e.g. surging glaciers higher resolutions in the order of days to months are of interest. Snow / ice area on glaciers are related to mass changes. For water management time series of snow / ice maps during the year (e.g. monthly) are of interest, for mass balance studies the snow /ice are maps at the end of the ablation period (late summer snow line) are needed.

2.3.3 *Lake/River ice products*

User requirements related to lake/ river ice products were described by the IGOS Cryosphere Theme report (IGOS, 2007) (chapter 2.2.1), the PolarView (chapter 2.2.12), the ESA STSE North Hydrology (chapter 2.2.13 and by the NMA internal projects (chapter 2.2.15).

The CryoLand project concentrates on the derivation of two main lake and river ice products, (i) Lake and river ice extent, and (ii) Snow burden on lake ice.

The main user groups interested in these satellite products are the climate and hydrological modelling community and weather forecasting authorities. Snow burden on lake ice is defined in CryoLand as snow cover fraction on ice [%]. No user requirements concerning this parameter were defined by any of the project reviewed. CryOS aims instead at integrating a parameter describing the snow depth on ice, which is relevant for the estimation of winter conductive heat loss from lakes.

Therefore, the following paragraphs will summarize thematic, temporal and geometrical aspects concerning the lake/river ice extent product only.

2.3.3.1 Thematic aspects

The lake and river ice extent classifies a section of the freshwater body as either ice-covered or ice-free. The extent is usually defined in terms of area (in square kilometres). The targeted thematic accuracy for this parameter is 5 % according to IGOS Cryosphere Theme report and less than 5 % according to ESA STSE North Hydrology project.

Products with sufficiently good thematic accuracy can be delivered when using ASAR land mode (dual polarization). Since Envisat ASAR wide swath mode only work with one polarization (VV or HH), the thematic accuracy is poorer.

2.3.3.2 Geometrical aspects

Mapping of ice on lakes and rivers requires fine spatial resolution due to the small size of some river and lakes. The current spatial resolution for global and basin-scale applications for the parameter lake/ river ice extent is 300 m and 150 m for optical data and SAR, respectively with location accuracy of 1 pixel (ESA STSE North Hydrology). Target spatial resolution for global application is 30 m based on SAR data (IGOS, 2007) and the NMA internal project aims at the spatial resolution of < 10 m for regional applications.

Presently Envisat ASAR could provide datasets that yields a spatial coverage and spatial resolution that is adequate for most users relating to lake ice. In the future Sentinel-1A/B will also provide sufficient high spatial resolution to be used for river ice products.

2.3.3.3 Temporal aspects

Spatial and temporal consistent data sets are important for climate modellers and numerical weather predictions. Climate modellers need data sets over large areas (continental scale) and for long time periods (decades). Aggregated (gridded) data sets in space are preferred. The data sets do not need to be very frequent in time (monthly values are sufficient).

Within hydrological modelling, most present models do not have a river ice component since the needed data are unavailable. As a result there is great uncertainty in simulation of stream flow particularly in the spring.

Daily coverage is requested by all reviewed projects for the parameter lake/river ice extent**.** When bridging the often wishful thinking from users with what is actually possible to achieve with current and near future satellite sensors, it should be realistic to obtain close to daily coverage using SAR for the lake/ river ice extent product. A temporal resolution of one week instead is realistic when using of optical sensors, due to frequent cloud coverage at high latitudes where river and lake ice occur. There is hence a need to also provide a level of refinement to the ice products, where temporal interpolations provide the data regularity desired.

Near real-time data: The climate modellers have little need for real-time data. Weather predictors may in principle need near real time data, or at least data for the last day. The most urgent need for real time data seems to be within the hydrological community, where real time data is a pre-requisite for flood management. In particular ice jam monitoring is challenging.

2.3.3.4 Other aspects

Satellite data on freezing and break-up dates of lake ice is also of interest for all approached users, and in particular for validation of models. These data types can also be of interest for environmental assessment and for biological monitoring.

2.4 Spatial data infrastructure

2.4.1 *General*

The review of user requirements for Spatial Data Infrastructures and Services is based on the documents listed below. In addition, recommendation for the development of Spatial Data Infrastructures have been analysed and the sources are provided in the listing below.

- Beusen B., Borstlap G., Coene Y.; Grid Technology for EO applications, On using Grid Computing Technology in the Processing and Archiving Facilities (PAF) of EO Data Providers.
- EnviSnow – User Requirements Draft Document, Deliverable no 24, D2-WP7, EVG1-CT-2001-00052, 28.Feb. 2005.
- ESA – GSC-DA, DAIL, and HMA Interface Requirements
- GCSDA_ICD Package 2.0
- GCM v2.0_Requirements_revs, Aug. 2010
- GCM v2.0_Specification – ICD_revs, Aug. 2010
- GCDA Data package, Aug. 2010
- HMA-FO, Requirement Baseline Document – Technical Note
- EO Online Data Access Background Analyzes, HMA-FO_ODA-RB_EOX, ver.1.1, 2010-05-27
- HMA-FO, Requirement Baseline Document – Software System Specification, HMA-FO_ODA-RB-SSS_EOX, ver.1.4, 2010-11-03
- HMA-FO, Design Definition File (DDF) -
- Software Design Document, HMA-FO_ODA-DDF-SDD_EOX, ver.1.0, 2010-11-26
- HMA-FO, Design Definition File (DDF) - Software User Manual, HMA-FO_ODA-DDF-SUM_EOX, ver.1.0, 2011-01-19
- ESTEDI, European Spatio-Temporal Data Infrastructure For High-Performance Computing; D1A-Requirements and Analysis Report, 30.Aug.2000; IST Project IST-1999-11009
- GCOS-107 – Systematic Observation Requirements for Satellite-based Products for Climate, Supplemental details to the satellite-based component of the “Implementation Plan for the Global Observing System for Climate in Support of the UNFCCC”, Sept. 2006, WMO/TD No. 1338

- GCOS-138 – Implementation Plan for the Global Observing System for Climate in Support of the UNFCCC (Update 2010), August 2010, GOOS-184, GTOS-76, WMO-TD/No. 1523
- geoland2 – Land Monitoring Core Service, Proposal Ref. FP-7-218795
- Design dossier – System Concept document, SP-RP-SP031, June 2009
- Geoland2 SDI Baseline, Release and Services Integration Note, SDI-PL-0010, 16/07/2009
- SDI Interface Control Document for CIS and CMS, G2-SDI-RP-0001, 17.07.2009
- Spatial Data Infrastructure – Requirements and review, G2-SDI-RP-SD04-I1 00, 30.10.2009
- SDI and SDI Portal, Architecture Design Document, G2-SDI-RP-0003, 15.11.2009
- GEOSS – Global Earth Observation System of Systems
- AIP-2GEOSS Unified Modelling Team Engineering Report, GEOSS Architecture Implementation Pilot, Phase 2, 09/01/2009,98p, (http://www.ogcnetwork.net/AIP2ERs)
- AIP-2 Summary Engineering Report, GEOSS Architecture Implementation Pilot, Phase 2, 09/01/2009,38p, (http://www.ogcnetwork.net/AIP2ERs)
- End to End Discovery and Access Engineering Report, GEOSS Architecture Implementation Pilot, Phase 2, 09/01/2009,29p, (http://www.ogcnetwork.net/AIP2ERs)
- GIGAS,GEOSS, INSPIRE and GMES an Action in Support (FP7-224274)
- Technology Watch Report Architecture Technical Note 079, Issue 102, 28/11/2008
- Technology Watch Report Summary Technical Note 081, Issue 102, 30/06/2009
- Technology Watch Report Observations and Measurements 085, Issue 101, 16/01/2008
- Technology Watch Report WMS 095, Issue 104, 22/06/2009
- The "GIGAS Forum", http://www.thegigasforum.eu/project/material/deliverables.html
- GLIMS – Global Land Ice Measurements from Space, http://www.glims.org/
- GlobSnow – Requirements Baseline Document, ESA ESRIN Contract 21703/08/I-EC, Deliverable 1.4, ver.1.0/04, 03. June 2009
- GMES Data Access Specifications of the Earth Observation needs over the Period 2011-2013 (Data Warehouse Requirements V1.1), Data Access under the EC-ESA Delegation Agreement, 17 Dec. 2009, Brussels
- GMES Network of Users (GNU), FP6-CA-30956

- GNU – Criteria for an optimised setup of GMES and related Data portals, May 2010
- GNU – Reflections of the Extended Consortium, May 2010
- GNU – Practical approaches towards a new generation of GMES projects and actions, Oct. 2010
- GNU – Evaluation of current GMES and related data portals, June 2010
- IGOS - Cryosphere Theme Report for the IGOS partnership, Aug. 2007, WMO/TD-No. 1405
- INSPIRE – Infrastructure for Spatial Information in the European Community (Directive 2007/2/EC of the European Parliament and of the Council)
- Technical Guidance for the implementation of INSPIRE Discovery Services 30.03.2011, ver. 3.0
- Technical Guidance for the implementation of INSPIRE View Services 30.03.2011, ver. 3.0
- Technical Guidance for the INSPIRE Schema Transformation Network Service 15.12.2010, ver.3.0
- Draft Technical Guidance for INSPIRE Coordinate Transformation Services 15.03.2010, ver. 2.1
- Draft Technical Guidance Download Services (version 2.0) 25.09.2009
- Good practice in data and service sharing 31.01.2011,ver. 1.1
- Orchestra – Open Architecture and Spatial Data Infrastructure for Risk Management, (FP6-511678)
- Villa, M. Technical Report: SOAP HTTP Binding Status - Survey on OGC and ORCHESTRA Specifications Relevant for the INSPIRE Network Services, 22/09/2008
- Reference Model for the ORCHESTRA Architecture, v2.0, Jan. 2007
- Outline of a Technical Solution to a Global Cryospheric Climate Monitoring System 2006
- SOSI – Spatial Observation Services and Infrastructure (ESA ESRIN)
- Architectural Design Document, Issue1.0, 2009-04-08
- Information Services Technical Note, Issue 1.1,2009-04-08

The user requirements are analysed with respect to INSPIRE directive regulations. According to INSPIRE, 'Infrastructure for Spatial Information' means metadata, spatial data sets and spatial data services; network services and technologies; agreements on sharing, access and use; and coordination and monitoring mechanisms, processes and procedures, established, operated or made available in accordance with this Directive.

A further focus in the analysis is to ensure interoperability with international standardisation bodies (e.g. OGC), international initiatives, (e.g. IPY, GCOS, IGOS, GLIMS, etc.) and with global systems like GEOSS.

In general, a Service like CryoLand which shall provide large scale environmental information derived from multiple input data sources requires multiple interfaces. These are input interfaces for satellite and in-situ data, interfaces within the Service to generate, manage, and archive the desired products, and interfaces to the final user communities. For all these interfaces distinct requirements may be derived from the respective user or provider (internally as well as externally). In the following sections user and provider side requirements, which have been collected and analysed, are presented. The internal CryoLand service (necessary to enable the product generation) will be defined and presented in the System and Interface Requirements Document (ID03-1) and in the Architectural Interface and Design Document (D03-1).

2.4.2 *Service infrastructure requirements*

In the IGOS-2007 report the following is stated "The data and information management component must facilitate the flow of data and information in cryospheric research, long-term scientific monitoring, and operational monitoring. However, it must go beyond the traditional metadata service or web portal by encouraging the development of tools to combine all types of data, including model fields, from diverse and distributed data centres." Furthermore, CryOS recommends "the systematic development of standardized distributed environmental data processing, together with the development of commonly accepted standards for data visualization and quality control and assessment " The need facilitate the transition of research-based products into sustained monitoring systems is also clearly expressed.

Two other issues are discussed with high priority: reprocessing of historical data and fusion of data from different resources (e.g. in-situ, optical and SAR satellite data, airborne, etc.). CryOS envisions an integrative approach to processing and managing cryospheric data, where data from multiple sources are routinely combined to create higher-level products that can be easily used for integrated analyses. The data and information management component must facilitate the flow of data and information in cryospheric research, long-term scientific monitoring, and operational monitoring. It must go beyond the traditional service of archiving and serving data, by encouraging the development of flexible integration engines to combine a variety of data types ranging from model fields to socioeconomic data to point data from diverse and distributed data centres. Using identifiable and well-established facilities such as the World Data Centres, archives of the space agencies, or national data centres with lasting mandates will ensure that data are preserved for future use and reanalysis.

A model of the data integration engine for CryOS is the WCRP Coordinated Enhanced Observing Period (CEOP) activity. CEOP has been accepted as the main water and energy cycle data processing engine for GEOSS. It produces water and energy cycle data sets using a four-dimensional data assimilation of satellite and in situ observations supplemented by calibration and validation on the base of high quality measurements at a set of reference stations.

A very different example of an integration engine is the recent emergence of visual globes. These tools allow easy visualization and overlay of quite broad geographically based data. Visual globes are relatively easy to learn and use, and allow quick visualization of an extremely broad range of data types from distributed data sources. However, they do not often provide a means of quantitative analysis or data quality control.

However, flexibility is required to ensure that the data system remains relevant as technology and needs evolve. This includes identifying data archives that are not open for easy access, and promoting the use of standards to improve access.

As recommendations for Implementation, the Cryosphere Theme Report IGOS (2007) provides a short notice aiming at a high target. It states "The use of GIS, e.g., the visual globes approach like that provided by Google Earth (Figure 4.1), will make it possible to overlay different types of data and to identify gaps. However, not only is visualization required, but also an increased ability to support quantitative applications." Further, it states "In the future, it is expected that many of the Earth observations made for global monitoring of the environment will be integrated under GEOSS, which will provide integrated global Earth observations to meet the decision-making needs of a wide ranging user community."

In a mid-term time-range the development of processing of distributed data (eventually based on GRID technology) and the implementation of standard data formats for distributed web and data visualisation services is recommended. On a long-term basis seamless integration and distribution of cryospheric data products, including data fusion products (e.g. mass balance of sea ice, land ice, terrestrial snow cover) should be facilitated.

The EnviSnow project, based on User surveys, recommended certain snow products and their needed update cycles (weekly to monthly with a strong seasonal dependency during the melting period. The users also favoured that data is made available via the internet (e.g. WWW) as soon as possible. This, however, was connected to the user needs that "*Data must also be delivered in a form* *that enables easy incorporation into the HBV models.*" No other recommendations to the build-up of a spatial data infrastructure were concluded.

In the Requirements Baseline Document from the Global Snow Monitoring for Climate Research (ESA ESRIN Contract 21703/08/I-EC, v1.0/4, 03-06-2009) the satellite data provider side has been analysed, and the needs of the Snow/Ice Community" is expressed. Clearly the need for automatic pre-processing of the enormous global datasets, collected since decades, and representing a highly valuable input as FCDRs (Fundamental Climate Data Record) is expressed. This includes the geometrically correction of optical datasets as well as the utilisation of available on-orbit calibration data and orbital/positioning data. These pre-processed datasets have then to be made available through a machine-readable interface. All products must be made available to the public at no charge. The GlobSnow website shall disseminate the products in a standardized format with quick-looks of the monthly products. Web tools to facilitate the access and presentation of the products shall be considered.

A standard data format is requested for all data and products and shall be defined in collaboration with the users. The following formats have been proposed: for data HDF and for products GRIB, BUFR, NetCDF, GeoTIFF.

GCOS-107 (2006) report provides Key commendations and Actions to be undertaken to meet the needs of the UNFCCC to allow global access to climate data records, and to ensure the possibility for their global utilisation. As Cross-cutting needs the following issues have been identified?

- Develop modern distributed data services that
- handle the increasing volumes of data
- make access to increasingly large volumes of data more effective; this is especially important for countries with inadequate IT infrastructure or technical skills in using complex data
- provide access to metadata, as well as physical data
- maintain access to historic data

As Climate Monitoring Principles the following statements are provided in GCOS-107/Appendix 4:

- Data management systems that facilitate access, use and interpretation of data and products should be included as essential elements of climate monitoring systems.
- Data systems needed to facilitate user access to climate products, metadata and raw data, including key data for delayed-mode analysis, should be established and maintained.

GCOS-138 (2010) provides some results based on the experience of the recent years. Expressing the needs to achieve an understanding of the global climate dataset highlighting the growing importance of data exchange and data access and points out the current inadequacies: "*The flow of data to the user community and to the IDCs is inadequate for many ECVs, especially for those of the terrestrial observing networks. Lack of national engagement and resources, restrictive data policies, and inadequate national and international data system (including telecommunication) infrastructure are the main causes of the inadequacy*". The GCOS Climate Monitoring Principles (GCMPs) points to the "*crucial importance of data management systems that facilitate access, use, and interpretation of the data*".

The GEOSS strategy foresees building comprehensive data architecture for a system of observing systems. GEO has been established outside the UN system. The functions of international data archiving and the provision of integrated global climate analyses and products are to be undertaken by national and multinational institutions on behalf of the global community. These institutions should endeavour to provide the data and products openly and without restriction to all other nations as part of their commitment.

Implementation of the GCOS satellite component would involve collecting and archiving all satellite metadata so that long-term sensor and platform performance is accessible. The creation of consistent data records from all relevant satellite systems (so that optimum use can be made of the satellite data in the integrated global analyses and reanalyses, for example through reprocessing of past records) requires the organization of data service systems that ensures an on-going accessibility to the data into the future (GCOS-138).

For the Data Management and Stewardship GCOS-138 identifies the following five main issues:

- Firstly, prompt and regular flow of data to the user community and to the International Data Centres for the ECVs (or groups of ECVs) must be ensured. This is currently inadequate for a number of variables and networks, especially in the terrestrial domain. Lack of engagement, data policies, prevalence of short-term research funding or overall lack of resources, and inadequately integrated data system infrastructures are the primary causes.
- Secondly, access to very large datasets is a continuing concern. Some satellite datasets and model simulations are becoming so large that it is difficult for many users to acquire them despite advances in technology. This is especially true in developing countries with inadequate information technology infrastructure or technical skills in using complex data. Access to these data must be made more effective through the development of derived products or product subsets and appropriate access mechanisms.

- Thirdly, the preservation of the data for future use requires facilities and infrastructure to ensure the long-term storage of the data. The rapidly-increasing volume of raw observations that must be saved and stored in an archive is such that without action, the data will often be inaccessible to many users. Once data are in electronic format, the data must be continually migrated to newer storage devices, and data access software and consistent data formats must be maintained, in order to preserve the data for sustained future use.
- Fourthly, a key component of data management includes adequate monitoring of the data stream. This includes timely quality control of the observations by the monitoring centres and notification to observing system operators and managers of both random and systematic errors, so that corrective action can be taken. An operational system is needed that can track, identify, and notify network managers and operators of observational irregularities, especially time-dependent biases, as close to real time as possible.
- Finally, many inconsistencies, apparent biases and in-homogeneities in the data can be addressed if adequate metadata information and original records are available to the analyst. International standards and procedures for the storage and exchange of metadata need to be extended to all variables and implemented for many climate-observing systems

To help address the issues raised above there is a growing interest in adopting a consistent and compatible family of data representation standards for all Earth observations. Integration spanning all domains (terrestrial, oceanic and atmospheric) will be best served with common standards for as many of the data management activities as are possible, including geographical location, metadata, archival strategies, data formats etc. The opportunity for standardisation extends beyond climate and includes the whole Earth observation mandate being covered in GEOSS (GCOS-138).

The WMO Information System (WIS), which is an extension of the WMO Global Telecommunication System (GTS), will be used for the exchange of data from the WMO Observing Systems. WIS has adopted the same data exchange systems as used by other major participants in GEOSS, and compliance with WIS automatically entails compliance with GEOSS. For instance, participants in WIS and GEOSS use the ISO 19115 metadata content standard for geographical information and the ISO 23950 interoperable search service, which can serve for extending the effort as broadly as possible (GCOS-138).

These finding are summarised in the following issues identified in the GCOS -138 report:

- Apply standards and procedures for metadata and its storage and exchange.
- Ensure interoperability with standards and initiatives

- Seek hosts for designated International Data Centres addressing the full range of terrestrial domain ECVs.
- Ensure national data centres are supported to enable timely, efficient and quality-controlled flow of all ECV data to International Data Centres (other than the very large satellite datasets that are usually managed by the responsible space agency).
- Ensure timely flow of feedback from monitoring centres to observing network operators.
- Ensure that data policies facilitate the exchange and archiving of all ECV data.
- Given the large growth in global environmental data taking place and expected to continue, there is a need to develop more efficient tools for data analysis, dissemination, and validation that will allow both observational and model-created information to be extracted, combined, and used in an efficient way. This may include the development of enhanced sub-setting techniques and automated analysis and pattern recognition routines, as well as accelerated models that can take advantage of advances (in both hardware and software) in computational technology.
- Data management systems that facilitate access, use and interpretation should be included as essential elements of climate monitoring systems.
- Data systems needed to facilitate user access to climate products, metadata and raw data, including key data for delayed-mode analysis, should be established and maintained.

The services shall be organised as distributed systems of databases and product production chains hosted by various organisations. The generation of the products to be stored in the databases may take place in different organisations. The infrastructure connecting sub-services of climate products should be a state-of-the-art, flexible and scalable solution in order to easily allow new sub-services to be connected and in order to adapt to other organisational changes that will occur in a living service.

The web service, the link between the databases and users, should provide tools for product search, simple analysis, retrieval and background information and metadata. The host depends on who has the best expertise on the corresponding algorithms. Production chains for indicator products should be produced by add-on modules to the production chains for baseline products. An indicator product will usually be based on one or a combination of two or a few baseline products. In the case of baseline products from different sub-service providers being applied in the production of an indicator product, baseline products will be retrieved from the database (via interfaces between the sub-services) (Outline of a Technical Solution to a Global Cryospheric Climate Monitoring System 2006)

The main purpose of the GlobSnow procurement is to define, implement and validate, a snow monitoring information service on a global scale. The service is supposed to support the GCOS implementation plan (GCOS, 2006) with systematic satellite-based Earth Observations on global snow areal extent and related products. It should further support snow monitoring activities of governmental institutions, intergovernmental bodies and scientific groups involved in climate change research. The ultimate aim of the GlobSnow project is the development of the knowledge and technical capacity necessary to implement a sustainable global snow monitoring service fulfilling the GCOS implementation plan requirements.

The delivered system within the GlobSnow project shall operate as a stand-alone system. Processing shall occur automatically, with minimal operator intervention. The processing system shall be further designed such that it meets Near Real Time (NRT) requirements. The architecture and implementation of the processing system should be as simple as possible in order to minimise software development and maintenance costs, but should ensure high performance as well. It is suggested to keep the architecture and implementation of the processing system as simple as possible in order to minimize software development and maintenance costs, and to ensure high performance. There are indirect requirements on the system that come out of the requirements of the products, such as spatial and temporal coverage or complexity of the classification algorithm. (GLOBSNOW 2009)

2.4.3 *Network services (machine-readable interfaces) requirements*

The analyses of requirements for the Network services viewpoint are strongly interconnected to the input and output interfaces of a service. On the output side specialised interfaces, for users which like to consume products directly, as well as general purpose interfaces like defined by INSPIRE or GEOSS have to be considered. On the input side a similar picture may be drawn. It is very likely that multiple, diverse interface towards in-situ data resources are needed while the interfaces towards the satellite data providers are already undergoing a process of harmonisation (see various ESA initiatives e.g. the Heterogeneous Mission Access project, (HMA), GMES space component - data access (GSC-DA), and Data Access Integration Layer (DAIL)).

2.4.3.1 INSPIRE

INSPIRE intends to trigger the creation of a European spatial information infrastructure that delivers to the users integrated spatial information services. These services should allow the users to identify and access spatial or geographical information from a wide range of sources, from the local level to the global level, in an interoperable way for a variety of uses.

According to INSPIRE Directive (2007/2/EC) network services are:

- discovery services making it possible to search for spatial data sets and services on the basis of the content of the corresponding metadata and to display the content of the metadata;
- view services making it possible, as a minimum, to display, navigate, zoom in/out, pan, or overlay viewable spatial data sets and to display legend information and any relevant content of metadata;
- download services, enabling copies of spatial data sets, or parts of such sets, to be downloaded and, where practicable, accessed directly;
- transformation services, enabling spatial data sets to be transformed with a view to achieving interoperability;
- services allowing spatial data services to be invoked; this means that spatial data processing may be triggered (started) by another service. This mechanism also enables the creation of complex processing workflows.

INSPIRE actively monitors standardisation developments, and seeks to implement and adjust the infrastructure architecture and data formats, to be as conformant as possible to a future common service infrastructure. In this way INSPIRE may also contribute to long term open system developments, and work as input to standardisation efforts regarding usability and practical application. In Europe are two important standardisation initiatives that should be taken into account when integrating and developing technology for services: INSPIRE and OGC.

The INSPIRE directive advises to utilize existing standards, OGC service bindings are taken as a guidance. Existing OGC Web Services (OWS) support a mix of protocols and technology bindings. These are Key-Value-Pairs send via HTTP GET, XML send via HTTP POST, SOAP via HTTP POST and combinations. In addition, the World Wide Web Consortium (W3C) suggests the usage of SOAP as a messaging protocol for Web Services.

In order to streamline integration and implementation as well as getting a maximum benefit from the offered services, a mix of technologies is to be avoided. Taking all requirements, opportunities and risks into account, the default communication-protocol and binding technology for INSPIRE services should be SOAP (using document/literal encoding style).

On the other hand, "*INSPIRE – Network Services Architecture*" (Series of Technical Guidance for the implementation) reports that existing OGC Web Services (OWS) typically support HTTP GET and/or

HTTP POST as messaging protocol and they publish the GetCapabilities operation to provide service Metadata. The World Wide Consortium suggests the usage of SOAP (currently version 1.2) as a messaging framework and WSDL (currently version 2.0) to describe service metadata.

Table 2.12:
INSPIRE Network Services definitions.

INSPIRE Services	***Based on:***
Discovery services	OGC catalogue service, with the ISO Application Profile : OGC CS-W 2.0 ISO AP
View services	OGC Web Map Service: ISO 19128 WMS 1.3
Download services	OGC Web Feature Service (WFS 1.2.0 ISO 19142), OGC Web Coverage Service, HTTP File download
Transformation services	Functions of a Web Processing Service (OGC WPS): Coordinate transformation services
	Schema transformation services
Invoke services	Chaining services: BPEL (Business Process Execution Language form OASIS)

A number of arguments can be listed in favour of SOAP/WSDL approach for the INSPIRE network services:

- SOAP Web services are becoming the standard information technology and thus support more sustainable implementing rules;
- SOAP Web service ensure smooth and complete integration in development environments;
- SOAP Web services yield a direct and full integration with other Web Service environments;
- SOAP Web services have the possibility to support geo rights management services by using SOAP envelope data.

The INSPIRE Directive asks Member States "to establish and operate a network" of "download services, enabling copies of spatial data sets, or parts of such sets, to be downloaded and, where practicable, accessed directly".

A download service supports:

- download of a complete dataset or datasets;
- download of a part of a dataset or datasets;
- where practicable, provide direct access to complete datasets or parts of datasets;
- gazetteer-like services are also covered by a type of download service.

OGC provides a couple of services that allow having access to two different kinds of geospatial information: the Web Coverage Service (WCS) and the Web Feature Service (WFS). The WCS may be compared to the OGC Web Map Service (WMS) and the OGC Web Feature Service (WFS): like them it allows clients to choose portions of a server's information holdings based on spatial constraints and other criteria. However, unlike the WMS, which portrays spatial data to return static maps (rendered as pictures by the server), the Web Coverage Service provides available data together with their detailed descriptions, defines a rich syntax for requests against these data and returns data with their original semantics (instead of pictures), which may be interpreted, extrapolated, etc. – and not just portrayed. Unlike WFS, which returns discrete geospatial features, the Web Coverage Service returns coverages representing space-varying phenomena that relate a space-temporal domain to a (possibly multidimensional) range of properties.

In summary, INSPIRE services shall be Web Services (W3C) using the SOAP protocol to exchange messages, and WSDL to describe the services. However, it should be noted that this sentence somehow contradicts the specifications used in the Technical Guidance documents. Table 2.12 provides an overview of the proposed services.

It must be noted that Web Coverage Services are mentioned in the draft technical guidance of the INSPIRE Download Services as a future addition required for types of data that are currently not yet envisaged by INSPIRE: "WFS and FE will have the capability of serving all download service requirements for Annex I themes. If later data specifications relating to Annex II or Annex III themes should require additional functionality, like those covered by the OGC Web coverage service (WCS), the Technical Guidance document will be extended accordingly." Indeed INSPIRE is currently only dealing with vector data sets not with images that are only dealt with in Annex III data theme Ortho-imagery. But this is currently under discussion.

2.4.3.2 GEOSS (Global Earth Observation System of Systems)

The Global Earth Observation System of Systems (GEOSS) promises to revolutionize our ability to understand and manage the planet. This emerging global public infrastructure will allow managers and decision makers to respond more effectively to the many environmental challenges facing modern civilization.

GEOSS is interconnecting existing and future Earth Observation systems. GEOSS promises to make these and other technologies fully "interoperable". GEOSS will make the production of comprehensive Earth Observations more sustainable by leveraging investments from a wide range of partners. It will also ensure that Earth Observations remain a global public good accessible to all.

This "System of Systems" will proactively link together existing and planned observing systems around the world and support the development of new systems where gaps currently exist. It will promote common technical standards so that data from the thousands of different instruments can be combined into coherent data sets.

GEOSS coordinates a multitude of complex and interrelated issues simultaneously. This cross-cutting approach avoids unnecessary duplication, encourages synergies between systems and ensures substantial economic, societal and environmental benefits. The architecture of an Earth observation system refers to the way in which its components are designed so that they function as a whole. Each GEOSS component must be configured so that it can communicate with the other participating systems.

GEOSS as a "System of Systems" is composed to a considerable extent of the constituent systems (e.g the European GMES) established or being established at both governmental and community levels. Nonetheless, there is intended to be a core system organized around the GEOSS Common Infrastructure (GCI) serving to connect the resources of the constituent systems.

GEOSS Use Cases define reusable activities within a service-oriented architecture, tailored for the GEOSS environment. As of now:

- Six SBA Scenarios show use of GEOSS for communities of interest
- Reusable process for applying Service Oriented Architecture to other SBAs

From the GEOSS 10 Year Plan Reference Document the following GEOSS Interoperability requirements can be deducted:

- Interoperability through open interfaces
- Interoperability specifications agreed to among contributing systems

- Access to data and information through service interfaces
- Open standards and intellectual property rights
- GEOSS adopting standards agreed upon by consensus, with preference to formal international standards
- GEOSS will not require commercial or proprietary standards
- Multiple software implementations compliant with the open standards should exist
- Goal is that one of the implementations should be available to all implementers "royalty-free"

One of the major outcomes of the GEOSS Architecture Implementation Pilot, Phase 2 (AIP-2) is a set of Engineering Reports (ERs). From these reports the GEOSS Floods Disaster Response Scenario defined Steps to be followed in the Floods Disaster Response Scenario and correlated corresponding use cases. Regarding data access the information in Table 2.15 is provided from GEOSS AIP-2. However, it is unclear if these component types are seen from the provider's side or from user's side. The GEOS End to End Discovery and Access Engineering Report provides the listing of GEOSS User Types shown in Table 2.16.

Table 2.13:
Steps in the Floods Disaster Response Scenario (from GEO Architecture Implementation Pilot, Phase 2, Floods Disaster Response Scenario Engineering Report).

Based on Alert issuing by a Processor, the Actuator (Regional civil protection) accesses the result of observations using WCS, WMS or SOS (e.g. Daily Flood Map Prediction).	UC#06 - Interact with Services (Activity of client to consume services for datasets, sensors, models, workflows, etc); → "Interact" specialized use case for WCS/SOS
One or more Processors (Data Providers) made ortho-image available (pre and after). Geometric processing / Ortho-processing can be activated via WPS. Publication is made through WCS / WMS.	UC#08 Construct & Deploy Workflow (Configure and deploy workflow consisting of one or more services) → WPS for orthoprocessing WCS output: http://ws.spotimage.com/wcs/coverage/Burma?request=GetCapabilities&service=WCS
The result of processing is released and make available through WCS or WMS. Depending on when the data is acquired, and whether the Alert was issued quite early before event, the data should be thematically processed to update the state of road network, and publish that map via WMS.	UC#07 Exploit Data Visually and Analytically (Use portals and clients to present data in useful ways for interpretation and decision support)

Table 2.14:
Use cases from GEO AIP-2, Floods Disaster Response Scenario Engineering Report.

UC#6: Interact with Services	Interact with Services	# Service Provider # Portals and Client Applications
UC#7. Exploit Data Visually and Analytically	Steps for exploitation in Client Applications of datasets served through Web Services and online protocols as used within GEOSS.	# GEOSS User # Components and Services Registry
UC#8: Construct and Deploy Workflow	Design, deploy and execute a workflow described in Business Execution Language (BPEL) or any other script language.	# GEOSS Integrator # Client Application # Service Provider

Table 2.15:
GEOSS Engineering Component Types.

Component Description Example Interoperability	Arrangements	Product Access Servers
Services to access Earth Observation data.	Typically hosted by a facility that provides redundant resources for both high availability and high performance.	WMS, WFS, WCS, ftp, OpenDAP

Table 2.16:
GEOSS User Types.

Integrator	A class of user typically engaged in support of one or more application areas who is able to use GEOSS to locate suitable services, data, and related resources, and to develop and deploy integrating software solutions (e.g. applications) that cater to a specific context or subject area	CSW, SRU, SOS, NetCDF, OpeNDAP, WCS, WPS
Experienced User	Users who understand the concepts of GEOSS and seek registered resources through the GEO Web Portal interface or desktop applications	O&M, NetCDF, WMS, WCS, KML, GeoRSS

2.4.3.3 GMES (Global Monitoring for Environment and Security)

The objective is to rationalize the use of multiple-sources data to get a timely and quality information, services and knowledge, and to provide autonomous and independent access to information in relation to environment and security. In other words, it will pull together all the information obtained by environmental satellites, air and ground stations to provide a comprehensive picture of the "health" of Earth.

GMES also represents the European Union contribution to GEOSS, the Global Earth Observation System of Systems. GMES therefore needs to ensure the interoperability and harmonization of the various EO data sources and their related products, to underpin and ease the establishment of services, not only within each thematic domain but also in a transverse fashion.

In the proposal for the GMES Initial Operation (GIO, 2011-2013) the following is stated "This Community action will focus on the full service chain for emergency response and land monitoring, data access and infrastructure operations". Furthermore, data access is explicitly listed as a scope of GMES. However, so far data access and data flow scenarios, especially regarding the data input, have been rather neglected by the various EC projects.

In order to achieve their goals all services eligible for data access within the GMES framework need to receive EO data for further processing and product generation. This data access is currently achieved by utilizing very traditional techniques ranging from sending Disks (CDROM, DVD, Hard-Drives) by mail to the provisioning of ftp servers; sometimes containing vast sets of files (e.g. Image2009) without possibility for a pre-selection/pre-inspection based on its content.

From the data input point of view especially Geoland2, the Land Monitoring Core Service (LMCS) providing Land cover and Land use classifications, is of special interest to CryoLand.

2.4.3.4 EC Geoland2 project

Geoland2 intends to constitute a major step forward in the implementation of the GMES Land Monitoring Core Service (LMCS). The three components (Local, Continental, and Global) of the LMCS are addressed. The architecture of geoland2 is made of two different layers, the Core Mapping Services (CMS) and the Core Information Services (CIS).

These form ten service groupings, all together responsible for the definition, algorithmic evolution and pre-operational generation of some 70 different products (geospatial data set series and algorithmic tools). The processing relies upon availability of space, in-situ, references and other (partially user-provided) input data streams. In most cases an internal value chain is established such that the CIS are building output products from CMS. The ultimate goal of each Core Service is to make its products accessible to its users via widely agreed mechanisms, generally respecting INSPIRE implementing rules.

The Spatial Data Infrastructure (SDI) task aims at setting up pre-operational services for the discovery, viewing, access, and delivery and support all products generated in the geoland2 project by the CMS and CIS. The SDI task takes INSPIRE as the baseline. The CMS and CIS can be both data producer and/or data consumer. The SDI task is user-driven: the SDI is designed to fulfil the needs of the different data providers and data consumers in the project. In addition this is done with respect to the INSPIRE directive to ensure an easy integration of the SDI in the context of the European Spatial Data Infrastructure. Generally the SDI has to ensure online product discovery and dissemination between users and providers; where users themselves are often providers to other users. This applies both internally and externally of LMCS:

SDI establishes the mechanisms for discovery of all services and of all geospatial data sets provided by geoland2, i.e. it provides access to a registry and all the metadata needed in order to enable (external) applications and (geo)portals to "*find and bind*" individual product services inside the CMS and CIS production centres; the "bind" operation can be done from the application/portal or external client directly to the CMS/CIS service. There is a native SDI Geoportal provided (currently at www.land.eu/internalportal) which supports a rich set of functions for human interactions for detailed exploration of (the CMS/CIS) data set series.

SDI also provides productivity tools for service providers to register and connect their services (supporting the Ordering Services for EO Products, OGC 06-141).

SDI offers, in principle, also the mechanisms to establish interoperability at requested levels to geospatial data services in the wider community network, i.e. SDI can host the "find and bind" information related to space, in-situ, and reference data access services (e.g. used by the CMS and CIS to interoperate with such input data sources); proper meta-data harvesting mechanisms are foreseen. SDI can serve such information even if not needed internally by geoland2 CMS and CSI but in order to build up a wider land domain metadata and interoperability service (e.g. by including SEIS, national, GEOSS etc. service sources).

The following service taxonomy has been defined for the Geoland2 SDI:

- View Services: WMS
- Download Services: WFS, WCS, FTP Push/Pull, satellite multicast
- Ordering Service

Since the geoland2 definition foresees CMS and CSI as both, data provider and data consumer, the identified download services can be seen as requirements for both, the users of geoland2 products as well as for the providers of the input, the baseline EO imagery. Additional, the internal geoland2 needs e.g. CSI needs data input from CSM, also have to be satisfied via these download services, mainly WFS, WCS, and FTP Push/Pull. For example, the SOSI initiative, is already bringing the seamless soil sealing dataset from EEA (2006 version) on-line for discovery, view and download. The dataset is available both at European as well as at country-level (A, CZ, HU, LUX).

In order for the geoland2 Core Services to deliver the high-level operational services needed, it is necessary for them to integrate space observation products. This includes receiving from GSC-DA and hosting of the Image2009 data set series as new elements of the series are ready to be loaded, put at disposition for view, and in particular for download (e.g. via WCS) by the EUROLAND production teams.

The main problem currently is of non-technical nature: The SDI Task, tough competent and equipped with the right technology is neither mandated nor funded to implement the integration between the GSC-DA and the Core Services. It was meant to be under the responsibility of each Core Service to build up the technical capability necessary and to perform the integration task individually. As of today the Core Services will not be prepared to perform the integration when the space-side services will become at disposition.

The geoland2 Spatial Data Infrastructure (SDI) implemented various solutions in order to enable users the access to geoland2 datasets. Depending on the needs of the different CIS/CMS and their provided products the implementation of the solution range from simple file download via ftp/http-server, to WMS, WFS, and WCS and even EUMETCast. However, no detailed consideration for requirements or even implementations are available regarding the data access and transfer from the space data providers to the Core Mapping Services or to the Core Information Services within geoland2.

2.4.3.5 ESA SOSI (Spatial Observation Services and Infrastructure) project

SOSI is a project funded by ESA It demonstrates innovative "*Spatial Observation Services and Infrastructure*" within the context of land monitoring initiatives at European and Member State levels.

The programmatic objectives of the European Shared Environmental Information System (SEIS) and related user requirements have provided much of the conceptual foundation for the SOSI demonstration systems. In particular the SEIS activity to implement the Land Cover Data Service

(LCDS), a joint initiative of EEA and twelve Member States to establish an information sharing and reporting environment for land use and land cover change, is addressed by the SOSI project. For example, the SOSI Land Cover Service is a fully functional demonstration of the concept of a "locally administered, globally shared" data repository, i.e. each participating country provides and maintains a service with local (national) data. A common access service enables the user to access and retrieve cross-border datasets (from the involved national servers) as a homogeneous, seamless dataset. This common access services involves data sub setting and CRS transformation in a distributed environment.

The primary technology and operational procedures of SOSI are implemented by utilizing the Service Support Environment (SSE) of ESA. SOSI offers a distributed node-based infrastructure of Web-services following Service Oriented Architecture (SOA) principles and standards, thus establishing access to a number of content services and one land cover generation processing service operated by the participating organizations. The SSE infrastructure provides coupling and user access mechanisms (binding, workflows and portal).

The SOSI project also defined some requirements regarding online EO data access needs, however, these requirements are towards the end users representing the services offered and not the from the input viewpoint. SOSI uses RM-ODP standard to describe the requirements which are mostly OGC based standards for services and interfaces.

2.4.3.6 Service viewpoint

<u>Web Map Service (WMS):</u> Produces maps of spatially referenced data.

Applicable Specification and Standards

- OGC 06-042 and 01-068 (ISO 19128): Web Map Service (WMS) Implementation Specification
- OGC 07-063: WMS - Application Profile for EO Products

<u>Web Feature Service (WFS):</u> Provides access to vector data.

Applicable Specification and Standards

- OGC 04-094 (ISO 19142): Web Feature Service (WFS) Implementation Specification

<u>Web Coverage Service (WCS):</u> Provides access to geographic data in its original semantics and allows complex queries against these data.

Applicable Specification and Standards

- OGC 03-083: Web Coverage Service (WCS) Implementation Specification

FTP Push/Pull: File transfer protocol. Transfer files between 2 computers via a network.

- Standard: RFC 959 (Secure FTP - RFC 4217)

2.4.3.7 Engineering viewpoint – SSE Portal Server

Online Data Access Interface Wizards

- Web Map Service (WMS) versions 1.1.0, 1.1.1, and 1.3.0
- Web Feature Service (WFS) versions 1.0.0 and 1.1.0
- Web Coverage Service (WCS) version 1.0.0
- Sensor Observation Service (SOS) version 0.0.31 and 1.0.0

2.4.3.8 Engineering viewpoint – SSE WebMapViewer Client (excerpt)

- Web Coverage Service 1.0.0
- Raster data files: GeoTIFF, GeoJP2, GMLJP2, and GDAL
- Web Feature Service 1.0.0, 1.1.0
- Transactional Web Feature Service
- Sensor Observation Service (Discrete Time Series) version 0.0.31 and 1.0.0
- Web Map Service (WMS) versions 1.1.0, 1.1.1, and 1.3.0

2.4.3.9 Satellite data access

In recent years the European Space Agency has made a large effort in harmonising the provision of and access to satellite derived information. This can be seen in initiatives like he Heterogeneous Mission Access project, (HMA), the GMES Space Component - Data Access (GSC-DA), and the Data Access Integration Layer (DAIL). These efforts focused strongly on the application and developments of adequate standards to achieve the highest possible level of interoperability between various missions managed or accessed by ESA. The focus of the standardisation has mainly been placed on standards of the geospatial domain. Within this geospatial domain the Open Geospatial Consortium (OGC) has acted very successfully in issuing widely used standards. Some of them have been taken over by the ISO committee and also INSPIRE is recommending them at various levels.

Especially in the ESA's various HMA projects a series of OGC standards have been defined and are actively applied by ESA to their infrastructures. One of the latest standards coming out of HMA is the new version for the Web Coverage Service (WCS 2.0) which regulates the direct online access to inter alia satellite datasets. It allows the sub-setting of entire data collections in time and space and will therefore reduce the burden on the user side to select and download large single files via FTP. This will not only reduce the overall data volume to be transferred but further enables the development of automated service and processing chains as web services.

Web services OGC standards are well documented and for most standards reference implementations exist. The tools used for these Reference implementations are mostly Open Source software implementations which are usually already widely in use and well approved in the geospatial domain. To access satellite imagery in the future will therefore get much easier. Also for the new Sentinel Satellite Series the data policy will not restrict the access or use which further will ease the wide use of space derived information products.

2.4.3.10 Access to GMES Earth Observation Data – User hearing (17 Dec. 2009)

The GMES Data Access Specifications (Data Warehouse Requirements V1.1, 2009) defines the principles governing the access to GMES Earth Observation Data from third party missions for the GMES users during the period 2011-2013. In other words, it provides an overview of the next data access grant agreement between the EC and ESA, also known as the "*Data Warehouse requirements*". In this agreement the policies for the relevant services for online data access (View and Download) are defined as follows:

The VIEW service shall allow the beneficiary (respective User Category):

- to access Primary Products by connecting directly to the View service from an individual computer or an internal computer network;
- to produce Derivative works from Products accessed through the View service;
- to make hardcopies of any extract of the Altered Product at any resolution, with the display of the following credit: "includes material © Mission name (year of acquisition), all rights reserved";
- to access Altered Products through the View service for internal or external demonstration purposes; and
- to retain all Intellectual Property Rights associated with any Derivative work developed on the basis of the Product.

The DOWNLOAD service shall allow the beneficiary:

- to make an unlimited number of copies of the Primary products as needed (archiving and backup purposes included);
- to install on as many individual computers as needed, including internal computer network;
- to alter or modify the Primary Product by invoking a computer application to produce Altered Products and Derivative work;
- to post Metadata of the Primary Product or its Altered Products on an internet website with the display of the following credit: "includes material, Mission name (year of acquisition), all rights reserved";
- to make hard copies of any extract of the Primary Product or its Altered Products at any resolution, with the display of the following credit: "includes material © Mission name (year of acquisition), all rights reserved";
- to use the Primary Product or its Altered Products for internal or external demonstration purposes; and
- to retain all Intellectual Property Rights associated with any Derivative work developed on the basis of the Product.

However, these points merely regulates the "policy" issues but provides no information about the technical implementations of these services.

In section 5 of Data Warehouse Requirements V1.1 the datasets specifications also contains the definition for the "*Delivery media*" which specifies the media for delivery as (e.g., DVD, tape, ftp get, ftp push or OGC service). From the provided listing, the overwhelming majority requests to have the opportunity to access the data utilising online tools. However, FTP is given as the main choice. Only a single service is currently streamlined towards an OGC service, here WMS as a View service.

2.4.3.11 GSC-DA / HMA / DAIL

The GSC-DA represents the Coordinated Data access System (CDS) Customer Interface which is also known as the EO-DAIL (EO Data Access Integration Layer). The CDS system and the corresponding interfaces at the participating GMES contributing missions are being designed and implemented by various concurrent studies and projects.

Previous HMA documents contained description of Use Case, which reflect the needs expressed for GSC-DA capabilities. There, the requirements are organized as Scenarios corresponding to the GMES Scenarios. For Online Data Access 3 scenarios are described under the Use Case 9 (Dissemination):

- Scenario1: US9_1 – Online Data Access via FTP
- Scenario2: US9_2 – Online Data Access via OGC Web Services
- Scenario5: US9_5 – Virtual FTP Server

The description of US9_2 – Online Data Access via OGC Web Services states that the functionality of OGC Web Service servers is part of the Missions GS which may offer these services through the HMA. Especially, WMS, WFS, and WCS are mentioned by name with WCS as being the most wide spread choice for EO data. The user would need to indicate this type of data delivery method in the order/programming request. When the product is available on the mission GS server, it indicates the URI of the server to the user who can then retrieve the data using the respective standard Web Service interface.

The HMA follow on project has just recently finished with the definition of specialised Earth Observation Profiles (all of them currently in the final process of becoming OGC Implementations Standards) of the above mentioned services. These EO Profiles enable the passing of parameters between Catalogue Search, Sensor Programming, Ordering, and Delivery service. The later is handled via the provided "*DescribeResultAccess*" operation. This operation is in charge of returning the URL of products ordered specifying on-line delivery e.g. using WCS. This will finally allow building complex service chains like: a WCS extract raw data from the archive, pass it to a rectification engine via a WCTS, and deliver the ortho-rectified product utilizing a WCS.

2.4.3.12 Summary

Reviewing the Spatial Data Infrastructure and Service needs of various initiatives and projects it has been found that more and more OGC web services are being proposed or used for service provisioning and data access. Due to the complexity of environmental algorithm developments, data fusion and information provisioning it seems that distributed web services, installed at the location of best expertise in combination with organisations which get funded to provide sustainable services could provide the high quality and reliability of the information needed.

With the application of OGC services the gap in the information provisioning chain is going to be closed from the satellite data provider to the value adder, but what is still missing in the chain is bridging the gap between the value adder and the information consumer/user.

CryoLand may follow the concepts applied by geoland2, SOSI, and others and to ensure the provisioning of widely interoperable interfaces which can be consumed by automated web services and user's applications alike.

2.4.4 *Metadata*

Since, for the proper functioning of INSPIRE, it is necessary for a user to be able to find spatial data sets and services and to establish whether they may be used and for what purpose, Member States should provide descriptions in the form of metadata for those spatial data sets and services. Such metadata should be compatible and usable in a Community and trans-boundary context.

The definition of a set of metadata elements is necessary in order to allow identification of the information resource for which metadata is created, its classification and identification of its geographic location and temporal reference, quality and validity, conformity with implementing rules on the interoperability of spatial data sets and services, constraints related to access and use, and organisation responsible for the resource. INSPIRE metadata profiles for datasets and services are profiles of ISO 19115 and ISO 19119. In the INSPIRE Metadata Regulation a minimum set of metadata elements are defined. It does not preclude the possibility for organisations to document the information resources more extensively with additional elements derived from international standards or working practices in their community of interest.

Implementation rules for the INSPIRE metadata is quite new and therefore were not taken into account in most of the documents reviewed in this user requirements study.

ISO standards have been recommended as metadata standards. To maintain interoperability between data and metadata centres, adherence to the ISO 19115 and ISO 19139 standards is seen essential (IGOS Cryosphere Theme 2007). In addition, participants in WIS (WMO Information System) and GEOSS use the ISO 19115 metadata content standard for geographical information (GCOS-138).

According to IGOS, in addition to the ISO 19115 standard, all metadata should also conform to the WMO Core Metadata Profile, to the CEOS-IDN guidelines, and to the GEOSS interoperability specifications. The use of WMO metadata profile was recommended also by the GLOBSNOW project: "*The format of data and corresponding metadata of all provided products shall comply as far as possible to the IPY recommendations and the WMO metadata requirements: IPY data standards and profiles (ipydis.org), WMO Core Metadata Profile (wis.wmo.int)*" (GLOBSNOW 2009).

2.4.5 *Data policy*

INSPIRE directive encourages to share spatial data free of charge. INSPIRE data policy principles are:

- Member States shall adopt measures for the sharing of data and services between public authorities for public tasks relating to the environment without restrictions occurring at the point of use.
- Public authorities may charge, license each other and Community institutions provided this does not create an obstacle to sharing.
- When spatial data or services are provided to Community institutions for reporting obligations under law relating to the environment then this will not be subject to charging.

Most of the documents reviewed have adopted the idea of free data policy. Most of the products should be free of charge for all relevant users. However, tailored products for customers like industry would be chargeable. (Outline of a Technical Solution to a Global Cryospheric Climate Monitoring System 2006, GLOBSNOW 2009, GCOS-107 2006).

3. USER SURVEY

This chapter summarizes the design of the user questionnaire. It also presents the analysis of the requirements for snow, glacier and land / ice products and services based on the responses completed user survey. The requirements were updated from the preliminary URD version 1 that was delivered in August 2011.

3.1 Design of questionnaire

A questionnaire was designed based on experience from previous projects. The partners in CryoLand refined the questionnaire several times to assure that the questions covered all aspects of the project. The questionnaire was organized in six sections.

Section 1 – General Information asks for information on the user, including contact person, address, type of organisation, and which group of products they are interested in (snow, glacier, lake and river ice).

Section 2 – Snow and Land Ice Products used by the organisation asks for the present status of using snow and ice information in the organisation and if yes what the source of the information is.

Section 3, Section 4 and Section 5 deal with the *requirements for snow, glacier and lake ice products*, respectively. Among others spatial resolution, latency time for product delivery, frequency of the products, and map projections are asked. Additionally the users are asked to specify the area of interest for the products.

Section 6 asks for technical information on service interfaces and services itself. The questionnaire closes with the question if users are joining the user group.

3.1.1 User group

The Cryoland user group includes about 60 organisations from 11 counties in Europe, and Greenland (Status 15 May 2012), operating in very different application fields.

3.1.2 *Web questionnaire*

The questionnaire was implemented as a web-questionnaire in the software tool *Enalyzer* (www.enalyzer.com) available at the project partner NORUT. The questionnaire was designed in a hierarchical structure, enabling the selection of branches for the product classes snow, glacier and lake / rive ice products. This functionality allowed the user to specify the requirements only for the product class in which he is interested and saved time to complete the survey. The implemented questionnaire was tested thoroughly in the most common internet browsers (IE, Firefox and Chrome).

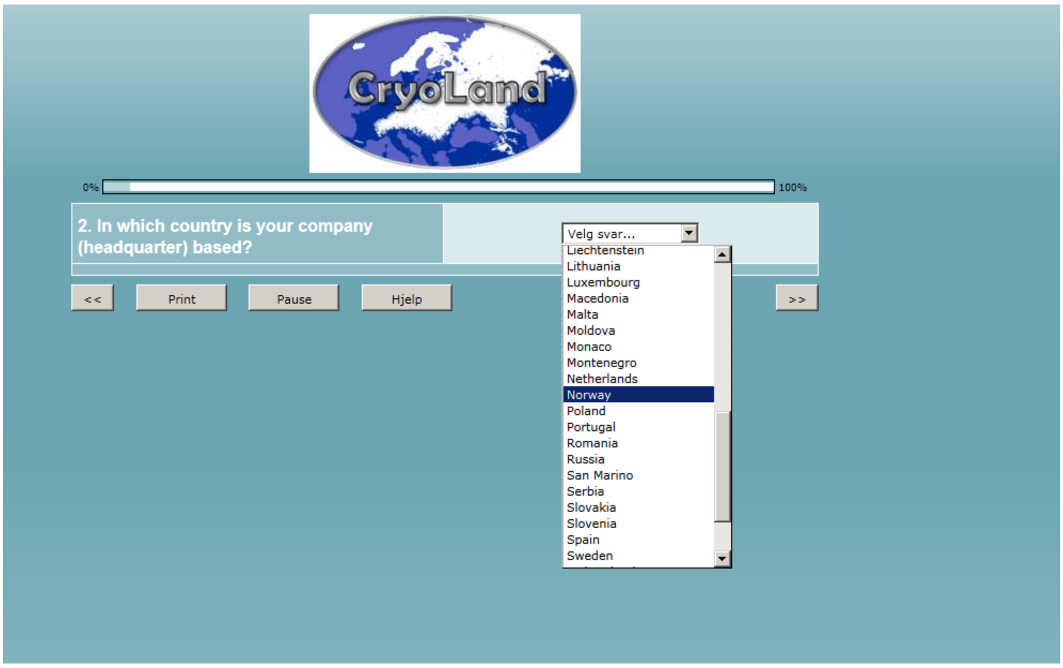

Figure 3.1: Screenshot from one question in the user survey.

3.2 Implementation and realization of questionnaire

The questionnaire was launched on 6 June 2011 for the Alpine users and on 9 June 2011 for Nordic users. As a total 140 users were contacted to complete the questionnaire. When web-statistics was extracted on 23 June 2011 40 users had completed the questionnaire, and 18 users had partially completed the questionnaire. Currently, 60 users agreed to participate in the CryoLand user group. The results of all completed user questionnaires are presented in this report.

A majority of the users that were approached choose to answer the questionnaire. In general most users attending one of the User workshops also completed and submitted the questionnaire. Beside these users also other organisations which were approached, but were not able to participate at the workshops, submitted the survey.

3.3 Results from questionnaire

In this section a summary of the products, services and service interface requirements from the questionnaire is given. It is based on the results from the CryoLand questionnaire.

3.3.1 *Main findings from section 1 and section 2 (question 1 to 17)*

By 30 March 2012, 46 users had completed the questionnaire. The majority of responding users are from Austria, Norway and Sweden. Some users from Czech Rep., Denmark, Finland, Germany, Romania, Italy and Switzerland also responded.

A diversity of organization types were represented, but a majority (77 %) was national authorities.

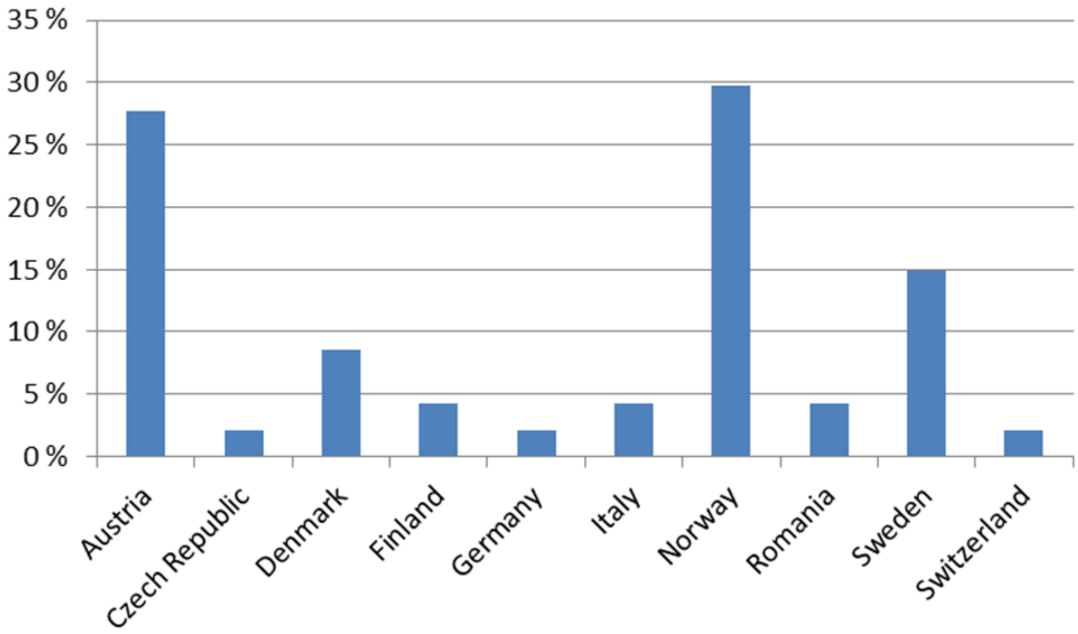

Figure 3.2: Countries represented in the questionnaire.

Related to the experience of the users with using satellite data for their applications:

- 78 % of the users have already experience with satellite products.
- 79 % indicated that snow and land ice information is important for their services.
- 85 % responded that snow products was important, around 24 % regarded lake ice and glacier products as important

About half of the users treat EO products manually, the remainder use EO data semi- or fully automatically.

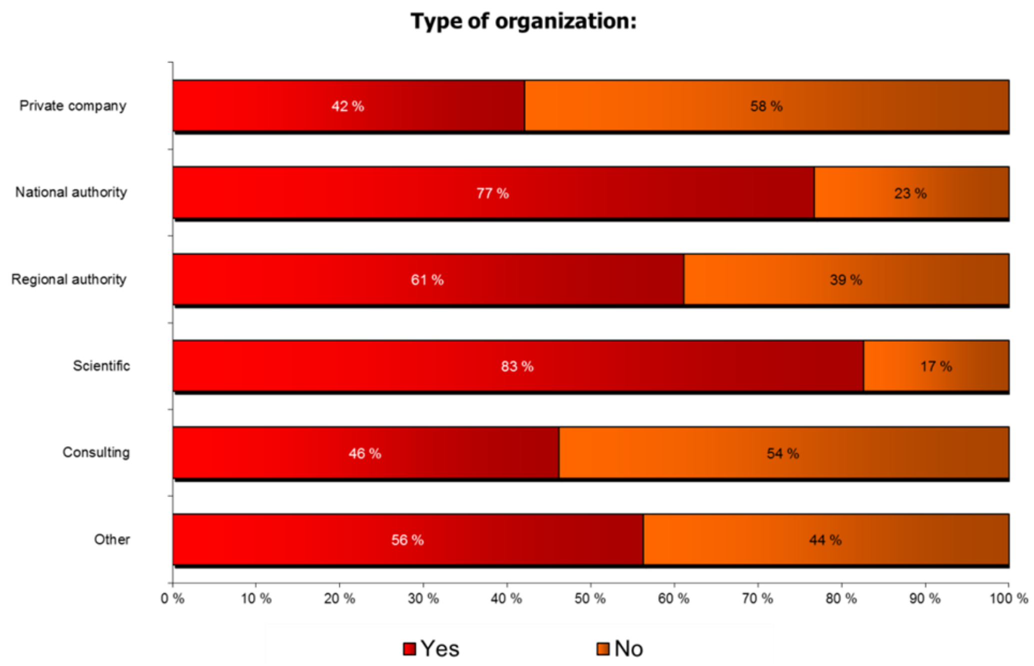

Figure 3.3: Types of organizations.

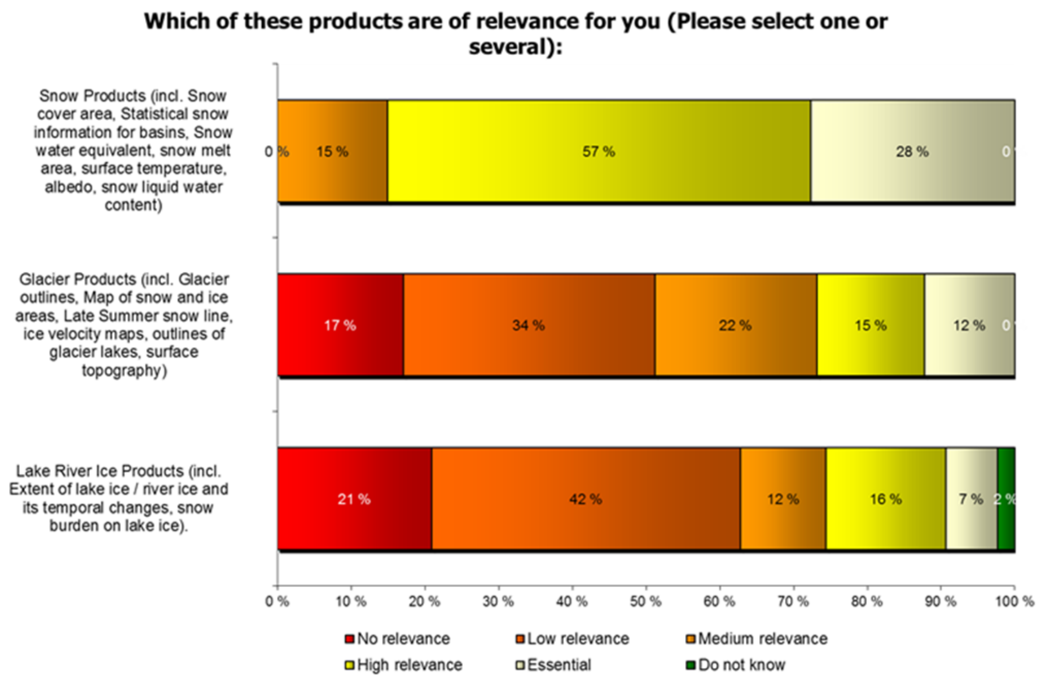

Figure 3.4: Overall need of snow, glacier and lake ice products for organisation.

The users provided a wide variety of final product types or services. The main sectors are: Avalanche and road mapping, hydrology and flood forecast, glaciology, weather forecast, vegetation research and climate research.

- A large majority (83 %) used in situ data as data source.
- 80 % thinks that the present solution partially fulfils the requirement of the organization.
- 62 % of the users spend less than 10k€ on snow and land ice products today.

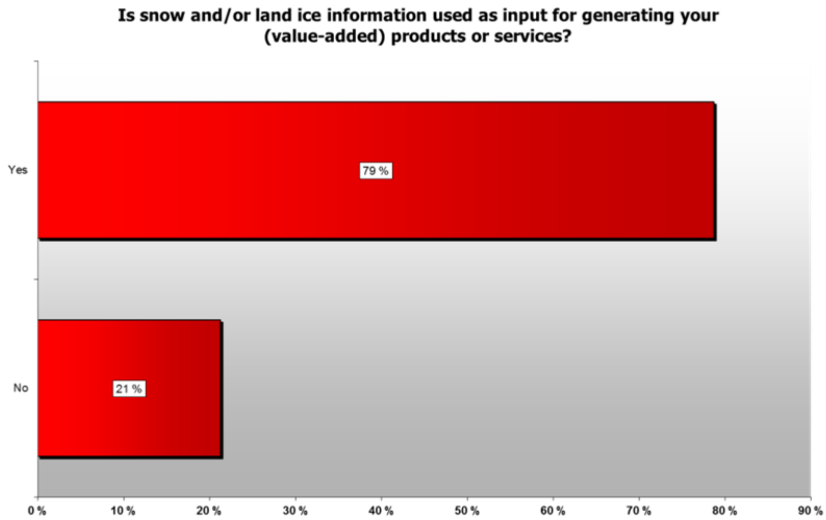

Figure 3.5: Is snow or land ice information generating value-added products or services.

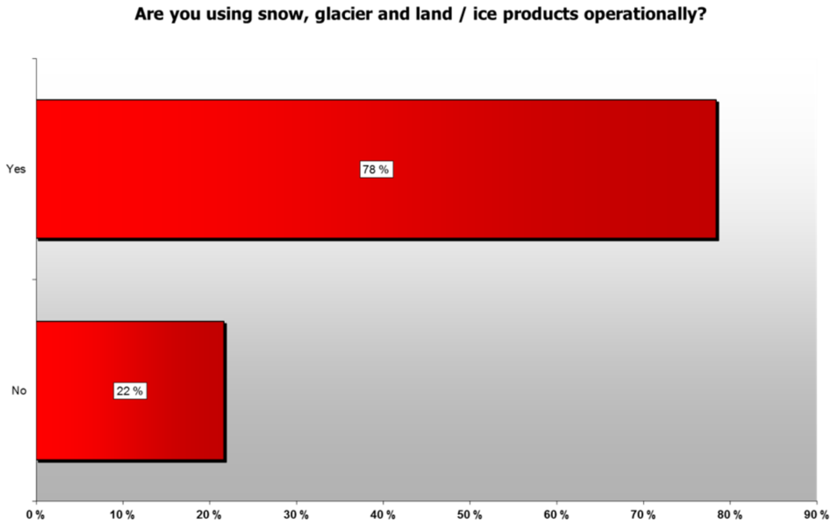

Figure 3.6: Operational use of snow, glacier and ice products.

3.3.2 *Main findings from section 3 - snow products (question 18 to 27)*

The main findings from the snow section are:

- 91 % of the responders were interested in snow products.
- Most users (84 %) regarded the snow cover product as important, the low resolution SWE product was ranked high by 55 %, whereas the other had ratings between 34-46 % ranked in descending order: Melting snow, statistical snow extent, surface wetness, albedo maps, snow surface temperature.
- Most users need snow product as a full year service, but regard fall/winter/spring as more important than summer. The fall season is ranked almost as important as spring for several products.
- The majority of responders indicate that all products should be provided on a daily basis.
- A majority need a latency time smaller than 12 hours, 31 % shorter than 6 hours.

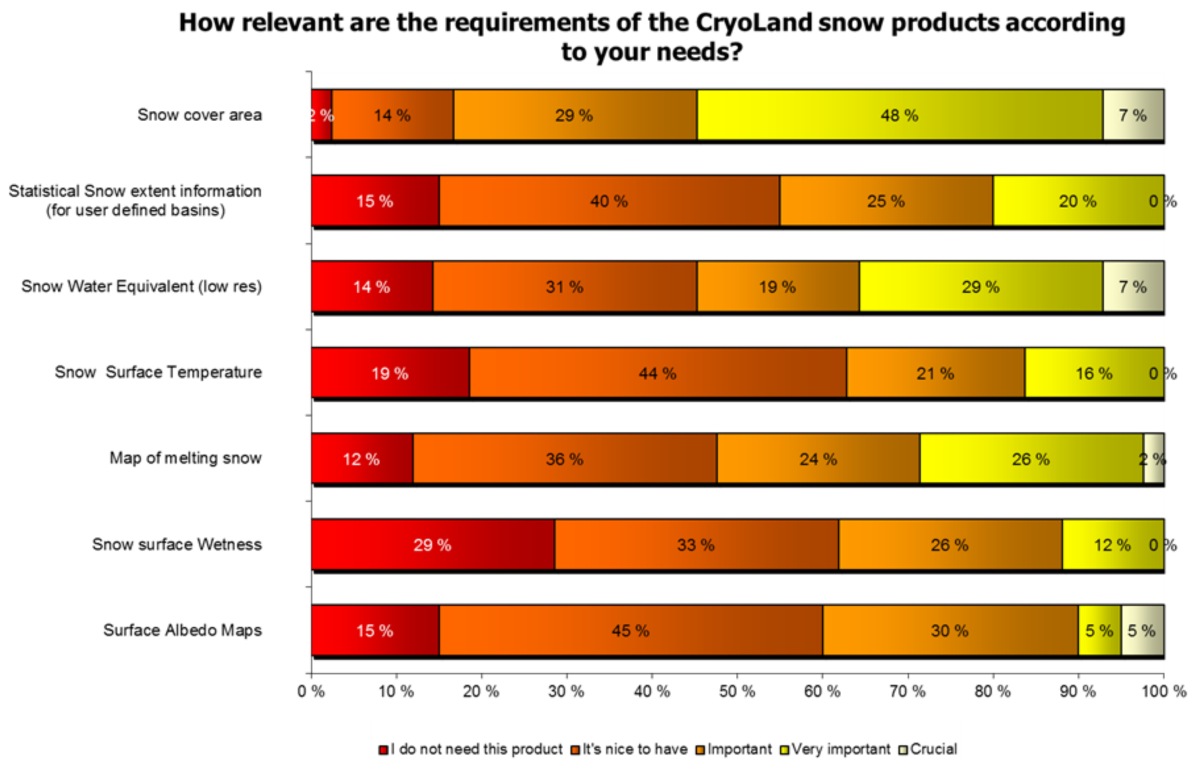

Figure 3.7: Relevance of specific snow products.

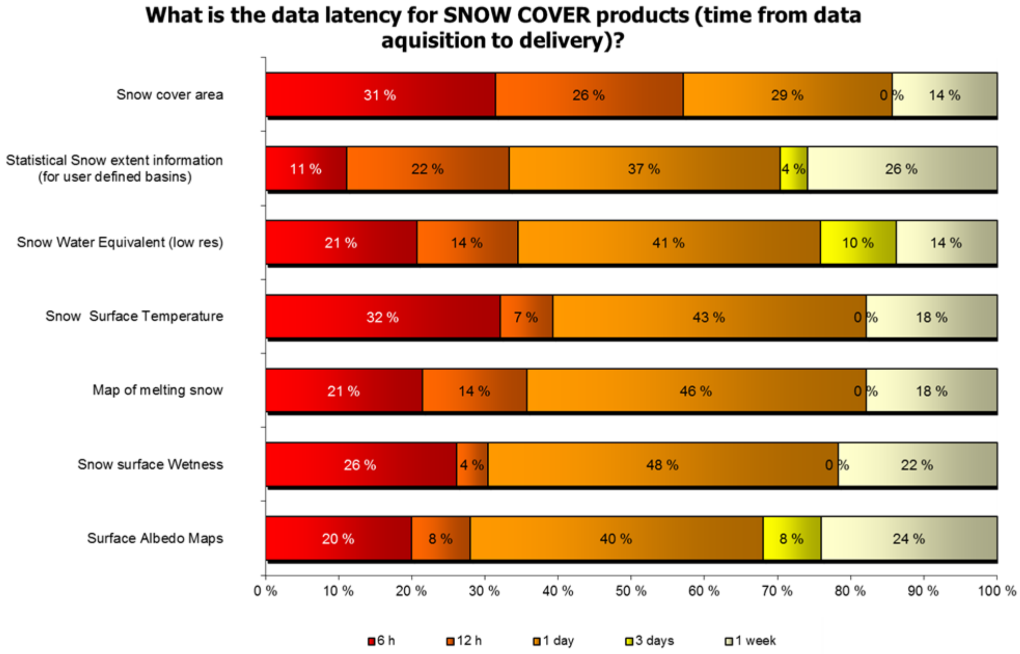

Figure 3.8: Latency for Snow products.

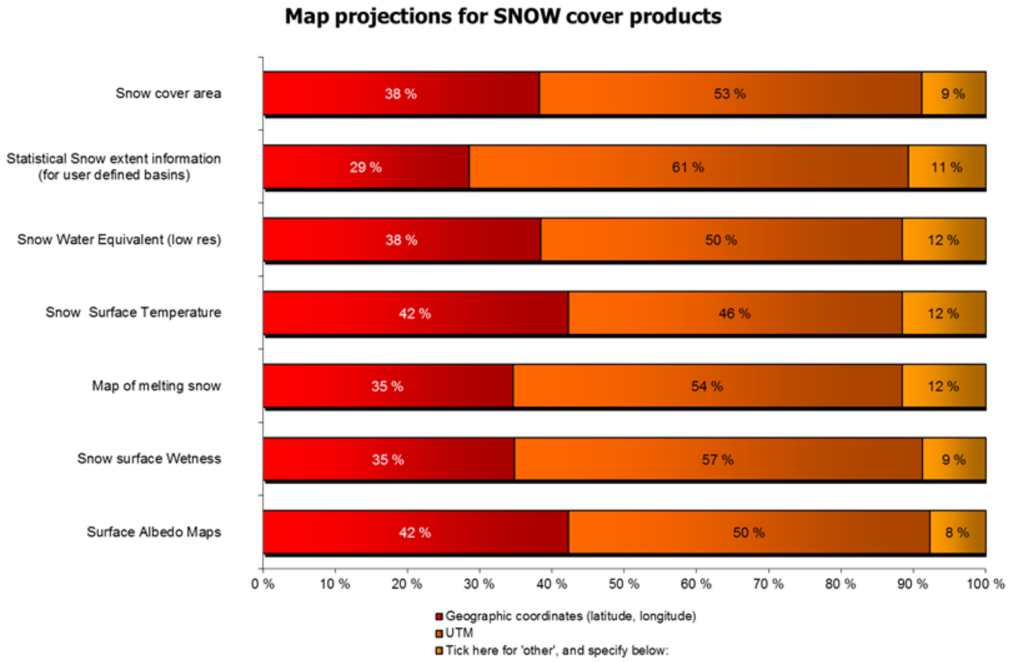

Figure 3.9: Map projections for snow products.

The requirements for spatial resolution are diverse. Most users can use products with 250 m resolution. Some users, like avalanche and road users need at least 50 m resolution.

The bulk of users ask for products over Alps including Romania and in the Nordic countries, also a Pan-European snow product is relevant for some users.

The majority of responders (53 %) preferred UTM projections. The remainder preferred geographic coordinates (38 %) or other projections (10 %), like the Lambert, European Equal Area.

In the free text field several users asked for a snow product that used spatial or temporal interpolation techniques to reduce cloud cover.

3.3.3 *Main findings from section 4 – glacier products (question 28 to 37)*

The main findings from the glacier section are:

- 36 % were interested in glacier products
- 88 % regarded the glacier outline product as most relevant,
- the other products had ratings between 80 - 50 % in descending order:
- summer snow line,
- snow/ice maps,
- glacier dammed lakes,
- ice velocity fields.

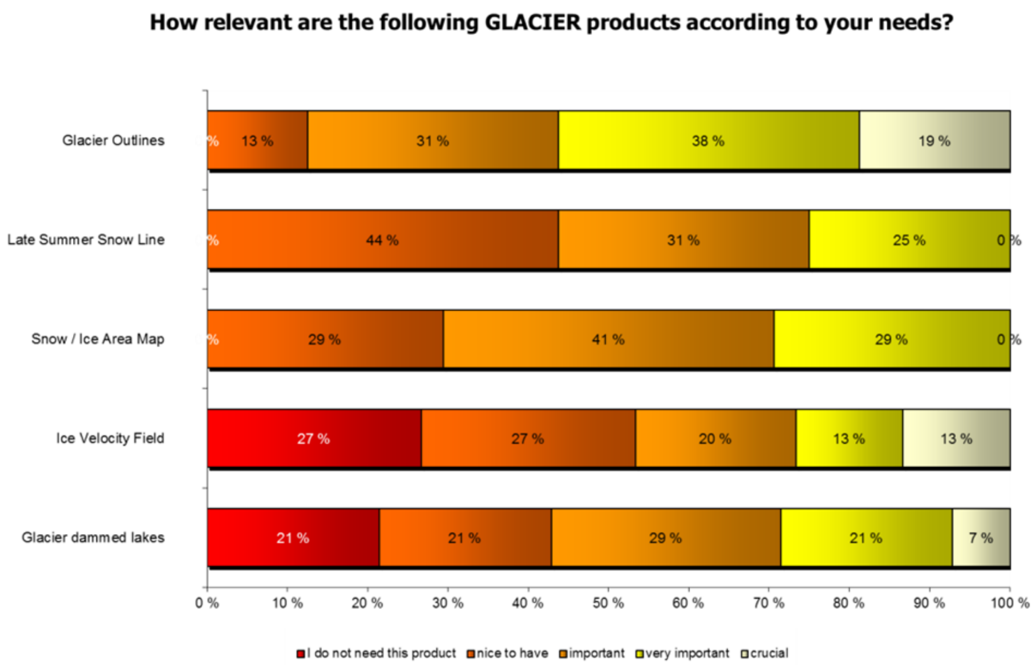

Figure 3.10: Relevance of glacier products.

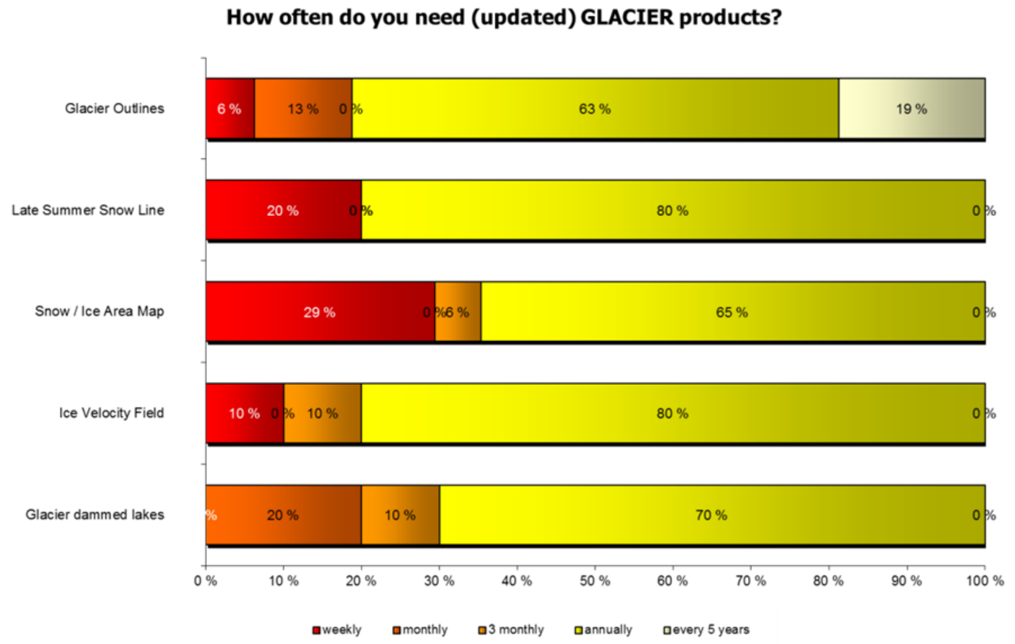

Figure 3.11: Latency for glacier products.

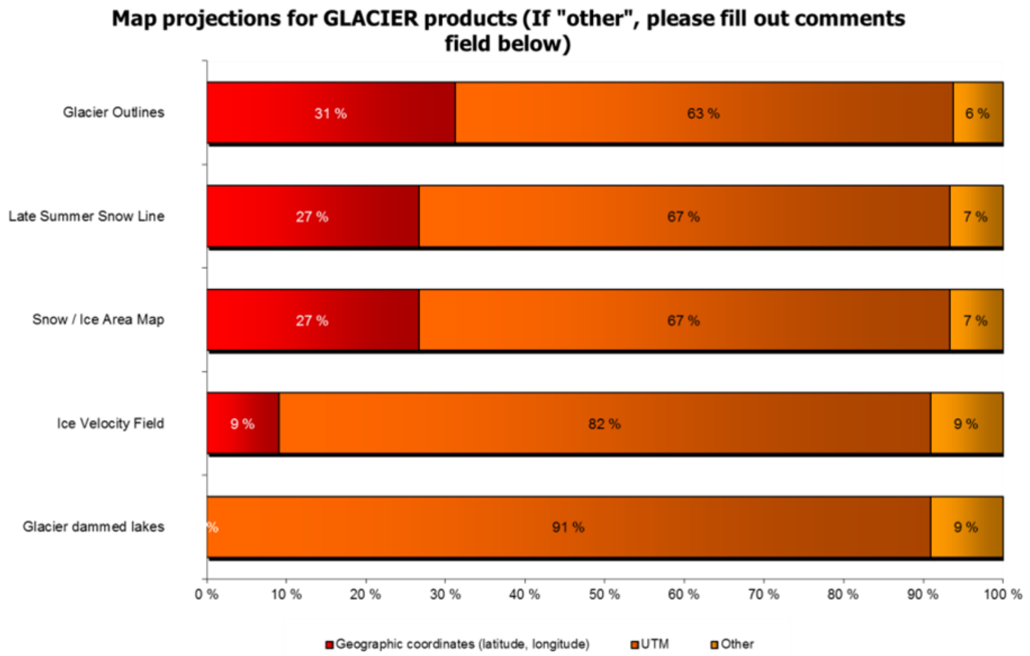

Figure 3.12: Map projections for glacier products.

- 90 % regarded the summer time as most important, other periods are rated significantly lower.
- Most users need annual updates of the glacier products.

- Latency: A majority (63 %) needed the data within 3 months.
- All glacier products are desired at relatively high spatial resolution (10 m - 25 m) by a majority of the responders.
- A majority of the users (63 -91%, depending on product type) preferred UTM projection.
- A majority of the users were interested in glacier products from the Alps and Scandinavia including Svalbard. Greenland is also mentioned. Among individual comments one user required other products (snow/ice melting and mass balance). Also a note on overlap with GLIMS should be noted.

3.3.4 *Main findings from section 5 – lake / river ice products (question 38 to 47)*

The main findings from the lake ice section are:

- 28 % of the users are interested in lake ice products.
- 84 % merited the lake and river ice extent product as important, first and last day of ice were rated high by 66 % and snow burden was regarded important by 13 % of the users.
- Temporal resolution: Scattered requirements, but the majority of users need lake ice products every 2-3 days or more frequent.
- Latency Time: Scattered requirements. A few need near-realtime data (ice jams), others need daily data. Some users require data annually.
- 33 % of the users are interested in data with high resolution (25 m), 33 % needed data with medium resolution (100 m) and the remainder needed data with less than 1 km resolution.
- The preferred map projection for lake ice products as specified by the users is geographical coordinates (Latitude, Longitude).
- Regions of interest: users in Scandinavia have a general interest on lake / river ice products. But there is also some interest from users in mid-latitudes.

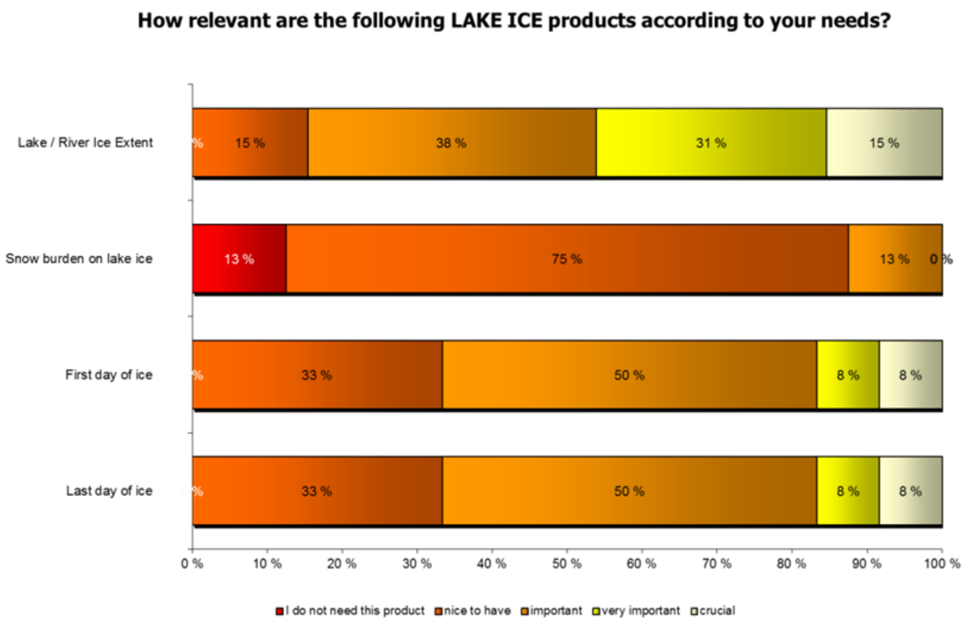

Figure 3.13: Relevance of specific lake ice products.

3.3.5 *Main findings from section 6 – services (question 48 to 56)*

The main findings from the user service section are (see Figure 3.14 Figure 3.20):

- Data format: 77 % require GEOTIFF raster files.
- Preferred vector file format is shape file (66 %).
- 94 % preferred to discover CryoLand products in a Web-GUI.
- 76 % preferred to view products in a Web-GUI, 61 % also wanted to view in CryoLand OpenGIS map service.
- The most favoured downloading methods seem to be FTP (73 %). Using OpenGIS web feature service (WFS) is also of high interest (46 %). 27 % of the users also ask for a locally installable client for batch downloads and subscription. WCS seems to be not well enough known.
- 62 % wanted to use the CryoLand Web-GUI to invoke processing services offered by CryoLand.
- 50 % preferred upload of reference data using WFS-T as a necessary option for data upload. 46 % liked the idea of uploading files utilising the CryoLand Web-GUI.
- ESRI ARC GIS is the dominating software system in use, with OpenSource tools being the second largest group.

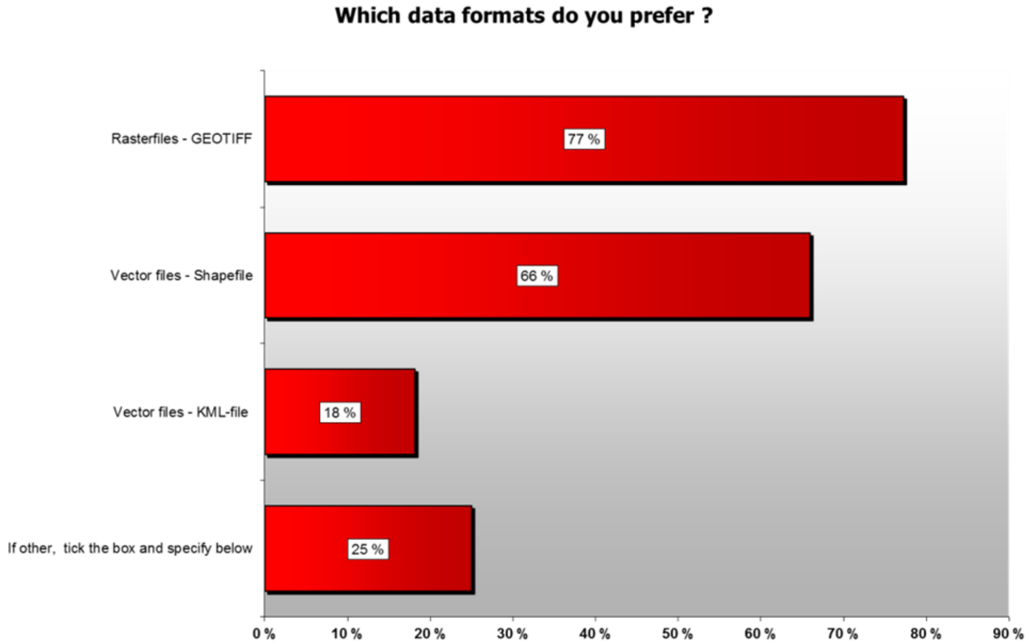

Figure 3.14: Preferred data formats.

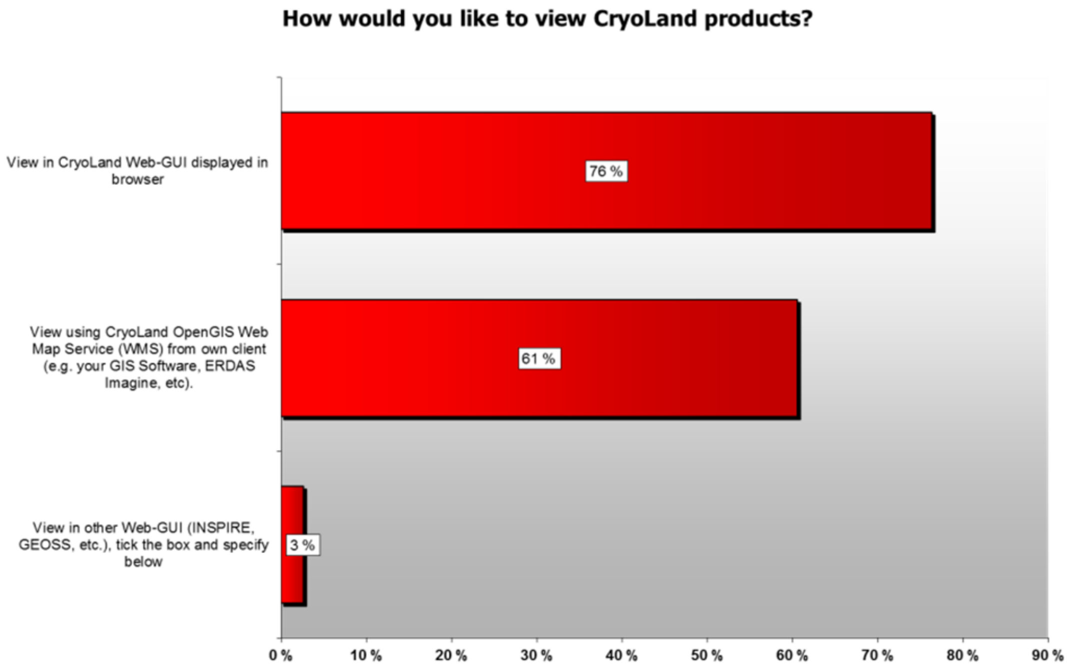

Figure 3.15: Preferred way to view CryoLand Products.

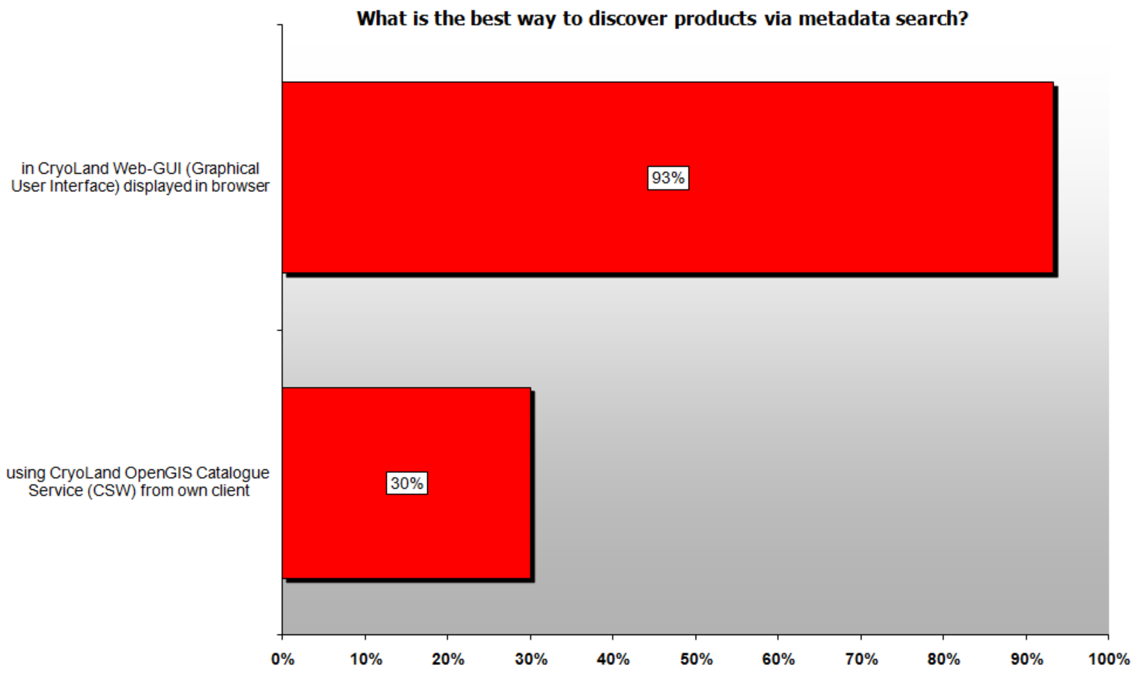

Figure 3.16: Preferred way to discover products via metadata search.

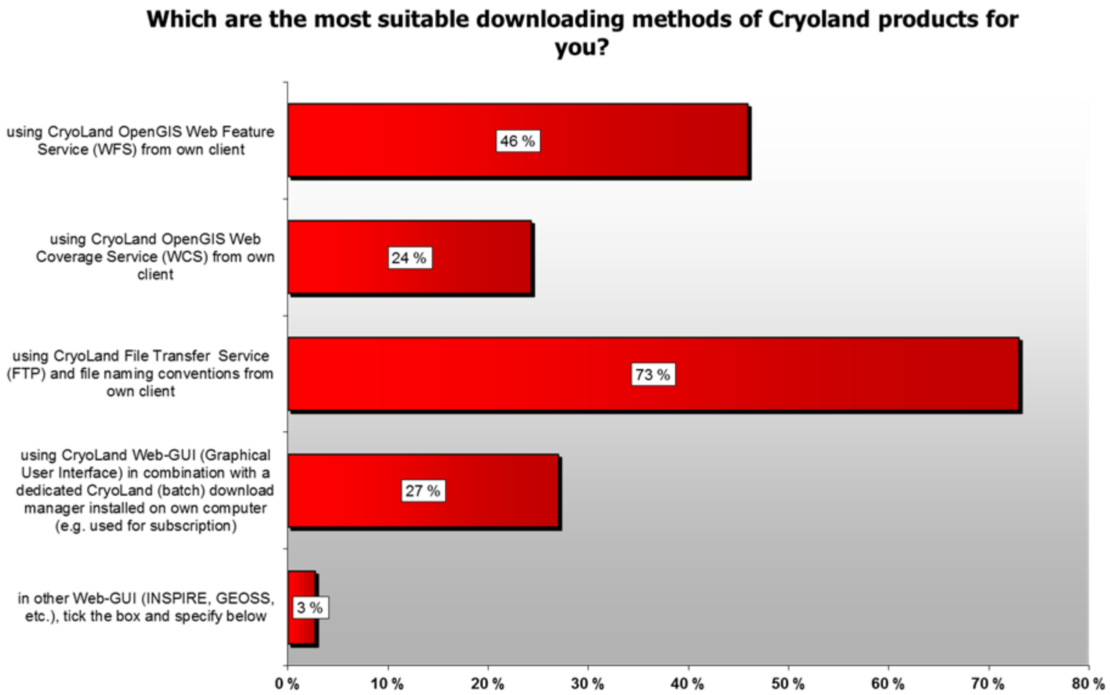

Figure 3.17: Preferred way to download CryoLand Products.

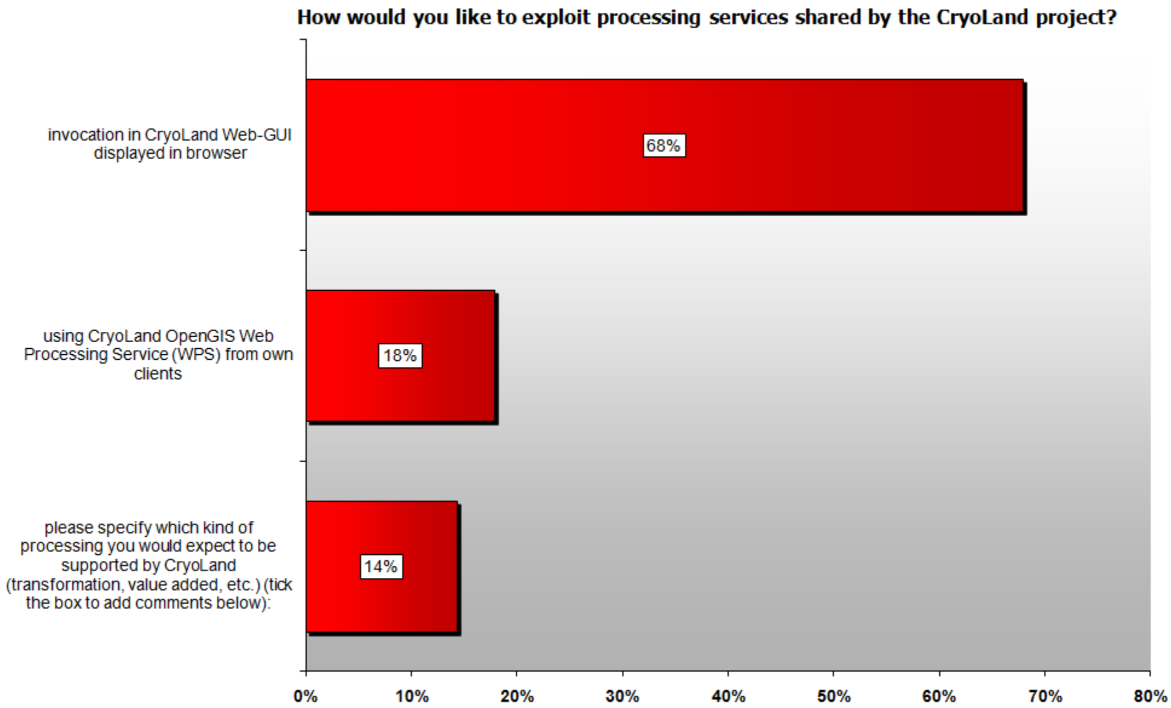

Figure 3.18: Exploit processing services shared by CryoLand products.

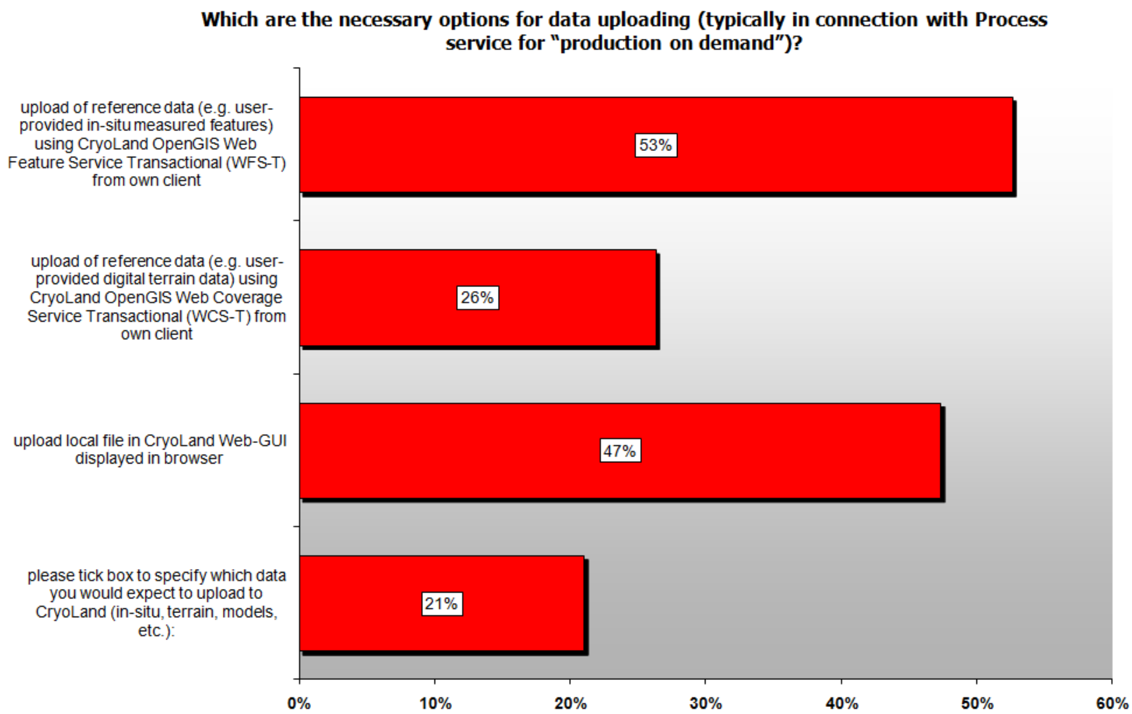

Figure 3.19: Preferred uploading methods.

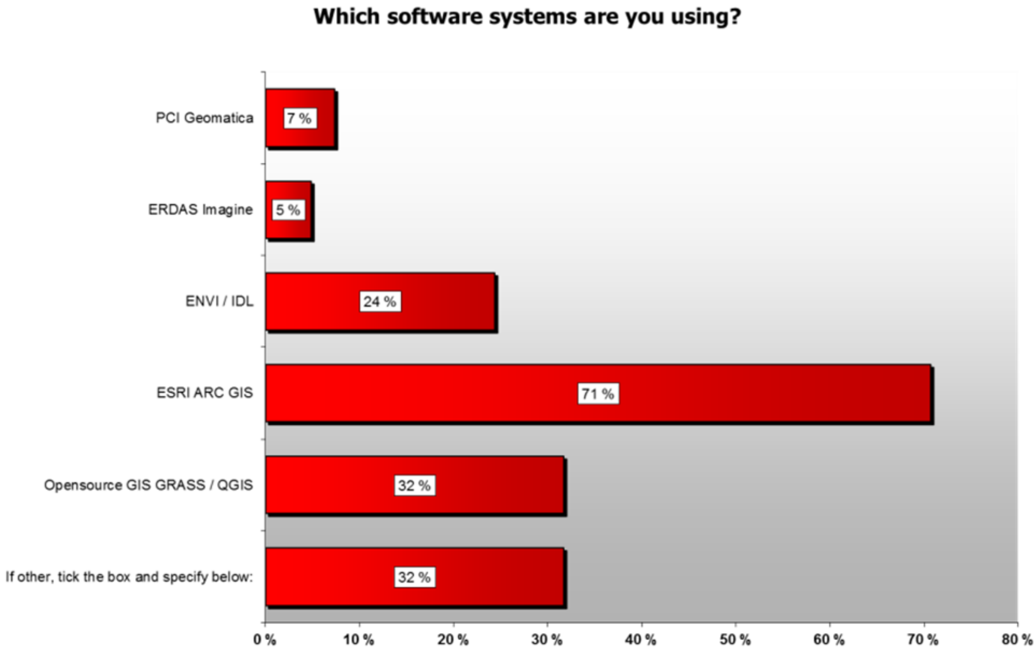

Figure 3.20: Software systems used by users.

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4. SYNTHESIS OF REQUIREMENTS, DISCUSSION AND CONCLUSION

4.1 Methodology

In this section we use the inputs from the CryoLand user survey together with recommendations from previous projects and inputs from the user workshops and user consultation meetings to draw conclusions about the priority for implementation of snow glaciers and lake / river ice products in CryoLand, and the targeted specifications the various products.

The analysis below takes into account the user requests on one hand and on the other hand also the available EO data and status of retrieval algorithms and processing lines for the different products of the CryoLand product portfolio. Based on discussion within the frame of the user workshops it was proposed to group the baseline CryoLand products into 3 categories depending on their level of maturity. The product categories are (Minutes from CryoLand internal meeting in Oslo, June 8, 2011):

1. Category 1: operational products
2. Category 2: pilot products (emerging towards operational products)
3. Category 3: experimental products (demonstration products).

Category 1 products are characterized by mature retrieval algorithms, available processing lines, and some knowledge on accuracy of the product. Most resources in the CryoLand project should go into improvement, further validation and implementation of Category 1 products (adaptation to CryoLand Product Format supporting INSPIRE, etc.). Category 2 products have less tested and validated algorithms and processing lines, and require more R&D resources. Within CryoLand it is planned to further develop selected Category 2 products towards operational level. Experimental products (Category 3) are important as they might be important products in the near future. CryoLand, with its GMES downstream focus, is however not able to put significant resources into R&D for this category, but the project will provide test samples to discuss these future products with the users.

4.2 Product ranking by users

Based on the user survey, personal discussions with CryoLand users and the CryoLand user coordination meeting held in Stockholm in May 2012 the priority for implementation of the CryoLand products by users was discussed and outlined. Table 4.1 shows the product ranking by users which has been derived from the percentage of users that indicated that the individual products were important or higher merited. In order to simplify we categorized it into high (1), medium (2), low (3)

Table 4.1:
User ranking of CryoLand products: high (1), medium (2), low(3). Note: The last 3 rows lists products which were not part of the user survey.

	Ranking	
Product type	**Order**	**Vote in % of users interested in the product**
Snow extent, regional in Nordic and Alps	1	83%
Snow extent, pan-European	1	83%
Snow Water Equivalent (Low res)	1	55%
Melting snow area	2	52%
Statistical snow Information	2	45%
Snow Surface Temperature	3	37%
Snow Surface Wetness	3	38%
Spectral Surface Albedo	3	40%
Glacier outlines	1	88%
Snow/ice area on glaciers	2	71%
Glacier lakes	2	57%
Ice velocity	3	47%
Ice extent and ice concentration	1	85%
First and last ice cover	2	67%
Snow covered area on lake ice	3	13%
River ice jam and flood inundation area	3	NA
Lake surface temperature	3	NA
Snow depth on lake ice	3	NA

4.3 Map projection

UTM and Geographic Latitude and Longitude coordinates are the projections voted by the users. Users prefer products in UTM projection for local and regional products. For large scale and continental products, like products covering the pan-European area WGS-84 geographical latitude/longitude-projection is wanted, which has also the advantage for easy integration with digital map tools like Google Earth.

The primary map projections wanted by users are

- UTM projection for local and regional products
- WGS-84, geographical coordinates (latitude, longitude), and / or
- Optionally, the European-wide projection ETRS-LCC and ETRS-LAEA for pan-European products

Additionally, some organisations asked for regional products in national map projections (e.g. Lambert EA Austria). This can be provided on demand by re-projection of the product from geographical coordinates (on-demand map projection transformation).

4.4 Area coverage

Based on the user inputs, a map was created that shows where the users were interested in snow, glacier and lake ice products. The map shows that there are two large concentrations of area of interests of users, in the Nordic countries and in the Alps. A few “out layers” can also be found at Greenland, Svalbard and Iceland.

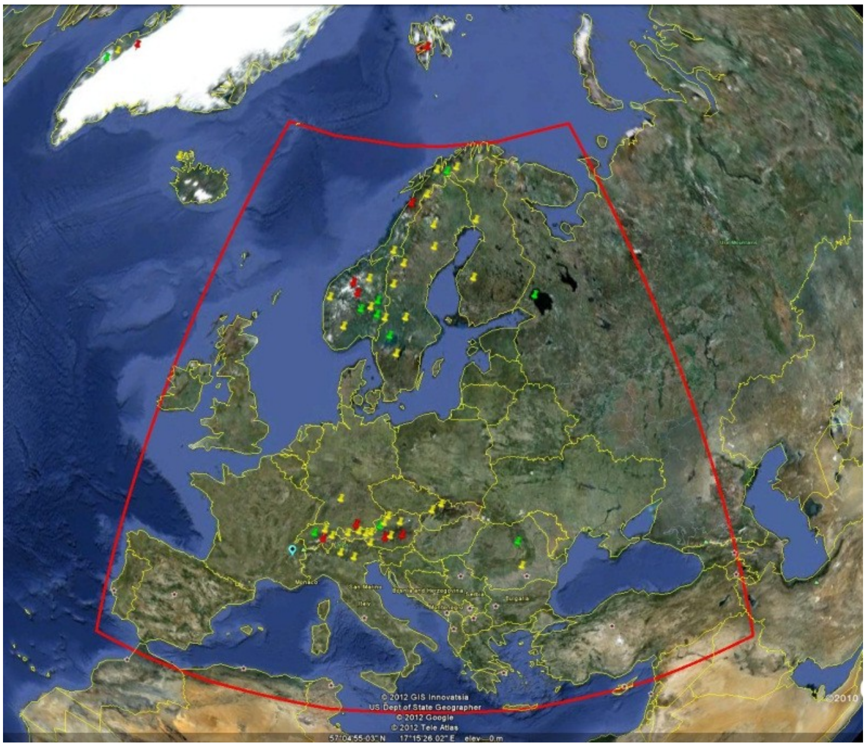

Figure 4.1: Map of Europe showing marks where users have indicated a need for snow products (yellow), glacier products (red) and lake ice products (green). Additionally, a pan-European product (covering EC countries where snow is relevant) is requested by users. The selected coverage area for the pan-European snow service is shown with a red polygon.

There is also a considerable interest for pan-European products (covering EC countries, where snow is relevant) from several users. Based on the maturity of services and the amount of interest it is clear that the snow cover fraction/extend service and the low resolution snow water equivalent service should be delivered as pan-European services. The coverage (see Figure 4.1) of the two products will be a common pan-European grid (approx. 35N / 10W – 71N / 45E).

The regional snow extent services in the Nordic and Alpine countries will be limited in coverage and partly overlapping (Finnish/Norwegian services). Lake ice and glacier services will be tied to certain lakes/rivers and glaciers where users clearly have indicated interest.

4.5 Spatial resolution and temporal resolution

Based on user requests and considerations with respect to available sensors and level of maturity we recommend the following spatial resolutions for the various products in the portfolio.

Table 4.2:
Spatial and temporal resolution of products.

Product type	Spatial resolution, m	EO sensors	Temporal resolution
Snow extent, regional in Nordic and Alps	250 – 500 m	MODIS, ASAR (archived), Sentinel S1, S3	Daily, full year
Snow extent (local)	25 – 50 m	Landsat, Sentinel S2	Monthly, full year
Snow extent, pan-European	250 – 1000 m	MODIS, Sentinel S1, S3	Daily, full year
Snow Water Equivalent (Low res)	10 – 25 km	SSMI/S, AMSR2	Daily, dry snow season
Melting snow area	25 – 100 m	ASAR (archived), Sentinel S1, S3	Daily, Spring/Summer/Fall/Winter
Snow Surface Wetness	1000 m	MODIS, Sentinel S3	Daily
Statistical snow Information	HRU/basin	NA	Daily
Spectral Surface Albedo	250 – 500 m	MODIS, Sentinel S3	Daily
Snow Surface Temperature	1000 m	MODIS, Sentinel S3	Daily
Glacier outlines	10 – 25 m	SPOT, Landsat, Ikonos, Sentinel S2	Annually
Snow/ice area on glaciers	< 25 m	ASAR (archived), TerraSAR-X, Landsat TM, SPOT, Sentinel S2	Annually
Glacier Ice velocity	10 – 25 m	TerraSAR-X, Sentinel S1	Annually
Glacier lakes	10 – 25 m	TerraSAR-X, Sentinel S1	Annually, weekly (fast analysis), hours (emergency)
Ice extent and ice concentration	100 m	MODIS, ASAR (archived), TerraSAR-X, Sentinel S1, S3	Daily, October-May
Snow covered area on lake ice	250 m	MODIS, Sentinel S1	Daily
Snow Surface Temperature	1000 m	MODIS, Sentinel S3	Daily
First and last day of ice cover	100 m	MODIS, ASAR (archived), TerraSAR-X, Sentinel S1, S3	Annually
River ice jam, flood inundation area	30 m	ASAR (archived), TerraSAR-X	Daily (emergency)
Lake surface temperature	500 m	MODIS, Sentinel S3	Daily
Snow depth on lake ice	25 km	SSMI/S, AMSR2	Daily

Based on the user requirements it seems clear that the main snow products are required for the whole year for a majority of the users. This requirement is relatively tough to fulfil since the cost (both in terms of acquisition of satellite data and in terms of human resources that must operate the services) increase by extending the period from typically 4 months (spring melting) to 12 months. In addition to this there are also challenges with respect to the product maturity, at least when the requirement is that the product should be pan-European.

The Nordic snow products rely on the availability of optical data. During the winter months large fraction of the Nordic countries cannot be mapped with optical sensors due to less illumination. SAR can be used to some extent if the snow is wet, but this is not typically the case.

As an alternative, we recommend that the low-resolution SWE-product from passive MW data is blended with the snow cover product in those areas where snow cover information is unavailable.

The SWE product is currently produced daily in the Northern hemisphere within the ESA GlobSnow project. A daily pan-European low resolution SWE product (maybe with improvements) is of interest.

The user requirements for temporal resolution have to be met by the actual availability of sensors. Since the project mainly deals with polar orbiting satellites, the lower limit for temporal resolution is basically daily for the medium resolution optical and passive microwave sensors. Sentinel-1 will have less frequent resolution, but depending on the latitude in Europe, we can expect products 1-2 times per week for Sentinel-1. High resolution optical sensors have lower temporal resolution. Envisat ASAR failed in April 2012. The generation of products based on this sensor will continue when Sentinel-1 has been launched.

4.6 Service requirements

In this section we summarise the requirements for services and service interfaces specified by the users. 3 categories for the services implementation are specified:

1. Operational services
2. Pilot services (emerging operational products; undergoing full validation)
3. Experimental services (demonstration products, limited validation)

For the CryoLand spatial data infrastructure the services listed below are proposed to be implemented. The selection is based on the input of respective users, requirements derived from other projects, and for interoperability and data exchange reasons required by global or European programs like INSPIRE, GEOSS, GLIMS.

1. Discover (Products and Services)
    - at the CryoLand Web GeoPortal

   - via a CryoLand Catalogue Service for the Web (CSW) The implementation of this service needs to be re-evaluated since the WCS/EO-WCS service requests "*DescribeCoverage*" and "*DescribeEOCoverageSet*" also provide information about the available datasets (Name, BoundingBox, Time). In addition the User survey showed the most interest for Data Discovery via the CryoLand Web-Portal. Nevertheless, the requirements of INSPIRE need to be considered.

2. View
   - at CryoLand Web GeoPortal
   - via WMS (direct access)
3. Download
   - via FTP or HTTP
   - via WFS (direct access)
   - From CryoLand GeoPortal (WCS and WFS)
   - via WCS (direct access)

The following two services have received quite some interest in the user surveys. This was not anticipated and therefore further user consultations should be performed. However, in both cases more discussion and an exact definition of the requirements are needed in order to provide the respective services. Due to the complex nature of the various datasets further discussion, which data might be relevant for data upload and especially a detailed definition of the corresponding data model(s) for the datasets to be uploaded, is required, before such a service can be provided.

Before implementing an invocation service an evaluation and exact definition which predefined "processing tools/chains" or which general types of processing algorithms are requested to be invoked/triggered by the respective users, need to take place.

4. Upload (vector data, e.g. AOI, municipal boundaries, roads, etc.) and raster data (e.g. DEM, land use masks)
   - WFS-T (direct access)
   - via CryoLand Web GeoPortal
5. Invoke processing
   - via CryoLand Web GeoPortal
   - WPS (direct invocation)

The invocation of processing also requires additional computing resources at the service provider side. Since especially geo-procession algorithms frequently are quite resource intensive the provisioning of such a service might be limited and based on special contracts (e.g. certain users).

The listed services represent only services visible to external users. Additional services (e.g. WCS-T) might be implemented for CryoLand internal use e.g. if required for data exchange or product generation (service chaining).

4.7 Requirement traceability matrix

In this section we resume the synthesis of requirement by deriving feasible and achievable products that fulfil the requirements for a majority of the users approached in WP 2 of the CryoLand project. The requirements are organized in two matrices in order to judge the current level of maturity of the various services and products, and to assess which services will be realized early in the project, or in a later stage.

4.7.1 *Requirements for snow and land ice products*

The land ice services were analysed in sections 0 - 4.5. Based on the various assessments we here define the following products in the requirement traceability matrix.

Table 4.3:
Requirements traceability matrix for snow and land ice products. (Status of sensor availability May 2012)

Req.	*User ID*	*Text*	*Feasible with sensors available for the project*	*Comply / non-comply*	*Alternative product*
1		Daily SCF, 250m spatial resolution, Regional products for Nordic countries and Alps including Romania, full year coverage	Yes	Yes	MOD L10 (NSIDC)
2		Daily Pan-European SCF product, 1km resolution, full year coverage	Yes	Yes	-
3		Daily Pan-European SWE map, 25 km resolution.	Yes	Yes	ESA GlobSnow

Req.	*User ID*	*Text*	*Feasible with sensors available for the project*	*Comply / non-comply*	*Alternative product*
4		Glacier outlines, annual updates for Alps, Greenland, Norway incl. Svalbard and Sweden	Yes	Yes	GLIMS
5		Lake ice extent, Nordic countries, 250 m spatial resolution	Yes	Partially	ESA North hydrology
6		Melting snow area based on SAR, regional product in Nordic and Alpine countries, 100 m resolution, full year	Partially, depending on availability of SAR (Sentinel-1)	Partially	Nordic snow product
7		Snow surface wetness based on optical sensors, regional product Nordic and Alpine countries, 1000 m resolution	Yes	Yes	
8		Snow/ice area on glaciers	Yes	Yes	
9		Snow covered area on lake ice	Yes	Yes	SYKE service (Finland)
10		Ice velocity, selected glaciers, high. res./annual updates	Yes	Yes	
11		Glacier lakes for selected lakes, high. res./annual updates	Yes	Yes	
12		Statistical snow Information for defined basins	Yes	Yes	
13		Spectral Surface Albedo	Yes	Yes	
14		First and last ice cover, annual updates	Yes	Yes	North Hydrology (Only Finland)
15		Snow Surface Temperature regional product Nordic and Alpine countries, 1000 m resolution	Yes	Yes	
		All products comply with INSPIRE and other standards	Yes	Yes	

4.7.2 *Requirements for the CryoLand service*

Section 4.6 analysed the various service requirements and recommended a feasible service that could be implemented. Based on this analysis we here define a requirement traceability matrix for the CryoLand service.

Table 4.4:
Requirements traceability matrix for web-map services.

Req.	***User ID***	***Text***	***Feasible with current technology***	***Comply / non-comply***	***Alternative service***
1		Web service for search of snow and land ice products	Yes	TBD	OGC EO-WCS DescribeCoverage/ Set requests
2		Web service for download of snow and land ice products	Yes	Yes	
3		Reprojection capabilities to other projections within the web service, single data set or data stack	Yes	Yes	local user tool
4		Data format in GeoTIFF	Yes	Yes	
5		Data format in shape	Yes	Yes	
6		Statistical snow Information (statistical parameters TBD)	Yes	Yes/ Partially	
7		Flexible storage system with automatically feeding of data from data producers (e.g. KSAT, SYKE) to the system	Yes	Yes	
8		Distributed nodes that produce snow and land ice products to the CryoLand Service	Yes	Yes	
9		Tools with simple WEB-GIS functionalities (to be specified)	Yes	partly	
10		OpenGIS Web Map Service (WMS)	Yes	Yes	
11		FTP download	Yes	No	File access via HTTP at Web site

Req.	*User ID*	*Text*	*Feasible with current technology*	*Comply / non-comply*	*Alternative service*
12		Open GIS web feature service	Yes	Yes	
13		Web GeoPortal to display results of services	Yes	Yes	
14		Possibility to upload reference data via WFS-T	Yes	Possible (data model TBD)	
15		Possibility to upload file in Web GeoPortal	Yes	Possible (data model TBD)	
16		Possibility to download other data formats (common GIS data formats, e.g. GDAL compliant	Yes	Yes / Partially (formats TBD)	

4.8 Conclusions

Based on the user inputs, user consultations, maturity of algorithms and available / near future EO sensors 15 snow and land ice products and 14 web-based services were identified and analysed. The products are organized in three categories, corresponding also to the implementation order of the products:

1. Category 1: Operational products
2. Category 2: Pilot products (emerging operational products; undergoing full validation).
3. Category 3: Experimental products (demonstration products, limited validation).

Most of the category 1 products are already in a mature state and are being delivered as products to the CryoLand web service. The category 2 pilot products are currently being investigated and selected products will be tested, validated and provided as services during the course of the CryoLand project. The category 3 products will be investigated, and depending on EO data and service maturity, and test samples will be provided to the users.

The CryoLand web-service is already operational as a test service. Many of the features requested by the users have already been implemented. At the current stage we focus on gaining experience, stream lining the service and providing additional features requested by the users as they get experience in the use of the service.

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6. APPENDIX A: RESULTS FROM USER REQUIREMENTS QUESTIONNAIRE

This review is based on the results from the CryoLand questionnaire dated March 29, 2012. The questionnaire was open summer of 2011 in order to get more responses from additional users. The number of responses increased from 40 to 47 in this period. The sections in this review are organized and numbered according to the outline of the questionnaire.

6.1 Number of responses

The total number of responses to the questionnaire was 47. 38 questionnaires were completed by 23 June 2011 (the deadline for Version 1 of the URD).

6.2 Nations

The table below shows the nationality of the users which responded to the questionnaire.

Table 6.1
User nationalities.

	Total	
In which country is your company (headquarter) based?	**Percentage**	**Number**
Austria	28 %	13
Czech Republic	2 %	1
Denmark	9 %	43
Finland	5 %	2
Germany	2 %	1
Italy	4%	2
Norway	30 %	14
Romania	4 %	2
Sweden	15 %	7
Switzerland	2 %	1
Total	***100 %***	***47***

6.3 Type of organization

The types of organizations are given below. Some users selected more than one answer.

Table 6.2:
Type of organizations.

	Total	
Type of organization:	**Percentage**	**Number**
Private company	40 %	19
National authority	64 %	30
Regional authority	38 %	18
Scientific	49 %	23
Consulting	28 %	13
Other	34 %	16
Total	100 %	119

- 38 estimates for the number of employees were provided.
- The numbers ranged from 1 to 5000.
- The mean number of employees was: 404
- The median number of employees was: 195

6.4 Already using satellite based products/services

The users were used if they already are using satellite based products or services.

- 80 % of the user organisations are already using satellite products.

6.5 Which of these products are of relevance for you

29 users responded to this question.

- 86 % responded that snow products were of high or essential relevance.
- 27 % responded that lake ice products were of high or essential relevance.
- 23 % responded that glacier products were of high or essential relevance.
- A majority of the users regard snow products as highly relevant for their application.
- Users interested in glacier and the lake / river ice products are almost equal in size and preference.

The figure below shows the preferences of the different users.

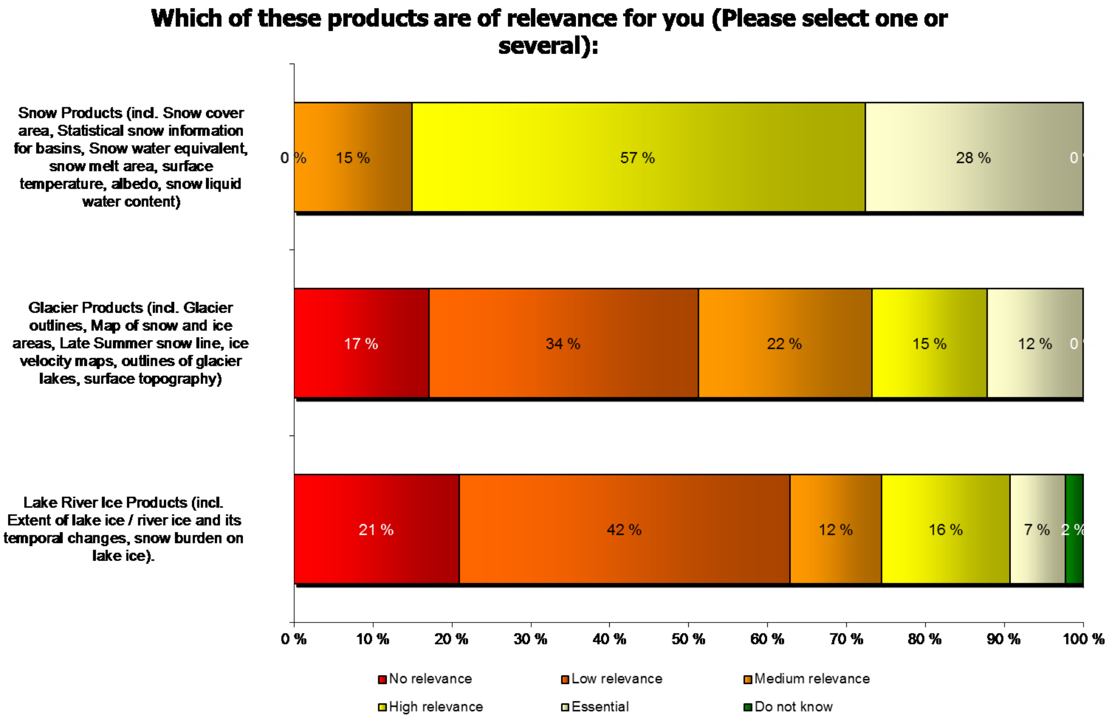

Figure 6.1: Relevance of snow, glacier and lake ice products.

6.6 Is snow and/or land ice info used as input for generating your (value-added) products or services?

79 % of the user organisations use snow and/or land ice products as input for generating their products and services.

6.6.1 *Which products are you using*

36 users responded to this question. The individual answers are provided below:

- Snow height measurements, snow surface temperature, from station data.
- Snow cover and SWE / raster maps.
- Satellite-based snow products / in-situ snow measurements.
- (Seasonal) Snow cover area, Extent of glaciers. Spatially detailed maps.
- Statistics (total area) and outlines of snow cover, glacier area, sea ice, and lake/river ice in Europe. The focus is on time series to monitor changes over time.
- Snow water equivalent and snow melt (in-situ measurements).
- Snow water equivalent, snow depth / point data, spatially detailed maps, vector.
- ASaG Snow extent Maps (Binary and Fractional) from MODIS, covering Austria.
- Snow info from meso-scale weather model INCA.
- Snow cover as spatially detailed map.
- Snow melt and glacier ice melt model integrated in a water balance rainfall runoff model.
- Station data (snow depth, water content), map products.
- Snow height and snow water equivalent (measurements point data, forecasts grid data), analyses & forecasts of snow melt and rainfall amount (grid data).
- Glacier outline (vector) / Glacier elevation (DEM) / Glaciers (points).
- Snow cover and snow depth from satellite and synop/in situ.
- Snow depth, snow water content and distribution as spatial maps for hydrological modelling. Ice coverage on rivers for flood management.
- Synoptic snow depth observations are used in the Numerical Weather Prediction models. 'Probability of snow products' based on optical satellite sensors are under development.
- Using products developed self (http://www.cryoclim.net/cryoclim/index.php/Svalbard_glacier_products).
- In situ measurements of snow and ice depth, point measurements.
- SCA, SWE.
- NASA snow covered area; raster.

- http://www.senorge.no/These are modelled gridded snow data (temporal resolution: 1day, spatial resolution: 1K, and extent: Norway).
- Measurement of SWE: Point data and snow track data and hydrological modelling of SWE.
- We are going to use maps of binary snow cover area and/or fractional snow cover area, of snow water equivalent, of lake ice extent.
- In-situ point observations of snow depth and water equivalent.
- Snow covered area / grid maps.
- Parameters: snow water equivalent, glacier area, snow distribution. / Use both point data and interpolated spatial data, mostly vector data.
- Glacier outlines, accuracy 15-30 m / Glacier dammed lakes, accuracy 15-30 m / Vector data as shape file / Raster data as GEOTIFF.

6.7 Are you using snow, glacier and land / ice products operationally?

78 % indicated yes.

6.8 Are the EO-products automatically used by your processing software or is manual operator interaction needed?

27 users responded. Half of the users indicated that EO-products were used manually, the other half used EO-products semi- or fully automatic.

Table 6.3:
Automatic use of EO products

	Total	
Are the EO-products automatically used by your processing software or is manual operator interaction needed?	**Percentage**	**Number**
Fully automatically	24 %	8
Manually	53 %	18
Semi-automatically (just verify OK/re-run)	24 %	8
Total	**100 %**	**34**

6.9 What is your final product type or service?

37 users responded to this section. The individual answers are provided below:

- Avalanche warnings (daily) / Avalanche bulletin / Data for avalanche commission and to the public.
- MSG-Seviri snow cover product over Europe.
- Consulting and Engineering Services in Hydropower and Water Management.
- Indicator-based reports that monitor changes in the European and Arctic cryosphere over time.
- Water Balance of drainage basins / flood forecast.
- Hydrological forecasts and warnings / Volume of water on snow pack, for selected basins.
- Topographic map in scale 1:150.000 (glacier outline) / individual products (e.g. estimating water discharge of glacier damned lakes.
- Hydrological prospecting for hydro power construction).
- Daily maps of global solar radiation over Austria; daily sums and sub-daily sums. direct / diffuse components on horizontal and inclined surfaces.
- Making roads clean of snow; accounting of costs for winter cleaning of roads / Combined products needed: / - Fresh Snow fall / - days with snow fall / Topographic data: solar illumination on roads.
- Flood forecast.
- Weather analysis and forecast and products using weather information.
- Flood event forecasting system.
- Published hydrological data.
- Power production (hydro power).
- Input to hydrological model, civil engineering.
- Water level and runoff forecasts.
- Glacier inventory / Glacier mask.
- Weather prediction.
- Software for modelling and decision support, research, consultancy.

- Research on phenology of land vegetation.
- Avalanche maps, avalanche hazard maps.
- Runoff forecasts.
- Weather forecasts (including snow depths/density/water equivalent) / 2). Probability maps for snow.
- Runoff forecasts / Models and data for runoff forecasts (including probability forecasts of spring flood volume).
- Hydrological modelling.
- Hydropower production.
- Remote sensing research.
- Scientific papers and reports on animal space use and movements, and animal population dynamics.
- Long and short term forecasting for river discharge for power companies.
- Hydrological forecast.
- Avalanche warning and mapping.
- Numerical Weather Prediction.
- Runoff forecasts.
- Glacier inventory, snow distribution.

6.10 Which data sources do you presently use for your snow / land ice products or services?

This question asks for the data sources on snow and land ice information presently used. Multiple selections are possible.

- In-situ measurements from stations are used by most users (83 %). They are complemented by modelled data, products from satellite data and spatially interpolated data are also used by 47 % of the users.

Table 6.4:
Presently used data sources.

	Total	
Which data sources do you presently use for your snow / land ice products or services?	***Percentage***	***Number***
in-situ measurements at stations	83 %	39
spatially interpolated in-situ measurements at stations	47 %	22
modelled data (e.g. climate models),	62 %	29
products from satellite data	62 %	29
if other, specify in text box below:	26 %	12
Total	279 %	131

Other data sources listed by the users are:

- Snow cover / SWE/ raster maps.
- Satellite-based snow products / in-situ snow measurements.
- (Seasonal) Snow cover area, Extent of glaciers. Spatially detailed maps.
- Statistics (total area) and outlines of snow cover, glacier area, sea ice, and lake/river ice in Europe. The focus is on time series to monitor changes over time.
- Snow water equivalent and snow melt (in-situ measurements).
- Snow water equivalent, snow depth / point data, spatially detailed maps, vector.
- Glacier outlines, accuracy 15-30 m / Glacier dammed lakes, accuracy 15-30 m / Vector data as shape file / raster data as GEOTIFF.
- ASaG Snow extent Maps (Binary and Fractional) from MODIS, covering Austria.
- Snow info from mesoscale weather model INCA.
- Snow cover as spatially detailed map.
- Snow melt model and Glacier ice melt model integrated in a water balance rainfall runoff model.

- Station data (snow depth, water content), map products.
- Snow height and snow water equivalent (measurements point data, forecasts grid data), analyses & forecasts of snow melt and rainfall amount (grid data).
- Glacier outline (vector) / Glacier elevation (DEM) / Glaciers (points).
- Snow cover and snow depth from satellite and synop /in situ.
- Snow depth, snow water content and distribution as spatial maps for hydrological modelling. Ice coverage on rivers for flood management.
- Synoptic snow depth observations are used in the Numerical Weather Prediction models. / 2) 'Probability of snow products' based on optical satellite sensors are under development.
- Using products developed self (http://www.cryoclim.net/cryoclim/index.php/Svalbard_glacier_products).
- In situ measurements of snow and ice depth, point measurements.
- SCA, SWE.
- NASA snow covered area; raster.
- http://www.senorge.no/ / / These are modelled gridded snow data (temporal resolution: 1day, spatial resolution: 1K, and extent: Norway).
- Measurement of SWE: Point data and snow track data and hydrological modelling of SWE.
- We are going to use maps of binary snow cover area and/or fractional snow cover area, of snow water equivalent, of lake ice extent.
- In-situ point observations of snow depth and water equivalent.
- Outer owned measuring and MS Excel.
- Snow covered area / grid maps.
- Parameters: snow water equivalent, glacier area, snow distribution. / Use both point data and interpolated spatial data, mostly vector data.

6.11 Does the present solution you use in your organisation meet your requirements?

A majority (77 %) indicated that the present solution only partially meet the requirements of the organization.

Table 6.5:
Does the present solution meet the organizations requirements?

	Total	
Does the present solution you use in your organisation meet your requirements?	***Percentage***	***Number***
Yes	10 %	4
No	13 %	5
Partially	77 %	30
Total	100 %	39

6.12 What is your annual expenditure on snow and land ice data or products today?

A majority indicates that the annual expenditure on snow and land ice data is less than 10 k€. About 1/3 spends 10-50 k€. Only one user uses more than 100 k€.

Table 6.6:
Annual expenditure for snow and land ice products.

	Total	
What is your annual expenditure on snow and land ice data or products today (in 1000 Euro)?	***Percentage***	***Number***
less than 10k€	62 %	21

	Total	
What is your annual expenditure on snow and land ice data or products today (in 1000 Euro)?	***Percentage***	***Number***
10- 50 k€	32 %	11
50 – 100 k€	0 %	0
>100 k€	6 %	2
Total	100 %	34

6.13 Are you interested in SNOW COVER products/services?

91 % of the response was interested in snow cover products.

6.14 How relevant are the requirements of the snow products according to your needs

We judge relevance according to whether the users grade the product as important, very important or crucial. The judgement of the various products is provided in ranked order:

- 83 % regarded snow cover area as important or higher merited.
- 55 % regarded low resolution SWE as important or higher merited.
- 52 % regarded melting snow as important or higher merited.
- 45 % regarded statistical snow extent information as important or higher merited.
- 40 % regarded surface albedo maps as important or higher merited.
- 38 % regarded snow surface wetness as important or higher merited.
- 37 % regarded snow surface temperature as important or higher merited.

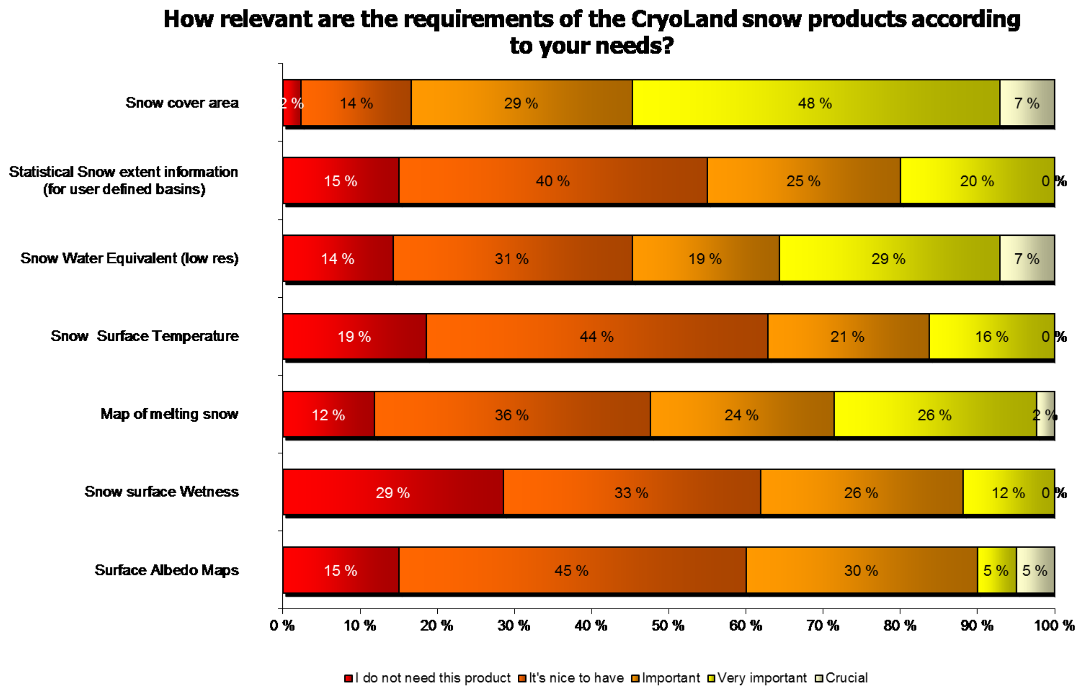

Figure 6.2: Relevance of snow products.

6.15 At what time of the year are SNOW COVER products needed?

The table below shows the results from when snows cover products are needed for the whole year. In general it seems like all snow products are desired throughout the whole year, with (as expected) more interest in the fall/winter/spring than in the summer. It is interesting to note that data from the fall season is highly desired.

Table 6.7:

					Total	
At what time of the year are SNOW COVER products needed? (Winter (Nov-Febr))	Yes		No		Percentage	Number
Snow cover area	86 %	30	14 %	5	83 %	35
Statistical snow extent information (for user defined basins)	67 %	20	33 %	10	71 %	30
Snow water equivalent (low res)	72 %	23	28 %	9	76 %	32
Snow surface temperature	81 %	21	19 %	5	62 %	26
Map of melting snow	60 %	15	40 %	10	60 %	25
Snow surface wetness	54 %	13	46 %	11	57 %	24
Surface albedo maps	62 %	16	38 %	10	62 %	26
Total	70 %	138	30 %	60	100 %	198

					Total	
At what time of the year are SNOW COVER products needed? (Alpine spring (March -	Yes		No		Percentage	Number
Snow cover area	94 %	33	6 %	2	83 %	35
Statistical snow extent information (for user defined basins)	74 %	23	26 %	8	74 %	31
Snow water equivalent (low res)	75 %	24	25 %	8	76 %	32
Snow surface temperature	85 %	22	15 %	4	62 %	26
Map of melting snow	81 %	21	19 %	5	62 %	26
Snow surface wetness	70 %	16	30 %	7	55 %	23
Surface albedo maps	67 %	18	33 %	9	64 %	27
Total	79 %	157	22 %	43	100 %	200

					Total	
At what time of the year are SNOW COVER products needed? (Nordic spring (Apr.-July))	Yes		No		Percentage	Number
Snow cover area	84 %	26	16 %	5	74 %	31
Statistical snow extent information (for user defined basins)	68 %	21	32 %	10	74 %	31
Snow water equivalent (low res)	67 %	20	33 %	10	71 %	30
Snow surface temperature	71 %	17	29 %	7	57 %	24
Map of melting snow	72 %	18	28 %	7	60 %	25
Snow surface wetness	58 %	14	42 %	10	57 %	24
Surface albedo maps	63 %	17	37 %	10	64 %	27
Total	69 %	133	31 %	59	100 %	192

					Total	
At what time of the year are SNOW COVER products needed? (Summer (May-Sept))	Yes		No		Percentage	Number
Snow cover area	67 %	20	33 %	10	71 %	30
Statistical snow extent information (for user defined basins)	46 %	13	54 %	15	67 %	28
Snow water equivalent (low res)	54 %	15	46 %	13	67 %	28
Snow surface temperature	57 %	12	43 %	9	50 %	21
Map of melting snow	50 %	10	50 %	10	48 %	20
Snow surface wetness	45 %	9	55 %	11	48 %	20
Surface albedo maps	54 %	13	46 %	11	57 %	24
Total	54 %	92	46 %	79	100 %	171

					Total	
At what time of the year are SNOW COVER products needed? (Fall (Oct-Nov))	Yes		No		Percentage	Number
Snow cover area	87 %	27	13 %	4	74 %	31
Statistical snow extent information (for user defined basins)	64 %	18	36 %	10	67 %	28
Snow water equivalent (low res)	63 %	17	37 %	10	64 %	27
Snow surface temperature	64 %	14	36 %	8	52 %	22
Map of melting snow	48 %	10	52 %	11	50 %	21
Snow surface wetness	38 %	8	62 %	13	50 %	21
Surface albedo maps	58 %	14	42 %	10	57 %	24
Total	62 %	108	38 %	66	100 %	174

6.16 How often do you need (updated) SNOW COVER products?

The majority of responders indicate that all products should be provided on a daily basis.

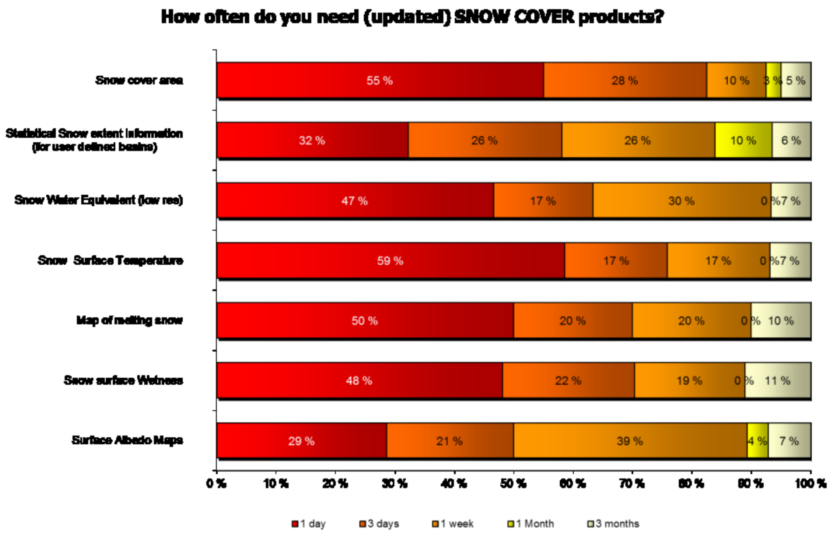

Figure 6.3: How often snow products should be updated?

6.17 What is the data latency for SNOW COVER products?

Snow cover information is required rather urgent. About a third of the responders wanted data within 6 hours. 25 % wanted data less than 12 hours after acquisition. Other information types (SWE, Snow temperature, melting snow, albedo) are needed within 1 day.

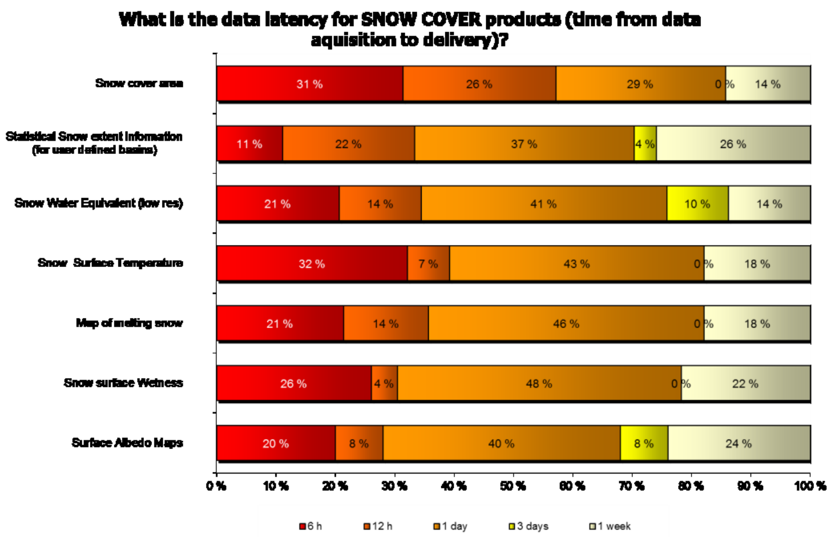

Figure 6.4: Latency of snow products.

6.18 What are the spatial resolution requirements for SNOW COVER products?

The requirements for spatial resolutions are diverse.

- A majority of the responders can use snow information that has 250 m spatial resolution which is within reach of the project.

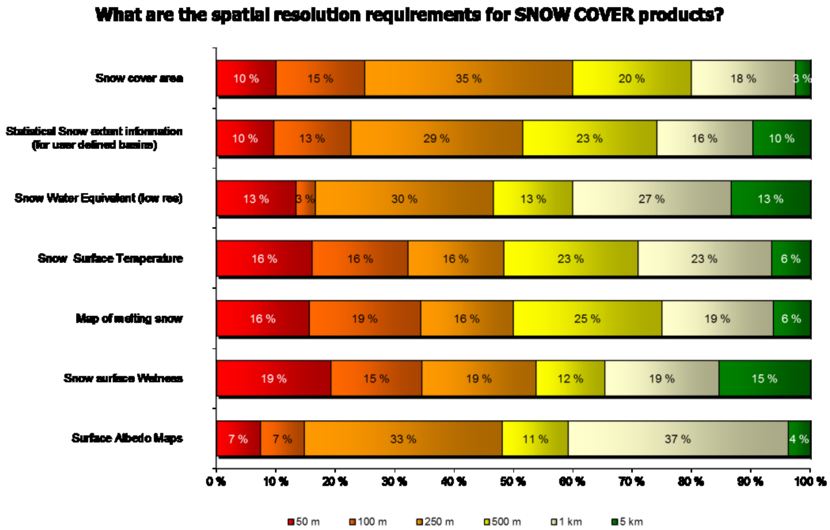

Figure 6.5: Spatial resolution of snow products.

- An important minority (10 % and 15 %) desired improved resolution (50 m and 100 m). These are probably users within the avalanche community.
- For the low resolution SWE product, it seems like the answers options were a bit in adequate since all users preferred higher resolution than is possible to achieve with current sensors.

6.19 Please provide name of geographic region(s) of interest for SNOW COVER products

Most users provided the names of their core region of interest. The main regions are as expected the Alps and the Nordic countries. Some users indicate a need for a pan-European product. Below are the individual answers:

- Tirol (Northern + Southern).
- Switzerland.

- Pan-European Alps.
- Alps, SE Europe (Balkan), Turkey, Caucasus, Central Asia, Karakoram, Himalaya.
- Europe (38 EEA member and collaborating countries), / Arctic.
- Carinthia / Kärnten.
- Romania and the upper parts of Siret, Prut and Tisa river basins (from Ukraine). / Entire Danube River Basin.
- Greenland, coastal area.
- Alps.
- Salzburg, Upper Austria and bordering regions.
- Austria.
- Tyrol.
- Tyrol, Austria.
- Austria.
- federal state Salzburg.
- South Tyrol.
- All river basins that belong to or drain to Bavaria.
- Scandinavia.
- Global - Asia, Scandinavia, North and South America.
- The Nordic countries.
- Norway, European Alps.
- Catchment areas of Umeälven, Ångermmanälven, Indalsälven Ljungan, Ljusnan and Dalälven.
- Europe.
- Northern Scandinavia.
- Mainly the mountain range between Sweden and Norway, but also Northern Sweden in general.
- Sweden, Scandinavia, Pan-European.
- Nordic countries.

- Baltic Sea drainage basin.
- Project dependent: / For reindeer project: Southern-Norway / For moose-projects: Norway, Sweden and Finland. / For roe deer-projects: Europe (Southern Scandinavia) till Southern Italy till Eastern-Europe.
- The Swedish rivers: / Umeälven / Ångermanälven / Indalsälven / Ljungan / Ljusnan / Dalälven.
- Lulealv.
- Western part of Norway.
- Most essential is Europe, especially its Northern part. But global coverage is very welcome.
- Norway.
- Norway.
- Southern Norway (Glomma catchment).

6.20 Specify Lat/Long range for the area(s) of interest for SNOW COVER products

Latitude and longitude ranges are provided below:

- UL: N47.8d 10.15E / UR: N47.8d 13.20E / LL: N46.6d 10.00E / LR: N46.6d 13.20E
- 49.5, 5.0 / 49.5, 17.5 / 43.5, 5.0 / 43.5, 17.5
- UR 48°N 13°E / LL 46°37'N 10°E
- 48 N, 12 E / 48 N, 14 E / 47 N, 12 E / 47 N, 14 E
- 51.0 N 8.0 E / 51.0 N 14.0 E / 46.5 N 8.0 E / 46.5 N 14.0 E
- UL 73 N 5 E / UR 73 N 42 E / LL 55 N 5 E / LR 55 N 42 E
- Approximate coordinates / WGS 84 decimal (lat, lon): / UL 66.78445, 14.88003 / UR 66.01926, 17.16519 / LL 63.46169, 11.49624 / LR 63.32392, 14.48452 / / UL 63.46169, 11.49624 / UR 63.32392, 14.48452 / LL 61.17650, 11.71597 / LR 61.03849, 14.24282
- 84N 30W / 82N 40E / 40N 24W / 40N 35E
- Mountain range: / UL 68N 12E, UR 68N 19E, LL 60.5N 12E, LR 60.5N 19E / Northern Sweden: / UL 68N 12E, UR 68N 22E, LL 62N 12E, LR 62N 22E

- ULC 70 30 / LLC 58 5
- 66.276934, 14.294181 / 64.023061, 20.791221 / 60.458055, 11.818137 / 60.555414, 17.553001
- 63N 4,30 E / 63N 9E / 60N 4,3E / 60N 7,5E
- 70N 25W / 70N 50E / 35N 25W / 35N 50E
- utm33 / ul 50000 6970000 / ur 420000 6970000 / ll 50000 6500000 / lr 420000 6500000

6.21 Map projections for SNOW cover products

The majority of responders (about 50 %) preferred UTM projections. The remainder preferred geographic coordinates (40 %) or other projections (10 %).

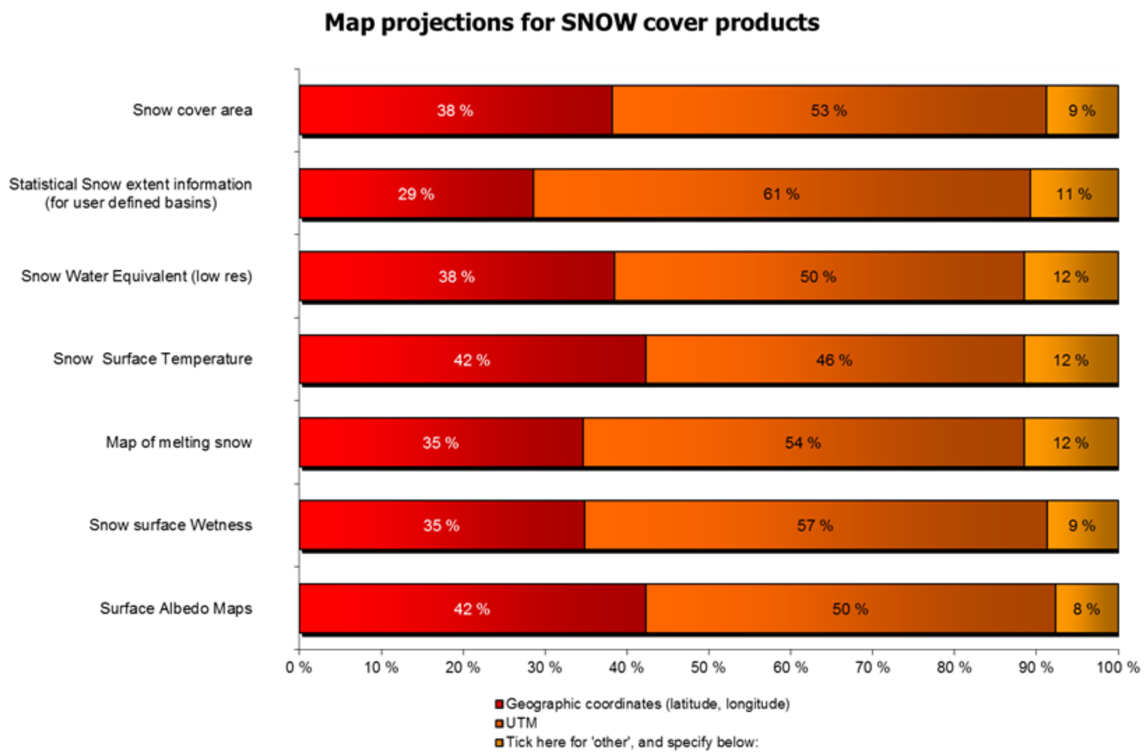

Figure 6.6: Map projections for snow products.

Other optional map projections:

- Bundesmeldenetz Austria.
- Lambert Equal Area Austria (EPSG 31287).

- Geographic WGS84.
- WGS84 ETRS89 / UTM zone 32.
- Swedish coordinate system (Svenska rikssystemet RT 90 gon väst [EPSG: 3021]).

6.22 Please provide other comments regarding SNOW COVER products

The individual comments regarding snow cover products are provided below:

- Product requirements: see GCOS Satellite Supplement.
- A service for estimation of snow cover on partly cloudy days (using neighbourhood statistics) would be appreciated!
- Annual updating of time series is sufficient.
- The products will be used for hydraulic simulations.
- Composite products over a few days to reduce cloud coverage / Time series needed from 01/2006 onwards.
- At the moment a resolution of 5 by 5 km solution of grid cells is used. for SNOW information it would be better to have a more detailed solution.
- Produced locally based on observations, satellite data and models.
- Snow depth or volume interpretations are crucial.
- Have not fully assessed the use yet.
- Both spatial and temporal resolution is of high importance. The higher resolution, the better use we can make of the products within our avalanche warning service.
- Of course we would like to have data on Snow Water Equivalent, but I have assumed that the product you call SWE (low res) is not relevant for the Swedish mountains.
- If tax payers have paid for it, then everything should be open and free.
- Our/my main interest in snow data lies in getting an as good as possible idea on snow depth for animal movements. If as good as possible means snow cover, so be it. Would it be possible to model snow depth (or SWE) at higher spatial resolutions with non-satellite ancillary data (DEM, distance to coast etc.) in addition to the satellite data: snow cover (high res) and SWE (low res). Or would such an approach not fit within the CryoLand project? / Anyway, thumbs up for this project.

- We need probably better resolution than 50 m.

6.23 Are you interested in GLACIER products/services

28 % of the organisations replying to the questionnaire were interested in glacier products.

6.24 How relevant are the following GLACIER products according to your needs?

If we group the responses in two categories (important, very important, crucial) and ("nice to have", "I do not need this product") we see that:

- 88 % regarded the glacier outline product as important
- 56 % regard late summer snow line as important.
- 71 % regard snow/ice area maps as important.
- 57 % regard glacier dammed lakes as important.
- 47 % regard ice velocity fields as important.

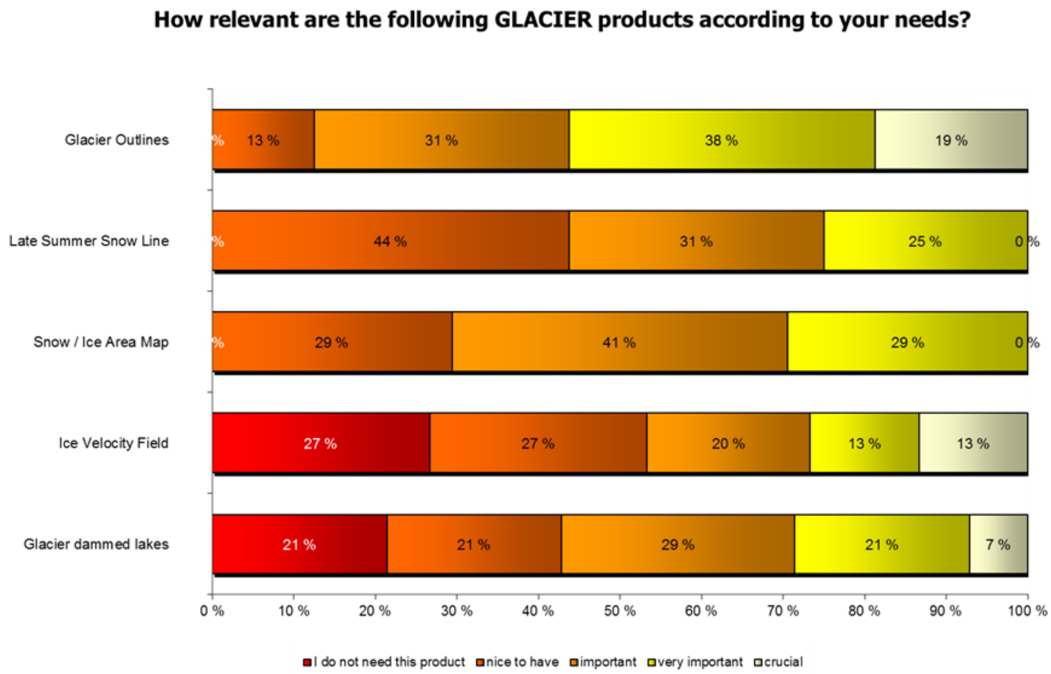

Figure 6.7: Relevance of glacier products.

6.25 At what time of the year are the following GLACIER products needed?

The summer time seems to be the most important period for glacier products, in particular for glacier outlines (100 %) but also for the other products. Other periods are significantly lower rated.

Table 6.8:
Time of the year when glacier products are needed.

					Total	
At what time of the year are the following GLACIER products needed? (Winter (Nov-	Yes		No		Percentage	Number
Glacier outlines	56 %	5	44 %	4	56 %	9
Late summer snow line	40 %	2	60 %	3	31 %	5
Snow / Ice area map	71 %	5	29 %	2	44 %	7
Ice velocity field	60 %	3	40 %	2	31 %	5
Glacier dammed lakes	40 %	2	60 %	3	31 %	5
Other products	50 %	1	50 %	1	13 %	2
Total	55 %	18	45 %	15	100 %	33

					Total	
At what time of the year are the following GLACIER products needed? (Alpine spring	Yes		No		Percentage	Number
Glacier outlines	50 %	4	50 %	4	50 %	8
Late summer snow line	40 %	2	60 %	3	31 %	5
Snow / Ice area map	75 %	6	25 %	2	50 %	8
Ice velocity field	60 %	3	40 %	2	31 %	5
Glacier dammed lakes	50 %	3	50 %	3	38 %	6
Other products	50 %	1	50 %	1	13 %	2
Total	56 %	19	44 %	15	100 %	34

					Total	
At what time of the year are the following GLACIER products needed? (Nordic spring	Yes		No		Percentage	Number
Glacier outlines	50 %	4	50 %	4	50 %	8
Late summer snow line	40 %	2	60 %	3	31 %	5
Snow / Ice area map	67 %	4	33 %	2	38 %	6
Ice velocity field	67 %	4	33 %	2	38 %	6
Glacier dammed lakes	40 %	2	60 %	3	31 %	5
Other products	67 %	2	33 %	1	19 %	3
Total	55 %	18	45 %	15	100 %	33

					Total	
At what time of the year are the following GLACIER products needed? (Summer (May-	Yes		No		Percentage	Number
Glacier outlines	100 %	14	0 %	0	88 %	14
Late summer snow line	100 %	12	0 %	0	75 %	12
Snow / Ice area map	100 %	11	0 %	0	69 %	11
Ice velocity field	89 %	8	11 %	1	56 %	9
Glacier dammed lakes	82 %	9	18 %	2	69 %	11
Other products	100 %	5	0 %	0	31 %	5
Total	95 %	59	5 %	3	100 %	62

					Total	
At what time of the year are the following GLACIER products needed? (Fall (Oct-Nov))	Yes		No		Percentage	Number
Glacier outlines	67 %	6	33 %	3	56 %	9
Late summer snow line	67 %	6	33 %	3	56 %	9
Snow / Ice area map	75 %	6	25 %	2	50 %	8
Ice velocity field	67 %	4	33 %	2	38 %	6
Glacier dammed lakes	63 %	5	38 %	3	50 %	8
Other products	50 %	1	50 %	1	13 %	2
Total	67 %	28	33 %	14	100 %	42

6.26 How often do you need (updated) GLACIER products?

With few exceptions most responders needed annually updated products.

Table 6.9:
How often glacier products are needed.

How often do you need (updated) GLACIER products?	weekly		monthly		3 monthly		annually		every 5 years	
Glacier Outlines	6 %	1	13 %	2	0 %	0	63 %	10	19 %	3
Late Summer Snow Line	20 %	3	0 %	0	0 %	0	80 %	12	0 %	0
Snow / Ice Area Map	29 %	5	0 %	0	6 %	1	65 %	11	0 %	0
Ice Velocity Field	10 %	1	0 %	0	10 %	1	80 %	8	0 %	0
Glacier dammed lakes	0 %	0	20 %	2	10 %	1	70 %	7	0 %	0
Total	15 %	10	6 %	4	4 %	3	71 %	48	4 %	3

6.27 What is the data latency time for GLACIER products?

A majority (47 %) needed the data within 3 months, 37 % within one month or less.

Table 6.10:
Latency time for glacier products.

What is the data latency time for GLACIER products (time from data aquisition to	1 day		1 week		1 Month		3 Months	
Glacier Outlines	0 %	0	31 %	4	15 %	2	54 %	7
Late Summer Snow Line	0 %	0	42 %	5	8 %	1	50 %	6
Snow / Ice Area Map	0 %	0	46 %	6	8 %	1	46 %	6
Ice Velocity Field	0 %	0	22 %	2	44 %	4	33 %	3
Glacier dammed lakes	13 %	1	13 %	1	25 %	2	50 %	4
Total	2 %	1	33 %	18	18 %	10	47 %	26

6.28 What are the spatial resolution requirements for GLACIER products?

All glacier products are desired at high spatial resolution (10 m - 25 m).

6.29 Map projections for GLACIER products

Most users prefer the UTM projection (72 %).

Table 6.11:
Map projections for glacier products.

Map projections for GLACIER products (If "other", please fill out comments field	Geographic coordinates (latitude, longitude)		UTM		Other	
Glacier Outlines	31 %	5	63 %	10	6 %	1
Late Summer Snow Line	27 %	4	67 %	10	7 %	1
Snow / Ice Area Map	27 %	4	67 %	10	7 %	1
Ice Velocity Field	9 %	1	82 %	9	9 %	1
Glacier dammed lakes	0 %	0	91 %	10	9 %	1
Total	21 %	14	72 %	49	7 %	5

6.30 Please provide name of geographic region(s) of interest for GLACIER products

A majority of the users were interested in glacier products from the Alps and Scandinavia including Svalbard. Greenland is also mentioned. Below is a summary of the individual answers:

- Alps (incl. Austria, Switzerland, Tyrol) (6 answers).
- Caucasus (1 answer).
- Central Asia, (Himalaya, Karakoram) (1 answer).
- Greenland, coastal areas (2 answers).
- Norway (Mainland) (2 answers).
- Svalbard (1 answer).
- North Scandinavia.

6.31 Specify Latitude and Longitude Range for the area(s) of interest for GLACIER products

Below the regions are provided:

- 47,22 N 11,89 E / 47,22 N 14 E / 47 N 11,89 E / 47 N 14 E
- UL: lat. 71.6 lon. 0.8 / UR: lat. 71.7 lon. 28 / LL: lat. 57.6 lon. 4.7 / LR: lat. 58.3 lon. 20.7

6.32 Please provide other comments regarding GLACIER product

Comments regarding glacier products are provided below:

- Start of ice melting / ice mass balance / Snow melting and ice melting from glaciers
- Projections are different for the regions of the list but UTM is ok.
- Requirements are specified in see GCOS Satellite Supplement and GTN-G (GLIMS).
- Information on Volume/Mass of Glaciers would be highly interesting!
- Products are used for updating topographic maps 1:150.000.
- Start of ice melting / ice mass balance / Snow melting and ice melting from glaciers.
- We are mostly interested in the total area of individual glaciers.

6.33 Are you interested in LAKE ICE products/services?

28 % of the users (who replied) were interested in lake ice products.

6.34 How relevant are the following LAKE ICE products according to your needs?

Relevance of products grouped in two groups (important, very important, crucial) and (nice to have, do not need):

- 85 % merited the lake and river ice extent product as important or higher.
- The snow burden product was regarded as important (or more) by 13 %.
- The other products such as first day of ice and last day of ice were ranked as important (or more) by 67 %.

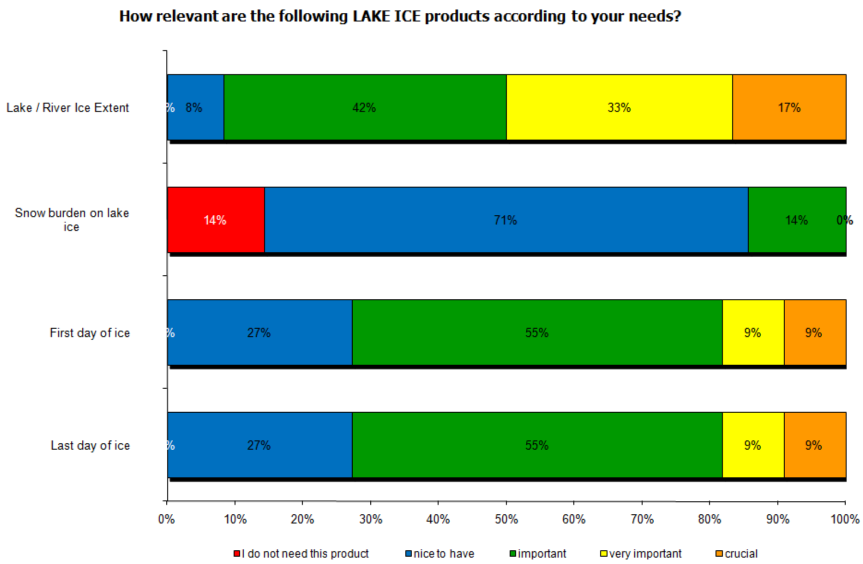

Figure 6.8: Relevance of lake ice products.

Other text responses: mentioned River Ice Jam formation and break / River Ice movement.

6.35 At what time of the year is the LAKE ICE product needed?

All products were ranked as needed in the fall, winter and spring season (88 - 100 %), but slightly less in the summer season (67 %).

Table 6.12:
Time of the year when lake ice products are needed.

At what time of the year is the LAKE ICE product needed? (Winter (Nov-Febr))	Yes		No		Total Percentage	Total Number
Lake / River Ice Extent	100 %	10	0 %	0	83 %	10
Snow burden on lake ice	100 %	3	0 %	0	25 %	3
First day of ice	100 %	8	0 %	0	67 %	8
Last day of ice	100 %	8	0 %	0	67 %	8
Other products, please specify	100 %	1	0 %	0	8 %	1
Total	100 %	30	0 %	0	100 %	30

At what time of the year is the LAKE ICE product needed? (Alpine spring (March -	Yes		No		Total Percentage	Total Number
Lake / River Ice Extent	88 %	7	13 %	1	67 %	8
Snow burden on lake ice	67 %	2	33 %	1	25 %	3
First day of ice	86 %	6	14 %	1	58 %	7
Last day of ice	86 %	6	14 %	1	58 %	7
Other products, please specify	100 %	2	0 %	0	17 %	2
Total	85 %	23	15 %	4	100 %	27

At what time of the year is the LAKE ICE product needed? (Nordic spring (Apr-July))	Yes		No		Total Percentage	Total Number
Lake / River Ice Extent	100 %	8	0 %	0	67 %	8
Snow burden on lake ice	100 %	3	0 %	0	25 %	3
First day of ice	100 %	6	0 %	0	50 %	6
Last day of ice	100 %	6	0 %	0	50 %	6
Other products, please specify	100 %	2	0 %	0	17 %	2
Total	100 %	25	0 %	0	100 %	25

At what time of the year is the LAKE ICE product needed? (Summer (May-Sept))	Yes		No		Total Percentage	Total Number
Lake / River Ice Extent	67 %	4	33 %	2	50 %	6
Snow burden on lake ice	33 %	1	67 %	2	25 %	3
First day of ice	67 %	4	33 %	2	50 %	6
Last day of ice	67 %	4	33 %	2	50 %	6
Other products, please specify	50 %	1	50 %	1	17 %	2
Total	61 %	14	39 %	9	100 %	23

At what time of the year is the LAKE ICE product needed? (Fall (Oct-Nov))	Yes		No		Total Percentage	Total Number
Lake / River Ice Extent	100 %	7	0 %	0	58 %	7
Snow burden on lake ice	100 %	2	0 %	0	17 %	2
First day of ice	100 %	6	0 %	0	50 %	6
Last day of ice	100 %	6	0 %	0	50 %	6
Other products, please specify	100 %	1	0 %	0	8 %	1
Total	100 %	22	0 %	0	100 %	22

6.36 How often do you need (updated) LAKE ICE products?

The majority of users need lake ice products every 2-3 days or more frequent. The needs are quite scattered from hourly to annually. The needs probably reflect different groups where some are focussed on operational events like ice jams and floods whereas other are interested more climatology.

Table 6.13:
How often lake ice products need to be updated.

How often do you need (updated) LAKE ICE products?	Hourly		Daily		Every 2-3 days		Every 4-6 days		Weekly		Monthly	
Lake / River Ice Extent	15 %	2	23 %	3	23 %	3	0 %	0	8 %	1	8 %	1
Snow burden on lake ice	0 %	0	14 %	1	29 %	2	0 %	0	0 %	0	29 %	2
Total	10 %	2	20 %	4	25 %	5	0 %	0	5 %	1	15 %	3

Other comments:

- For dangerous river ice jam, the need for update could go down to hourly.

6.37 What is the data latency time for LAKE ICE products?

The responses are somewhat scattered. A few users have near-real time requirements. Others need data on a daily basis, and others need them within a month. The needs probably reflect the same division in two groups as in question 2.41 above.

Table 6.14:
Latency time for lake ice products.

What is the data latency time for LAKE ICE products (time from data aquisition to	3 h		12 h		1 day		1 week		1 month	
Lake / River ice extent	23 %	3	0 %	0	31 %	4	15 %	2	31 %	4
Snow burden on lake ice	0 %	0	0 %	0	43 %	3	0 %	0	57 %	4
Total	15 %	3	0 %	0	35 %	7	10 %	2	40 %	8

6.38 What are the spatial resolution requirements for LAKE ICE products?

33 % need data with high resolution (25 m), 33 % needed data with medium resolution (100 m) and the remainder (33%) need data with less than 1 km resolution.

Table 6.15:
Spatial resolution for lake ice products.

What are the spatial resolution requirements for LAKE ICE products?	<10 m		<25 m		<50 m		<100 m		<1 km	
Lake / River Ice Extent	0 %	0	33 %	4	0 %	0	33 %	4	33 %	4
Snow burden on lake ice	0 %	0	33 %	2	0 %	0	33 %	2	33 %	2
Total	0 %	0	33 %	6	0 %	0	33 %	6	33 %	6

Comment: Could be <10 m for small rivers.

6.39 Map projections for LAKE ICE products

The preferred projection within the lake ice community is geographical coordinates (53%), but UTM is also used by a large minority (47%).

Table 6.16:
Map projection for lake ice products.

Map projections for LAKE ICE products	Geographic coordinates (latitude, longitude)		UTM		Other (specify in text field)	
Lake / River Ice Extent	60 %	6	40 %	4	0 %	0
Snow burden on lake ice	40 %	2	60 %	3	0 %	0
Total	53 %	8	47 %	7	0 %	0

Comment:

- WGS84
- as with snow products, we know how to re-project.

6.40 Please provide name of geographic region(s) of interest for LAKE ICE products

Names of geographical regions are provided below. In addition to users in the Nordic countries, there is also identified needs for lake ice products in the Alps and in Romania. Even a lake ice product for Europe and Greenland is desired.

- Switzerland.
- Same as for snow.
- Bistrita River upstream Izvorul Muntelui Reservoir, as a pilot area. / Romania.

- Greenland, coastal areas.
- Scandinavia.
- Europe.
- Sweden, Scandinavia, Pan-European.
- Baltic Sea Drainage Basin.
- This would be mostly Southern-Norway (i.e. our reindeer project).
- Northern Europe, whole Europe, globe.
- Norway, Troms.
- Southern Norway (Glomma catchment).

6.41 Specify Latitude and Longitude Range for the area(s) of interest for LAKE ICE products

Regions defined below:

- 74N 0E / 70N 60E / 58N 0E / 40N 40E
- 75N 25W / 75N 50E / 35N 25W / 35N 50E
- UTM 33 / ul 50000 6975000 / ur 420000 6975000 / ll 50000 6500000 / lr 420000 6500000

6.42 Please provide other comments for LAKE ICE products

Individual comments for lake ice products:

- GCOS Satellite Supplement.
- Our main question is whether the animals can cross a lake/river or not. So, for managed lakes or rivers it is actually also important to know whether the ice surface is heavily disturbed. But, in all honesty, even though the ice products could be more interesting than we are imagining at the moment (especially in areas with lots of hydro-electric activity), our main interest is the snow products.

6.43 Which data formats do you prefer?

A majority (77%) preferred GEOTIFF format. A large portion of the users is also in favour of shape files (I guess for non-raster products line glacier outlines).

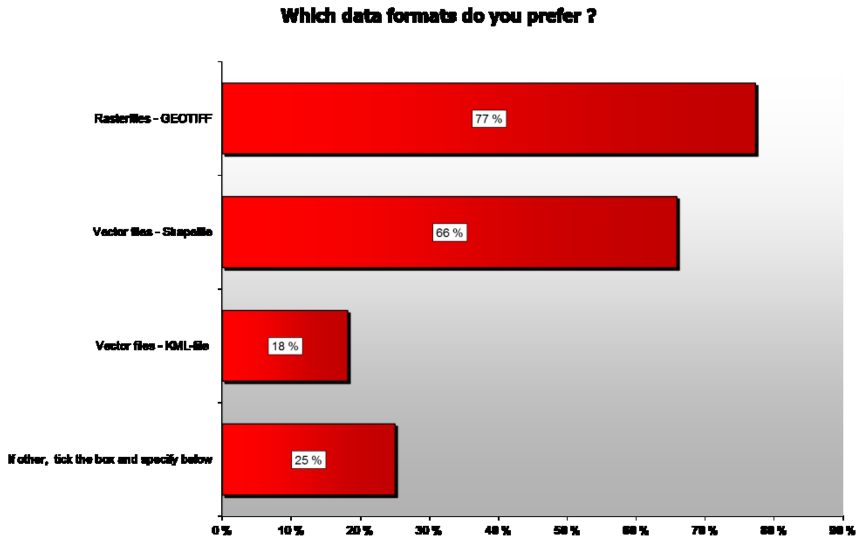

Figure 6.9: Preferred data formats.

Other formats:

- ESRI raster.
- hdf / / -> IDL routine for reading.
- In addition to spatially explicit information, summary statistics (ice extent, etc.) would be extremely useful.
- Raster: ArcView ASCII.
- NetCDF format.
- other raster formats are possible.
- ASCI grid, binary grid, GRIB.
- Flat binary files.
- Should use an open format easy to understand and interpolate.
- MapInfo.
- Numerical matrices that can be loaded to "R" software.

6.44 Which software systems are you using?

ESRI ARC GIS seems to be the dominating software system among the users, but there is a large diversity.

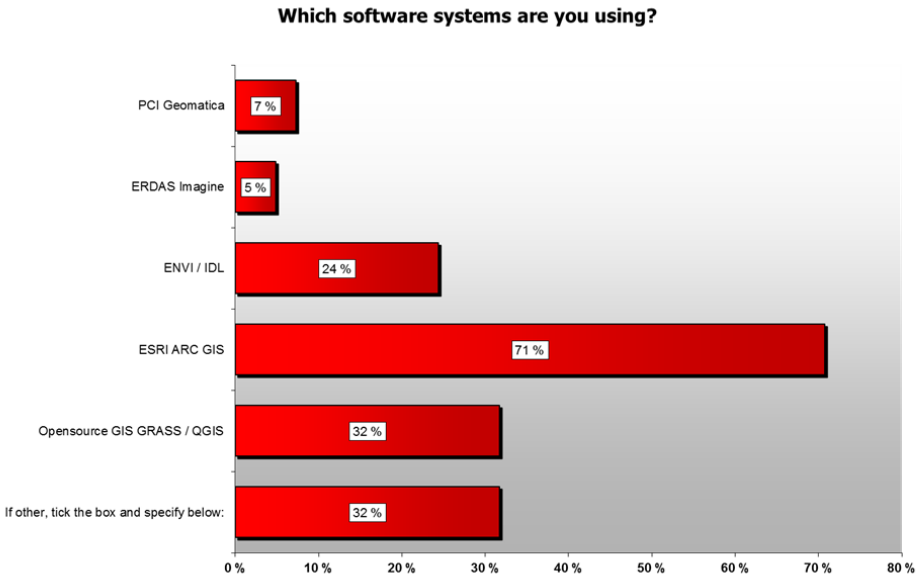

Figure 6.10: Software systems used by the users.

Other mentioned software systems:

- Ferret, JavaNetCdf, other netCDF libraries.
- Matlab.
- Surfer.
- The GUI Interface from FEWS a product from Deltatres/Delft Netherlands.
- For operational services we use our own software; for playing around standard products like ESRI, IDL and GRASS are used.
- Python, R, C, FORTRAN.
- Own software.
- ESA NEST SAR Toolbox more and more. Some Matlab.
- R-project
- MapInfo.

6.45 What is the best way to discover products via metadata search?

94 % preferred to discover CryoLand products in a Web-GUI.

Table 6.17:
The best way to discover products.

	Total	
What is the best way to discover products via metadata search?	Percentage	Number
in CryoLand Web-GUI (Graphical User Interface) displayed in browser	94 %	34
using CryoLand OpenGIS Catalogue Service (CSW) from own client	33 %	12
Total	**128 %**	**46**

6.46 How would you like to view CryoLand products?

76 % preferred to view products in a web-GUI, 58 % also wanted to view in CryoLand OpenGIS map service.

Table 6.18:
How users like to view CryoLand products.

	Total	
How would you like to view CryoLand products?	Percentage	Number
View in CryoLand Web-GUI displayed in browser	76 %	29
View using CryoLand OpenGIS Web Map Service (WMS) from own client (e.g. your GIS Software, ERDAS Imagine, etc).	61 %	23
View in other Web-GUI (INSPIRE, GEOSS, etc.), tick the box and specify below	3 %	1
Total	**139 %**	**53**

6.47 Which are the most suitable downloading methods of CryoLand products for you?

The most suitable downloading methods seem to be ftp (73 %). Using OpenGIS web feature service is also interesting for many (46 %).

Table 6.19:
Most suitable downloading methods.

	Total	
Which are the most suitable downloading methods of Cryoland products for you?	Percentage	Number
using CryoLand OpenGIS Web Feature Service (WFS) from own client	46 %	17
using CryoLand OpenGIS Web Coverage Service (WCS) from own client	24 %	9
using CryoLand File Transfer Service (FTP) and file naming conventions from own client	73 %	27
using CryoLand Web-GUI (Graphical User Interface) in combination with a dedicated CryoLand (batch) download manager installed on own computer (e.g. used for subscription)	27 %	10
in other Web-GUI (INSPIRE, GEOSS, etc.), tick the box and specify below	3 %	1
Total	**173 %**	**64**

6.48 How would you like to exploit processing services shared by the CryoLand project?

62 % wanted to invoke the CryoLand web-GUI to display results of services.

Table 6.20:
Exploitation of processing services shared by the CryoLand project.

	Total	
How would you like to exploit processing services shared by the CryoLand project?	Percentage	Number
invocation in CryoLand Web-GUI displayed in browser	62 %	21
using CryoLand OpenGIS Web Processing Service (WPS) from own clients	26 %	9
please specify which kind of processing you would expect to be supported by CryoLand (transformation, value added, etc.) (tick the box to add comments below):	12 %	4
Total	**100 %**	**34**

Other comments:

- Summary statistics (including time series).
- Download by ftp is most convenient. Have not enough experience with various web clients to be able to comment on them.
- Invocation of value-adding processes from exiting products (e.g. statistics from snow covered area data).
- Transformation, value added.

6.49 Which are the necessary options for data uploading (typically in connection with Process service for "production on demand")?

50 % preferred upload of reference data as a necessary option for data upload.

45 % liked the idea of upload local defile in the CryoLand web-GUI.

Text comments:

- in-situ, models.
- Should be discussed which method to be used.
- based on existing products for value-adding processes (e.g. interpolation of SWE, with own weather station data).
- MapInfo vector files (polygons).

Table 6.21:
Necessary options for data upload.

	Total	
Which are the necessary options for data uploading (typically in connection with Process service for "production on demand")?	Percentage	Number
upload of reference data (e.g. user-provided in-situ measured features) using CryoLand OpenGIS Web Feature Service Transactional (WFS-T) from own client	50 %	10
upload of reference data (e.g. user-provided digital terrain data) using CryoLand OpenGIS Web Coverage Service Transactional (WCS-T) from own client	30 %	6
upload local file in CryoLand Web-GUI displayed in browser	45 %	9
please tick box to specify which data you would expect to upload to CryoLand (in-situ, terrain, models, etc.):	20 %	4
Total	**145 %**	**29**

6.50 Describe your idea of a snow glacier land/river ice product or service that would be needed for your business. Describe it independent of cost and what is realistic today.

22 responses are provided below:

- Please, see GCOS ECV requirements; / we are interested not in near-real time data but on climate data records.
- (A) For hydropower design purposes the following products are of interest: / (a1) reliable information on max. extent of snow cover in a certain season (archived data). (a2) latest information on glacier extent and dammed glacier lakes / (B) For purposes of hydropower operation and for water information systems the following products would be of interest: latest (and high resolution) information on (b1) snow cover area, (b2) snow water equivalent, (b3) melting snow. (C) for Climate Change Impact Studies information on (c1) past and (c2) present extent of glaciers.
- Improve reporting of observed changes in the European/Arctic snow and land ice to European policy makers (for a reference see Section 5.3 in http://www.eea.europa.eu/publications/eea_report_2008_4/pp37-75CC2008_ch5-1to4_Athmosphere_and-_cryosphere.pdf).
- Glacier product: high res. multispectral satellite data and SAR data around the margin of Greenland ice sheet, including smaller isolated ice caps. Data acquisition once a year at the end of melting season. This product would improve glacier outline of existing maps. Existing

topographic maps are out of date and in some places (East Greenland, areas over 80 degrees N) rather inaccurate.

- Snow cover maps, albedo-maps for improvement in global radiation forecasts /snow temperature maybe as input in snow/energy models.
- Spatial distribution on snow so we would improve hydrologic prognosis during snowmelt.
- Snow products for modelling snow melt and water balance / glacier products for modelling ice mass balance and effects of climate change / / At the moment we use temperature based models, a new product gives more information and we use it operationally in the forecasting system and get additional results.
- Daily access to products (preferably on NetCDF format and free of charge e.g. as a part of a GMES core service) to be used automatically in regional NWP.
- On-line estimates of snow volume/water equivalent spatially distributed and available both for operational (forecasting over days to months) and planning (years) for water modelling.
- Will need to evaluate the products and services in more detail.
- Products needed:
    - Daily snow products on melting snow, snow surface temperature, snow surface wetness, snow height
    - Necessary resolution: high-resolution (= better than 100 m)
    - Such data would significantly increase the likeliness that potentially avalanche prone areas of the snow cover could be detected. Together with the data and expertise that we use today, this data would enable to cover larger regions (than today) with high-quality avalanche warnings.
- That it will be possible to update the hydrological model against satellite data on snow cover and SWE. This should generate better hydrological forecasts.
- The most essential data set would be daily high-res SWE. With that we could improve the snow routines of our hydrological models.
- For research the requirements for data processing are different from paper to paper. Therefore, I don't think it will be possible to go much beyond the more availability of finished products (i.e. maps of different features, like snow cover or snow melt). In addition the non-profit nature of our work could make high-cost services easily beyond our reach. I mentioned

in an earlier question that we have a large interest in rather high resolution snow depth (or SWE) data, possibly by combining satellite and also non-satellite data in a snow model.

- We calculate SWE through a hydrological model, which is very limited depending on the sparse meteorological network. To be able to update the model measurements of SWE is needed, and a combination of our manual measurements and satellite data would be perfect.
- As you properly already have noted (a lot of question without answer) am I without experience of satellite based snow cover products. The project sounds very interesting but I am hesitant if it is useful for me purpose. The most important information from my point of view is the amount of water stored in the snowpack during the accumulation and the melting period.
- Daily updated satellite images (snow products) with 1-5 m resolution for mapping of snow avalanche events on an daily basis.
- We are going to assimilate snow and lake ice products in Numerical Weather Prediction models. We hope this will make our forecasts better.
- high-resolution (1 km) snow water equivalent for mountainous terrain.
- Water equivalent in snow and depth or water equivalent all together for production planning in electric power plant.
- For SCA we need values for our model catchments (40). Relation between elevation and SCA is needed for each catchment. In melting season data is needed approximately every second day. Runoff forecasts could be improved, especially in rain periods when it is difficult to find out whether runoff comes from melting or rain. / / Ice and lake products are of interest at special occasions. A lake product is of interest when in the beginning and the end of the ice-season. A river ice product is of interest at special occasions, typically once a year.

6.51 Do you want to be informed on the progress of CryoLand and will participate in the User Group?

46 users answering the questionnaire agreed to participate in the CryoLand user group.