Documentation of Service Demonstration and Performance Document D5.5 – D5.8

Land Cover and Phenology: Deliverable 5.5

Snow mapping: Deliverable 5.6

Glacier products: Deliverable 5.7

Lake Ice products: Deliverable 5.8

Issue 1.0

Due date of deliverable: 1 June 2016
Actual submission date: 6 June 2016

SEN3APP

Processing Lines And Operational Services Combining Sentinel And In-Situ Data For Terrestrial Cryosphere And Boreal Forest Zone

FP7 Grant agreement No 607052

Document History

Date	Update	Contributor	Organization
06/04/2016	Initial draft and outline	Gabriele Bippus	ENVEO
10/05/2016	Documentation of ENVEO's Services Demonstration	Gabriele Bippus	ENVEO
16/05/2016	Land cover and phenology service documentation	Markus Törmä	SYKE
18/05/2016	Input to sections 4.1 and 4.5	Sari metsämäki	SYKE
25/05/2016	Glacier ice velocity service demonstration	Tazio Strozzi	GAMMA
25/05/2016	CryoLand GeoPortal	Gabriele Schwaizer	ENVEO
31/05/2016	Lake Ice Extent and Phenology services demonstration	Olli-Pekka Mattila	SYKE
31/05/2016	Update of Glacier and Snow services demonstration	Gabriele Schwaizer	ENVEO
01/06/2016	FMIARC GeoPortal	Mwaba Hiltunen	FMI
02/06/2016	Revision and homogenization of full document	Gabriele Schwaizer	ENVEO
06/06/2016	Input to Section 4.2	Mwaba Hiltunen, Matias Takala	FMI
06/06/2016	Final version	Gabriele Schwaizer	ENVEO

Document Release Sheet

Book captain:	Gabriele Schwaizer (ENVEO)	Sign Date
Approval (lead contractor for WP5)	Gabriele Schwaizer, WP Leader (ENVEO)	Sign Date
Endorsement:	Ali Nadir Arslan, Project Manager, (FMI)	Sign Date

Dissemination level	
Public	x
Restricted to a group (including the Commission Services) specified by the consortium	
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List of Acronyms:

AATSR	Advanced Along Track Scanning Radiometer
API	Application Programming Interface
CPS	Centre for Polar Studies
DEM	Digital Elevation Model
DHMS	Department of Hydro-Meteorological Service, Bhutan
DUE	Data User Element
ECMWF	European Centre for Medium-Range Weather Forecasts
ENVEO	Environmental Earth Observation IT GmbH
EO-WCS	Earth Observation – Web Coverage Service
EO-WMS	Earth Observation – Web Map Service
ESA	European Space Agency
ETRS	European Terrestrial Reference System
EU	European Union
EW	Extra Wide Swath
FMI	Finnish Meteorological Institute
FP7	Seventh Framework Programme
FSC	Fractional Snow Cover
FTP	File Transfer Protocol
GAMMA	GAMMA Remote Sensing AG
GLIMS	Global Land Ice Measurements from Space
GPS	Global Positioning System
GUIO	Department of Geosciences of the University of Oslo, Norway
HS	Hydrological Service
IP	Internet Protocol

IW	Interferometric Wide Swath
LIE	Lake Ice Extent
MAVI	MAVI
MERIS	Medium Resolution Imaging Spectrometer
MODIS	Moderate resolution Imaging Spectroradiometer
MSI	Multi-Spectral Instrument
NDSI	Normalized difference snow index
NDVI	Normalized difference vegetation index
NDWI	Normalized difference water index
NH	Northern Hemisphere
NPI	Norwegian Polar Institute
NPP	National Polar-orbiting Operational Environmental Satellite System Preparatory Project
NSDC	National Satellite Data Centre
NWP	Numerical Weather Prediction
OGC	Open Geospatial Consortium
OLCI	Ocean and Land Colour Imager
OLI	Operational Land Imager
PMW	Passive Microwave
REST	Representational State Transfer
RIE	River Ice Extent
RMSE	Root Mean Square Error
SAR	Synthetic Aperture Radar
SCAW	Wet Snow Covered Area
SD	Snow Depth

SLC	Single Look Complex
SLSTR	Sea and Land Surface Temperature Radiometer
SSMI/S	Special Sensor Microwave Imager Sounder
SSPI	Standardized Snow Pack Indicator
SSW	Snow Surface Wetness
STS	Snow Surface Temperature
SYKE	Finnish Environment Institute
SWE	Snow Water Equivalent
UK	United Kingdom
VH	Vertical / Horizontal polarization
VIIRS	Visible Infrared Imaging Radiometer Suite
VTT	Technical Research Centre of Finland
VV	Vertical / Vertical polarization
WCS	Web Coverage Service
WebGUI	Web Graphical User Interface
WMS	Web Map Service
ZAMG	Zentralanstalt für Meteorologie und Geodynamik

1. Introduction

In this document the demonstration of the SEN3APP products and services and their performances are described.

Twelve demonstration products (Table 1.1) are generated by different SEN3APP partners, and provided to users via the ERDAS Apollo System (WMS/WCS services) installed at FMI, the CryoLand GeoPortal (WebGUI and EO-WMS/EO-WCS services) and the associated server (access via file transfer protocol, FTP) installed at ENVEO, or directly sent or provided to particular end-users (e-mail, FTP), as described in Deliverable D2.4 – "Interfaces for product selection and access".

Detailed descriptions of products provided within the SEN3APP project, and applied algorithms are reported in Deliverable D3.2 – D3.7 – "Products and Algorithm/Processing Line Specification - Preliminary Document", and are thus not repeated here. The service characteristics are described in D5.1 – D5.4 – "Description of service characteristics".

The demonstration of the SEN3APP services and their performances are described in the following chapters, aim to meet as far as possible the user requirements identified at the beginning of the project period, documented in Deliverable D1.1 – "Product and Service Requirement Document".

Table 1.1: SEN3APP services participating in the demonstration phase.

Cate-gory	Product	Satellite / Sensor	Service status	Service provider	End-user
LAND COVER	Crop / vegetation classification	Sentinel-1 C-SAR / -2 MSI, Landsat 8 OLI	Pilot	SYKE	MAVI (Finland)
	Phenology Product	Terra MODIS	Under development	SYKE	SYKE, FMI
SNOW	Fractional Snow Cover (FSC) for NH	NPP VIIRS, Sentinel-3 SLSTR	Operational	SYKE & FMI	Community using snow cover information in hydrological, NWP and

Cate-gory	Product	Satellite / Sensor	Service status	Service provider	End-user
					climate change studies
	High resolution Pan-European SWE product	SSMI/S (PMW) & synoptic snow depth data	Operational	FMI	Fortum, SYKE, MetOffice UK, ECMWF
	Regional wet snow cover	Sentinel-1 C-SAR	Pilot	ENVEO	ZAMG, HS Tyrol (Austria), MetOffice UK (UK)
	Regional and pan-European FSC	Terra MODIS, NPP VIIRS, Sentinel-3 SLSTR & OLCI	Operational	ENVEO	ZAMG, HS Tyrol (Austria), MetOffice UK (UK)
	Extended Baltic Sea drainage basin direct broadcast FSC	NPP VIIRS, Sentinel-3 SLSTR	Operational	FMI & SYKE	Hydrological community
GLACIER	Glacier outlines	Sentinel-2 MSI	On demand	ENVEO	ZAMG, HS Tyrol (Austria), MetOffice UK (UK), DHMS (Bhutan)
	Glacier ice surface velocity	Sentinel-1 C-SAR / -2 MSI	On demand	ENVEO, GAMMA	ZAMG (Austria), MetOffice UK (UK), DHMS (Bhutan), NPI (Norway),

Cate-gory	Product	Satellite / Sensor	Service status	Service provider	End-user
					Department of Geosciences, Univ. of Oslo (Norway), Univ. of Silesia, Katowice (Poland)
	Snow / ice areas on glaciers	Sentinel-2 MSI / -1 C-SAR	On demand	ENVEO	ZAMG, HS Tyrol (Austria), MetOffice UK (UK), DHMS (Bhutan)
LAKE ICE	Lake ice extent	Sentinel-2 MSI / -3 SLSTR & OLCI, Terra MODIS, Landsat 8 OLI	Operational	SYKE	SYKE Freshwater centre (Finland)

2. SEN3APP Portal

SEN3APP products and services are provided through two geoportals: the FMIARC GeoPortal, installed at FMI, and the CryoLand GeoPortal hosted by ENVEO. Both portals are accessible through the SEN3APP Portal (http://sen3app.fmi.fi/index.php?style=main&page=Products).

2.1 FMIARC GeoPortal

Service provider: *FMI*

2.1.1 Service documentation

The FMIARC GeoPortal service (http://saana.nsdc.fmi.fi/fmiarc-geoportal/) is a commercial outbox software adopted by the Arctic Research Centre of FMI in 2012. The service offers high capabilities of handling a wide variety of large datasets and multiple users. Hence well suited to a wider user community.

The FMIARC GeoPortal server is implemented using OpenGeospatial Consortium (OGC) standards. Data is accessible from the web client and via http requests using the WMS, WCS, and REST API interface. This allows the user to also automate the download process by writing scripts that use the curl command to make the http requests.

2.1.2 Performance of FMIARC Erdas Apollo GeoPortal

The FMIARC-geoportal has been running operational since 2012. During this time there have been some upgrades, hence a few days downtime. To resolve this issue FMI will be installing a test fail back up system, which will be used in instances when upgrade.

2.1.2.1 General server operations and performance

The server running the FMIARC GeoPortal is hosted and operated by the FMI, and has the following general performance:

- Currently more than 2600 products are accessible on-line
- Products are ingested automatically with no user intervention.
- Products are made available automatically, when the user makes a request
- Operational automated processing lines do not require user intervention.
- 24/7 operational monitoring of the server and processing lines.
- Product processing lines are (mostly) automated, however some of the most complex products on the product provider side might require manual operations

- Since all products are ingested directly from operational processing lines in FMI, there are no product ingestion.
- It is very easy to add new datasets, with no pre-processing of the products and no changes are required to the FMIARC GeoPortal

2.1.2.2 *Data products offered through the FMIARC GeoPortal*

The following products are distributed through FMIARC GeoPortal. And are available using WCS and WMS.

- Fractional Snow Cover Extent for Northern Hemisphere from Optical Data
- High Resolution (5km) Pan-European SWE Product (Augmented Using Optical FSC)
- Extended Baltic Sea Drainage Basin Direct Broadcast FSC Based on NPP VIIRS/Sentinel-3 SLSTR

Other products that are distributed using other interfaces can also be accessed from the FMIARC GeoPortal. These include:

- Regional Wet Snow Cover from Sentinel-1 Data
- Regional and Pan-European Fractional Snow Cover Product from Synergistic Sentinel-3 SLSTR/OLCI Data
- Ice Velocity
- Phenology
- Crop / Vegetation Classification

2.2 CryoLand GeoPortal Service

Service provider: *ENVEO*

2.2.1 *Service documentation*

The CryoLand GeoPortal (http://neso1.cryoland.enveo.at/cryoclient/), implemented and established within the EU FP7 project CryoLand (2011 – 2015), has been widely accepted by European and international end-users. Thus, we decided to continue using this GeoPortal for providing existing and new services within the SEN3APP project additionally to the FMIARC GeoPortal to address a wider user community.

The implementation of the CryoLand GeoPortal is based on OpenGeospatial Consortium (OGC) standardized interfaces, and can be accessed in two ways:

- **Manual access using the CryoLand Interactive Map-Tool (WebGUI)**

  The CryoLand Interactive Map-Tool combines a Viewing Service (OGC Earth Observation Web Mapping Service [EO-WMS]) and a Downloading Service (OGC Earth Observation Web Coverage Service [EO-WCS]). The interface is mainly intended for human use to interactively explore the data offerings. All offered products can be viewed based on Area-of-Interest and Time-of-Interest.

  Multiple products can be viewed concurrently and overlays (e.g. forest, urban, glacier, water, country borders) are provided for better orientation and context relevant analysis. Legends for every product-group are supplied, describing the relationship between the product's color-coding and the physical/statistical value represented. An extensive Help section is also accessible directly from the WebGUI. Besides the basic WebGUI geographic navigation functions (Pan/Zoom/Coordinates) a timeline enables the user to select the Time-of-Interest.

  The integration of the direct access to the provided EO-WCS interface allows the simple download of a selected single dataset and as well as of a chosen time-series of data and even of multiple different datasets, corresponding to the selection criteria), concurrently. Additionally, by uploading a Shapefile (shp-file) containing a closed polygon the downloaded data can be a-priori limited to data only included in the area defined by the shp-file, e.g. representing a river-basin.

- **Automated access using HTTP**

  The system supports also automated download of products using EO-WMS and EO-WCS requests. This can be realized by simple scripts which generate an HTTP-KVP (HTTP – Key/Value Pairs) request. This method is mainly intended for automated usage e.g. as a machine-to-machine interface for decision systems developed by the users. Example scripts (in Python and IDL) are provided to users via the Help Section on the CryoLand GeoPortal.

  Access point: http://neso.cryoland.enveo.at/ows?

For a detailed description of available features and how to access and utilize the different access possibilities offered by the CryoLand GeoPortal, please see the following Documents:

- Detailed Description of Service Characteristics; (CryoLand project Deliverable D10.1), available at http://www.cryoland.eu

- "CryoLand4Newbies" - CryoLand's User Manual, available at: http://www.cryoland.eu and from the Help Menu of the CryoLand GeoPortal

2.2.2 Performance of CryoLand GeoPortal

The CryoLand GeoPortal has been up and running continuously since May 2012. Nearly no major downtime of the system has occurred. Smaller interruptions of the server connection can occur now and then, but are usually fixed within one working day.

2.2.2.1 General server operations and performance

The server running the CryoLand GeoPortal is hosted and operated by ENVEO, and has the following general performance:

- Currently more than 23'300 products are accessible on-line
- The CryoLand GeoPortal itself is running in an automatic mode, which requires no user intervention
- Pre-processing, ingestion, registration and provisioning of products is done automatically
- Product processing lines are (mostly) automated, however some of the most complex products on the product provider side might require manual operations
- Errors in the product ingestion procedure occur only rarely; mostly due to premature/incomplete file uploads (from product provider side to the GeoPortal)
- The CryoLand GeoPortal can be extended at any time to include further new products, as the multi-temporal wet snow cover service for the Alpine area developed and implemented within SEN3APP

2.2.2.2 Data products offered through the CryoLand GeoPortal

The current status of the data offered through the CryoLand GeoPortal is shown in Table 2.1.

Table 2.1:
Overview of number of data products offered by the CryoLand GeoPortal. Services operated within SEN3APP are indicated by bold style.

Area covered	***Product Type***	***No. of Products ****
Pan-European	**Fractional Snow Cover (FSC, incl. Uncertainty maps)**	**11'361**
	Snow Water Equivalent (SWE)	**3'522**
	Standardized Snow Pack Indicator (SSPI)	840
	MODIS RGB – composite of band 6, 5 and 1 (RGB651)	**604**
	10-day_cloud-free FSC (is daily newly calculated)	**1**
Alps	**Fractional Snow Cover (FSC)**	**2'011**
	Wet Snow Covered Area (SCAW)	**93**

Area covered	*Product Type*	*No. of Products **
Baltic	**Fractional Snow Cover (FSC)**	**791**
	Lake Ice Extent (LIE)	**676**
	10-day_cloud-free LIE (is daily newly calculated)	**1**
Scandinavia	Fractional Snow Cover (FSC)	1'352
	Wet Snow Covered Area (SCAW)	1'502
South Norway	Snow Surface Wetness (SSW)	282
	Snow Surface Temperature (STS)	282
Torne River	River Ice Extent (RIE)	1
Greenland	Glacier Images	8
	Glacier Lake Outlines	8
Austria	Glacier Images	1
	Glacier Outlines	1
Total		**23'337**

* as of June, 1st 2016

2.2.2.3 Downloaded data

Table 2.2, and Table 2.3 illustrate the monthly access and download statistics for the CryoLand GeoPortal for the years 2015 and 2016 (until 31 May 2016), respectively. The statistics show, as expected, that the most activity has been during the winter season. As some users have been aware of the service, they have downloaded large amounts of data, which shows spikes in the statistic in amount of data.

Table 2.2:
Traffic statistics of CryoLand GeoPortal showing number of visitors, visits and pages per month for the year 2015.

Month	*Unique visitors*	*Number of visits*	*Hits*	*Bandwidth*
Jan 2015	5	28	9,287	62.49 MB
Feb 2015	254	592	72,461	442.03 MB
Mar 2015	440	1,707	129,116	672.02 MB
Apr 2015	441	1,109	133,680	765.28 MB
May 2015	346	1,221	112,529	869.62 MB
June 2015	264	836	71,508	620.35 MB
July 2015	243	573	88,702	467.56 MB
Aug 2015	105	155	39,716	969.77 MB
Sep 2015	156	408	40,273	11.44 GB
Oct 2015	206	363	59,449	2.30 GB
Nov 2015	134	215	101,014	1010.96 MB
Dec 2015	111	177	73,079	392.96 MB

Month	Unique visitors	Number of visits	Hits	Bandwidth
Total	2,705	7,384	930,814	19.87 GB

Table 2.3:
Traffic statistics of CryoLand GeoPortal showing number of visitors, visits and pages per month for the year 2016 (January – May).

Month	Unique visitors	Number of visits	Hits	Bandwidth
Jan 2016	104	178	57,296	530.53 MB
Feb 2016	76	182	54,807	2.15 GB
Mar 2016	96	177	75,197	31.27 GB
Apr 2016	129	250	150,144	694.46 MB
May 2016	97	196	74,364	479.75 MB
Total	502	983	411,808	35.13 GB

2.2.2.4 *Origin of users*

The origin of end users accessing the CryoLand GeoPortal can be identified using the web statistics. Figure 2.1 provides the usage statistics for the CryoLand GeoPortal in 2015 (full year) and 2016 (until 1 June 2016), where access by country is shown, sorted by the number of accessed pages.

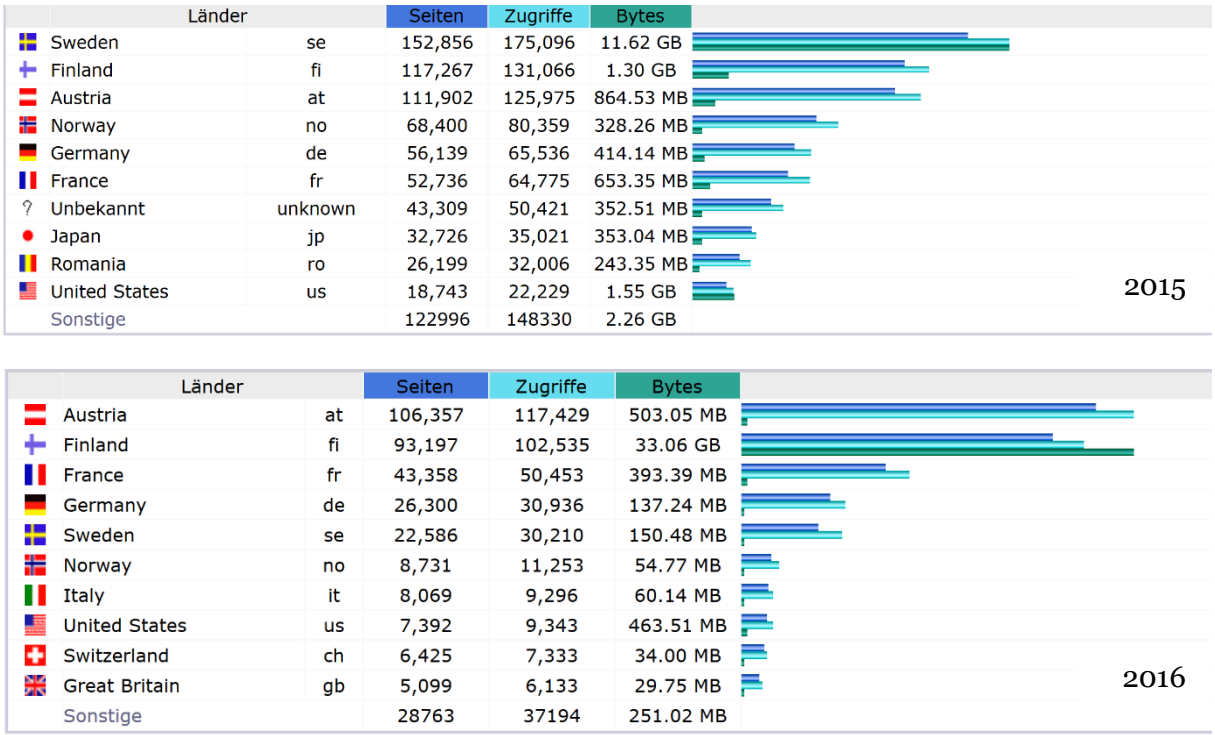

Figure 2.1: Access by country (top 10) in 2015 (top) and 2016 (bottom, status of 1 June 2016) sorted by accessed pages. Headers are in german: Länder = countries; Seiten = pages; Zugriffe = hits; Bytes = amount of downloaded data.

The statistics are based on the IP-range where for some reason not all IP-addresses are possible to make a successful lookup, resulting in unknown user origin. The statistics show that in 2015 most pages have been visited by users from Sweden, followed by Finnish users, while in 2016 most pages were visited by Austrian users followed by users from Finland. The statistics also shows that Swedish users have downloaded most data in 2015, and Finnish users have downloaded most data in 2016. The huge amounts of downloaded data usually occur when users download the full time series of the Pan-European Fractional Snow Cover product from 2000 till present.

3. Documentation of Service Demonstration and Performance for Land Cover and Phenology products (D5.5)

3.1 Crop/vegetation classification

Service provider: *SYKE*

The Agency for Rural Affairs (MAVI, Maaseutuvirasto) is responsible for control of EU agricultural subsidies. They need tools and processes to decrease the work-load of control and shorten the time used for control. Specific needs include plant classification, at least in general level, and information of ploughing of agricultural parcels.

The test area is in South-Western Finland. The images (Sentinel-1, Landsat-8, Sentinel-2) have been processed for area which upper left corner is lat. 61° 38'N long. 21° 25'E and lower right lat. 60° 6'N long. 25° 15'E. MAVI will provide the shapefile of agricultural parcels for summer 2016 and more precise area of interest with farmer's plant information during early June. This information will be used as training data for plant classification.

The aim of this service is to provide information for agricultural parcels that can be used to aid agricultural subsidy control of farmers.

3.1.1 Documentation of service demonstration

The service characteristics for crop/vegetation classification are provided in Table 3.1.

Table 3.1: Crop/vegetation classification characteristics.

Service status	Pilot. Summer 2015 was used for development and testing of service, summer 2016 will be pilot phase.
Service limitations	Heavy rain before and during image acquisition may limit the usefulness of image.
Spatial extent	60°6'N – 61°38'N, 21°25'E – 25°15'E
Spatial resolution	Sentinel-1 images are resampled to 20 m pixel, Sentinel-2 10 m, Landsat-8 25 m. These are used to compute parcel wise mean backscatter or reflectance values.
Temporal resolution	Growing season, from April to October.
Map projection	ETRS TM35FIN (EPSG 3067)
Satellite instrument	Sentinel-1, Landsat-8, Sentinel-2
Latency time	MAVI needs information about agricultural parcels in early August.
Length of service	Summer 2015 development phase, summer 2016 pilot.
Service operator	SYKE
Data access	Shapefile table using email, images using FTP, WMS under consideration.

3.1.2 Performance of products and service

The annual deadline for data delivery for MAVI is the early August. Therefore, the plant and ploughing classification is based on Landsat-8, Sentinel-1 and -2 time series of images from late March to late July. Also, late autumn images from previous season can be used.

The following satellite images will be used during summer 2016:

- Sentinel-1: Interferometric Wide (IW) swath-product, spatial resolution 5x20m, VV- and VH-polarizations. Extra Wide (EW) swath-product can be used if IW is not available but spatial resolution is poorer. Image processing (geometric and radiometric correction) will be done using ESA SNAP-toolbox.
- Sentinel-2: NDVI-computation and mosaicking using Sodankylä Calvalus-system or Erdas Imaging. These images were not used during 2015 due to lack of data.
- Landsat-8 OLI: Images are preprocessed using ENVIMON-software developed by VTT. NDVI-computation and mosaicking using Sodankylä Calvalus-system or Erdas Imaging.

The reliability of service depends on the availability of Sentinel-1 IW-images. EW-images could also be used but they have poorer resolution decreasing accuracy.

Service development was done during summer 2015. Due to poor weather conditions, the optical time series (i.e. Landsat-8) was so poor that it was not used. Plant and ploughing classification was made using Sentinel-1 SAR images. Plant classification (winter cereal, spring cereal, peas, potato, rapeseed, and grasses) was successful, the overall accuracy was about 95%. Summer 2016 will be service pilot phase. We expect that due to increased amount of optical imagery, the ploughing classification can be better and distinguish also lightly ploughed parcels, instead of basic ploughed / not-ploughed classification.

3.1.3 Product evolutions during demonstration phase

The product will be modified according to user feedback if it is technically possible.

3.2 Phenology product

Service provider: *SYKE*

3.2.1 Documentation of service demonstration

The phenological events derived from optical satellite data are largely a product under development. There is strong interest towards the product in the research community and it

has had applications in the estimation of CO_2- fluxes (Böttcher et al., 2014) and in estimating the moth peak flight period (Costa et al., 2014, CLIPC Deliverable 7.2.).

Table 3.2: The main characteristics of the phenology product and service.

Service status	Under development
Service limitations	Currently onset of vegetation active period available for deciduous and coniferous vegetation separately. Cloud cover and polar night (low light conditions). These restrictions apply to the underlying indices datasets (FSC, NDVI, NDWI), but as the product is fundamentally based on time-series the effect of the restrictions are less effective.
Spatial extent	Finland
Spatial resolution	0.05° (~5km)
Temporal resolution	Annual maps
Map projection	Geographical, WGS-84
Satellite instrument	MODIS
Latency time	Annual
Length of service	2001 – ongoing
Service operator	SYKE
Data access	Upon request (Kristin.bottcher@ymparisto.fi) FMI-ARC GeoPortal: http://saana.nsdc.fmi.fi/fmiarc-geoportal/ (sample products)

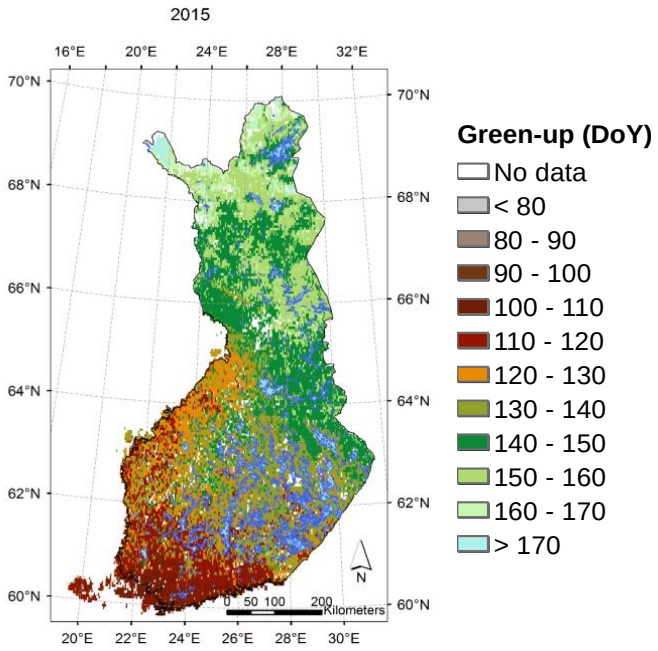

Figure 3.1: Sample phenology product in 2015. Green-up i.e. start of vegetation active period of deciduous forests in Finland. Day of year from start of the year.

The product comprises currently the onset of vegetation active period for boreal coniferous and deciduous forests. With the application of optical satellites, the determination of end of vegetation active period suffers from low light conditions in the high Northern latitudes. The research for methodology for determining these is ongoing.

3.2.2 Performance of the product and service

The product was compared to CO_2 -flux measurements and phenological field observations (Böttcher et al., 2014). The comparison shows a good agreement between the product and in-situ data. The calibration of satellite indicators to start of vegetation active period from CO_2 flux measurements provides possibility to evaluate the spatial distribution of land-surface model-derived beginning of growing season against satellite observations.

The product has also proven to have some predictive power for moth species with peak flight period in spring (CLIPC, Deliverable 7.1). The cloud cover and polar night are the main constraints for optical satellite products and services. As the phenology products are based on time-series of indices based on satellite data, they are not so sensitive to individual days of clouds. On the other hand, long cloudy periods are not uncommon in Northern latitudes during spring time, and therefore the product can suffer from weather conditions.

Polar nights are making the development of methodology for extracting the end of vegetation active period from the time-series more challenging, due to low light conditions in the high Northern latitudes. Preliminary efforts have been made, but the full methodology is still under research and development.

Sample products are found in the FMI-ARC Geoportal (http://saana.nsdc.fmi.fi/fmiarc-geoportal/).

4. Documentation of Service Demonstration and Performance for Snow Products (D5.6)

4.1 Fractional Snow Cover extent for Northern Hemisphere from optical data

Service provider: *SYKE & FMI*

4.1.1 Documentation of service demonstration

The near real time fractional snow cover service for the northern hemisphere is currently based on NPP VIIRS data, and is provided daily with 0.01° x 0.01° pixel size. The processing chain for the product generation can be transformed to use Sentinel-3 SLSTR data as input as soon as these data will become available in near-real time. An example of the current product is shown in Figure 4.1. The detailed product and service characteristics are summarized in Table 4.1.

Figure 4.1: SEN3APP Northern Hemisphere FSC product for 25 February 2016.

Table 4.1: Service characteristics for northern hemisphere fractional snow cover extent.

Service status	operational
Service limitations	polar night, clouds
Spatial extent	25°N–84°N, 168°W–192°E
Spatial resolution	0.01°, ~ 1 km
Temporal resolution	daily, thorough the years
Map projection	Geographical, WGS-84
Satellite instrument	VIIRS at the moment, transition to S3 SLSTR whenever available
Latency time	3-6 hours after satellite overpass
Length of service	Service running as a legacy of GlobSnow NH Snow Extent product
Service operator	FMI & SYKE
Data access	FMI-ARC GeoPortal: http://saana.nsdc.fmi.fi/fmiarc-geoportal/, FTP

4.1.2 *Performance of products and service*

The service is operational and daily with a 3-6 hours latency time. Products are provided through the FMIARC GeoPortal (Figure 4.2).

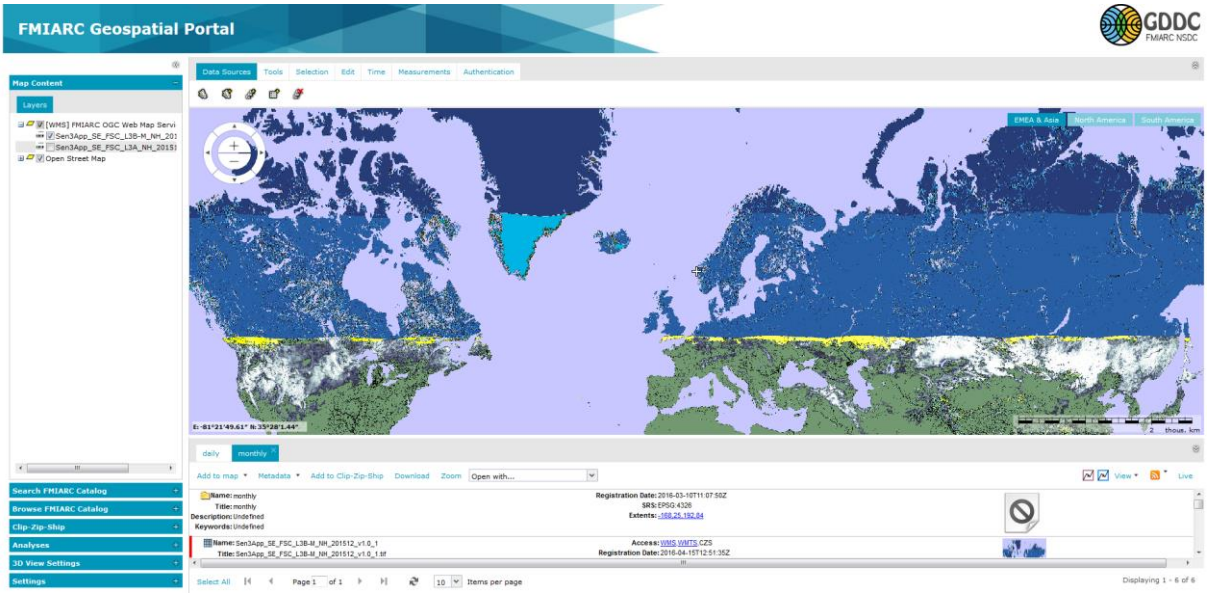

Figure 4.2: An example of the Fractional Snow Cover extent for Northern Hemisphere from optical data product from December, 2015, as shown in the FMIARC GeoPortal.

The product has been validated against high-resolution (Landsat) snow maps in different parts of the Eurasia and also against in-situ observations (Snow Depth and Snow Cover Fraction) over Finland. The evaluations were made within the ESA DUE-GlobSnow project, but are relevant for this product.

4.2 High resolution (5km) Pan-European SWE product (augmented using optical FSC data)

Service provider: *FMI*

4.2.1 *Documentation of service demonstration*

The Snow Water Equivalent (SWE) product is based on passive microwave observations and SYNOP weather station snow depth observation. The product is generated by an assimilation process resulting in maps of SWE estimates (0.05 degrees, WGS84 grid) over the Pan-

European region, covering all land surface areas with the exception of mountainous regions. A semi-empirical snow emission model is used for interpreting the passive microwave (radiometer) observations through model inversion to the corresponding SWE estimates. The SWE product is provided in spatial resolution of about 5 km on a daily basis covering the Pan-European area. The methodology provides the snow water equivalent in millimetres which can also be used to determine snow depth and snow mass. An example of the current product is shown in Figure 4.3. The detailed service characteristics are summarized in Table 4.2Table 4.2

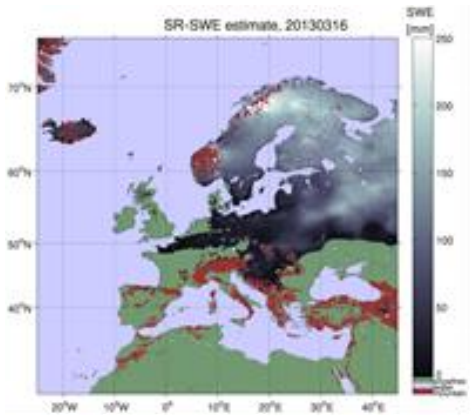

Figure 4.3: Pan-European SWE product example.

Table 4.2 Service characteristics for the high resolution Pan-European SWE product.

Service status	operational since 2016
Service limitations	mountains are excluded from the product
Spatial extent	25°N–84°N, 168°W–192°E
Spatial resolution	0.05°, ~ 5 km
Temporal resolution	daily
Map projection	Geographical, WGS-84
Satellite instrument	DMSP F18 (before breakup F17), SSMI/S, ECMWF synop Snow Depth
Latency time	< 2 days
Length of service	Service running since Feb 2015
Service operator	FMI
Data access	FMI-ARC GeoPortal: http://saana.nsdc.fmi.fi/fmiarc-geoportal/

4.2.2 *Performance of products and service*

The high resolution Pan-European SWE product is an operational product, provided with about two days latency time. The products are provided through the FMIARC geoportal as shown in Figure 4.4.

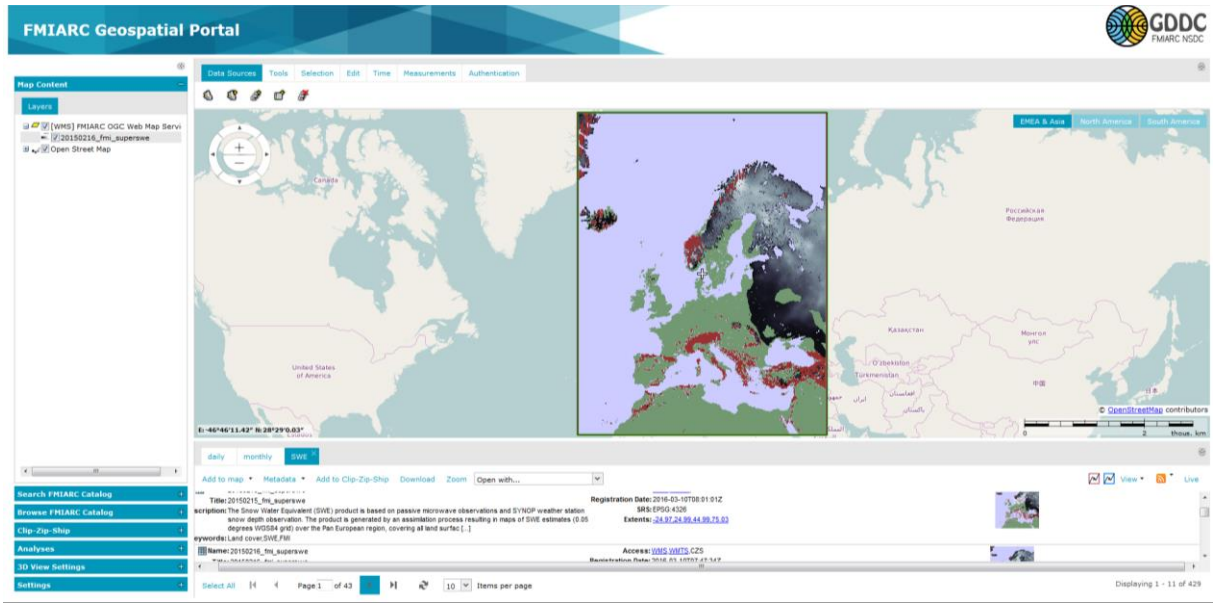

Figure 4.4: An example of the High resolution (5km) Pan-European SWE product (augmented using optical FSC data) on 16 February 2015, as shown in the FMIARC GeoPortal.

4.3 Regional wet snow cover from Sentinel-1 data

Service provider: *ENVEO*

4.3.1 *Documentation of service demonstration*

The Wet Snow Cover product is generated for the Alpine area (49.5°N/4.5°E – 43.5°N/17.0°E) with 0.001° x 0.001° pixel size from Sentinel-1 C-SAR data. Demonstration products were generated for the melting seasons 2015 and 2016 (ongoing). The detailed service characteristics are summarized in Table 4.3.

The products are provided through the SEN3APP portal, and accessible via the CryoLand GeoPortal. Figure 4.5 shows an example of the Alpine Wet Snow Cover product as shown in the CryoLand GeoPortal.

Table 4.3: Service characteristics for alpine wet snow cover.

Service status	pilot
Service limitations	radar shadow, radar layover, forested areas and water bodies are masked. Dry (cold) snow has very similar backscatter signals as bare ground; thus, these surfaces types are combined in one class.
Spatial extent	43.5°N – 49.5°N, 4.5° E – 17.0° E
Spatial resolution	0.001°, ~ 100 m
Temporal resolution	Melting season, multi-temporal (6 days repeat time per track)
Map projection	Geographical, WGS-84
Satellite instrument	Sentinel-1A/B C-SAR
Latency time	Currently irregular product generation, aimed on < 1 day
Length of service	Demonstration products available since the melting season 2015
Service operator	ENVEO
Data access	CryoLand GeoPortal: http://neso1.cryoland.enveo.at/cryoclient/, FTP

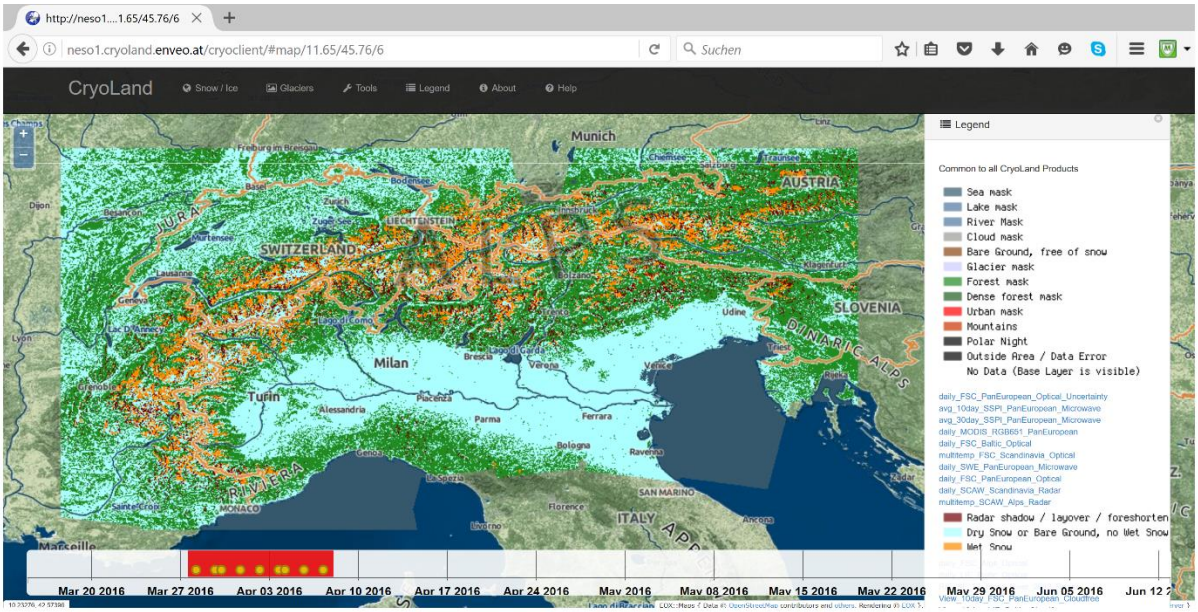

Figure 4.5: Example of the wet snow cover product over the Alpine area. For full coverage of the area, Sentinel-1 tracks from multiple days are needed. The example shows the wet snow from S1A tracks acquired from 28 March till 7 April 2016, as presented in the CryoLand GeoPortal.

4.3.2 Performance of products and service

The wet snow cover service for the Alpine area is currently running as a pilot service. Products are generated during the melting season in the Alpine area. So far, the production is performed at irregular intervals, as the processing chain is still under improvement. A more regular and thus more reliable service, transforming the current pilot service to a pre-operational service is planned for the melting season 2017.

Validation of the wet snow cover products is an ongoing process. First evaluation tests were performed for the Alpine area and over Island (Nagler et al., 2016). Further evaluation activities are ongoing, and results will be documented in the validation report (D4.4).

4.3.3 Product evolutions during demonstration phase

The wet snow cover product for the Alpine area has been developed during the SEN3APP project. Users from Romania and United Kingdom asked after the SEN3APP dissemination workshop in Vienna on 19 April 2016 for testing the product generation also for their countries. The preparation for these new test sites is ongoing.

4.4 Regional and Pan-European FSC product from synergistic Sentinel-3 SLSTR/OLCI data

Service provider: *ENVEO*

4.4.1 Documentation of service demonstration

The Fractional Snow Cover product for the Pan-European area (72°N/11°W – 35°N/50°E) with 0.005° x 0.005° pixel size from MODIS Terra data was developed within the EU FP7 project CryoLand, and is provided daily in near-real-time since 2012 by ENVEO. The service has been continued based on MODIS Terra data within SEN3APP, as Sentinel-3 data were not available within the SEN3APP demonstration phase.

The service characteristics are summarized in Table 4.4.

Table 4.4: Service characteristics for Pan-European fractional snow cover.

Service status	operational
Service limitations	Pixels affected by polar night, cloud cover and water bodies are masked
Spatial extent	25°N – 72°N, 11.0°W – 50.0°E
Spatial resolution	0.005°, ~ 500 m
Temporal resolution	Daily, full year

Map projection	Geographical, WGS-84
Satellite instrument	MODIS Terra, in future Sentinel-3 SLSTR/OLCI
Latency time	< 7 hours
Length of service	Service online since 2012, products available from Dec 2000 - present
Service operator	ENVEO
Data access	CryoLand GeoPortal: http://neso1.cryoland.enveo.at/cryoclient/, FTP

The products are provided through the SEN3APP portal, and accessible via the CryoLand GeoPortal. Figure 4.6 shows an example of the Pan-European Fractional Snow Cover product as shown in the CryoLand GeoPortal. For particular end-users this product is tailored to specific needs, and provided directly via FTP.

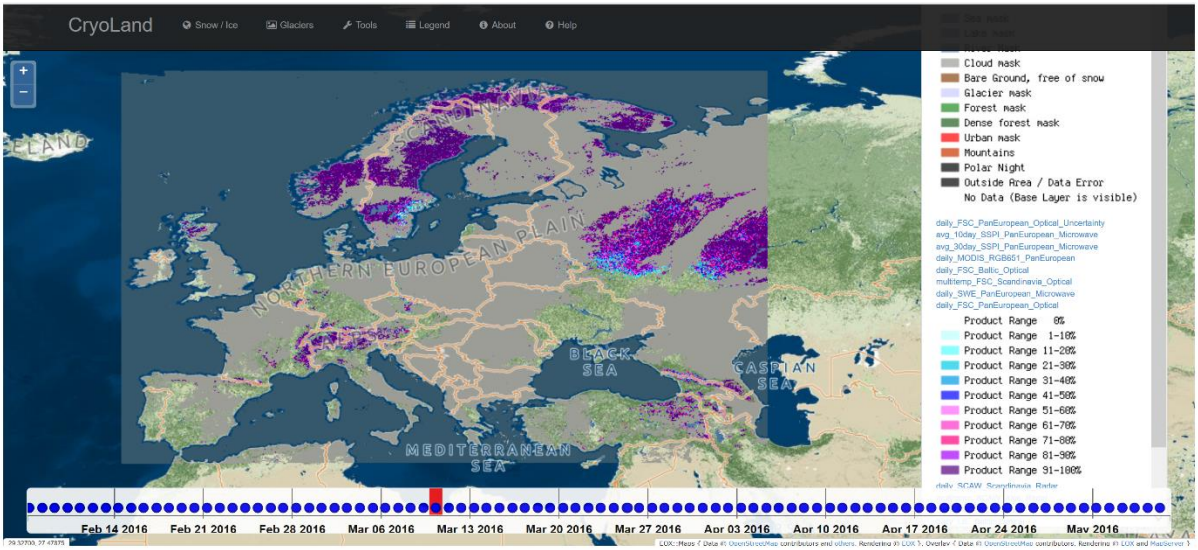

Figure 4.6: Example of the Pan-European Fractional Snow Cover product of 11 March 2016, as provided in the CryoLand GeoPortal.

A statistical estimate of (non-biased) error standard deviation for each clear-sky pixel of the Pan-European Fractional Snow Cover product is provided daily as associated uncertainty information. The uncertainty information is provided for the same spatial and temporal extent and resolution as the Pan-European Fractional Snow Cover product. Figure 4.7 shows the uncertainty layer associated to the product shown in Figure 4.6.

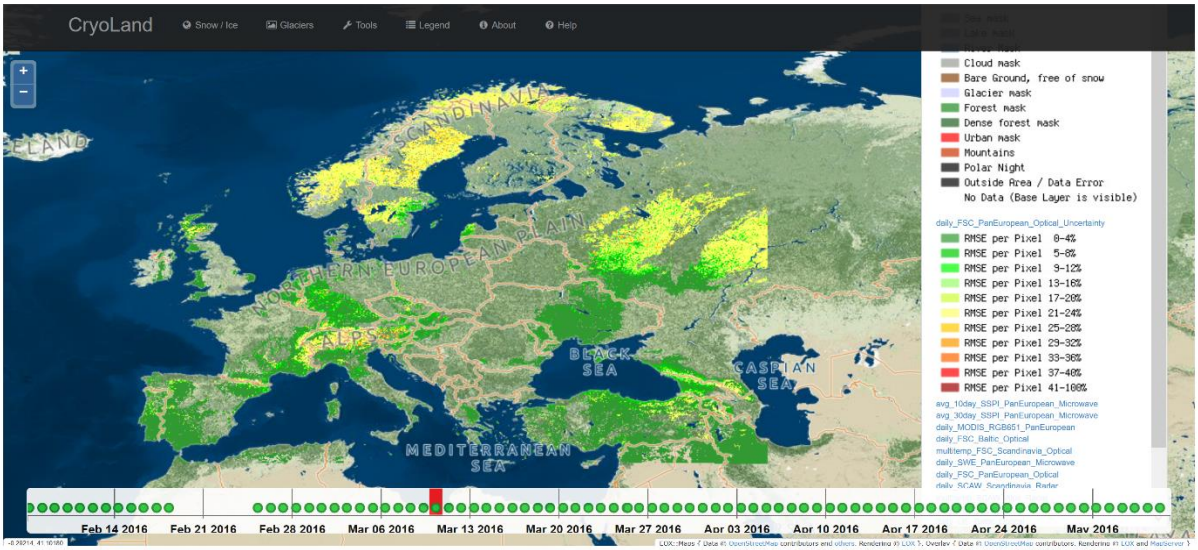

Figure 4.7: Example of the Pan-European uncertainty layer (unbiased RMSE, bottom) associated to the Pan-European FSC product of 11 March 2016, as provided in the CryoLand GeoPortal.

Additional to the Pan-European Fractional Snow Cover service, ENVEO provides operationally the daily Fractional Snow Cover product for the full Alpine area (49.57°N/4.66°E to 43.62°N/17.77°E) from Terra/MODIS data with a pixel size of 0.0025° x 0.0025°, which is approximately 250 m x 250 m. The algorithm applied for the product generation is particularly developed by ENVEO for high alpine, non-forested terrain. The service characteristics are summarized in Table 4.5.

Table 4.5: Service characteristics for alpine fractional snow cover.

Service status	operational
Service limitations	Pixels affected by cloud cover and water bodies are masked, snow in forested in classified binary
Spatial extent	43.62°N – 49.57°N, 4.66°E – 17.77°E
Spatial resolution	0.0025°, ~ 250 m
Temporal resolution	Daily, full year
Map projection	Geographical, WGS-84
Satellite instrument	MODIS Terra, in future Sentinel-3 SLSTR/OLCI
Latency time	< 3 - 6 hours
Length of service	Service online since 2012, products available from Oct 2011 - present
Service operator	ENVEO
Data access	CryoLand GeoPortal: http://neso1.cryoland.enveo.at/cryoclient/, FTP

The FSC products over the full Alpine area are provided via the CryoLand GeoPortal (Figure 4.8).

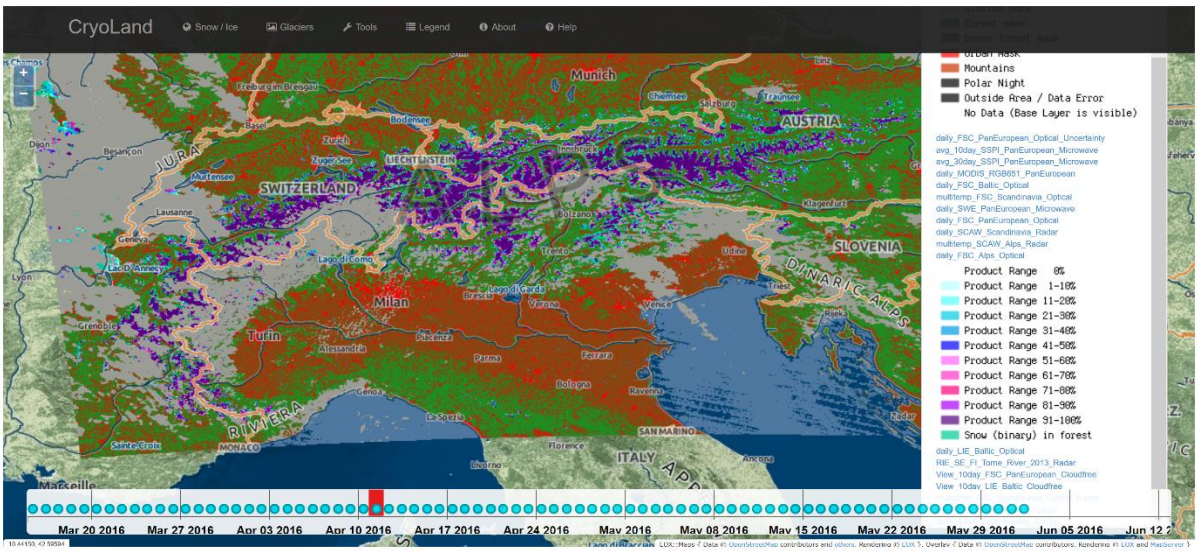

Figure 4.8: Example of the Alpine Fractional Snow Cover product of 11 April 2016, as provided in the CryoLand GeoPortal.

The processing chains for retrieving fractional snow cover for the Pan-European and the Alpine area from Sentinel-3 SLSTR and OLCI data have been prepared and were locally tested with archived Envisat MERIS and AATSR data, which have similar spectral and spatial characteristics as the Sentinel-3 instruments.

4.4.2 Performance of products and service

The Pan-European snow service runs fully operational and products are provided all the year round in near-real time whenever the required input satellite data are available in near-real time. The Pan-European FSC products and the associated uncertainty layer are provided within 7 hours after the image acquisition over the full area is completed.

Also the regional snow extent service for the Alpine area from optical satellite data runs fully operational, and products are provided daily all the year round in near-real time with only 3 – 6 hours latency time after image acquisition.

Recently, there were some problems with the near-real time availability of Terra MODIS data, currently used as input for the Pan-European and the Alpine FSC services. In such cases, data of NPP VIIRS are used for continuing the product generation in near-real time. As soon as MODIS data become available the products are reprocessed for that data. As soon as Sentinel-3 SLSTR and OLCI data will become available in near-real time the processing chains will be transformed to use these data as input.

Validation of all the snow products is an ongoing process. The Pan-European FSC product from MODIS data participates in the ESA SnowPEx – The satellite snow product intercomparison and evaluation exercise. For evaluation purposes, the product is compared with snow maps generated from multiple high resolution optical satellite data, mainly from Landsat, and with snow depth in-situ data made by courtesy available from various providers.

Intercomparisons of the Pan-European FSC products with more than 500 snow maps from (very) high resolution satellite data show a mean unbiased Root Mean Square Error (RMSE) < 20 % for the total areas, with about ± 10 % Bias. But, uncertainty can increase for instance for forested or mountainous areas.

The quality of the regional FSC product for the Alpine area has also been assessed by intercomparison with snow maps from Landsat data and with in-situ data available for Austria. The mean unbiased RMSE for this product is < 25 % with ± 6 % Bias.

Detailed validation results will be described in the SEN3APP Deliverable D4.4.

4.5 Extended Baltic Sea drainage basin direct broadcast FSC based on NPP VIIRS/Sentinel-3 SLSTR

Service provider: *SYKE & FMI*

4.5.1 Documentation of service demonstration

The extended Baltic Sea drainage basin direct broadcast Fractional Snow Cover (FSC) service is currently based on NPP VIIRS data, but the processing chain is ready to use Sentinel-3 data as input as soon as these data will become available in near-real time. Products are currently generated daily with 0.01° x 0.01° pixel size, but the spatial resolution will soon be improved to ~500 m as planned. As cloud cover is often affecting the daily products, composites of multiple days are provided, showing the most recent clear sky pixel information. Thus, the current status of the snow extent can be better visualized. An example of such a composite is shown in Figure 4.9.

The detailed service characteristics are provided in Table 4.6.

Table 4.6: Service characteristics for extended Baltic Sea drainage basin direct broadcast FSC.

Service status	operational
Service limitations	Pixels affected by polar night, clouds, or open water bodies are masked
Spatial extent	38°N-72°N, 11°W-65°E

Spatial resolution	(0.01⁰, ~ 1 km)
Temporal resolution	daily, thorough the years
Map projection	Geographical, WGS-84
Satellite instrument	VIIRS at the moment, transition to S3 SLSTR whenever available
Latency time	3-6 hours after satellite overpass
Length of service	Service running from February 2016 in its current form (extended area)
Service operator	SYKE & FMI
Data access	FMI-ARC GeoPortal: http://saana.nsdc.fmi.fi/fmiarc-geoportal/, FTP

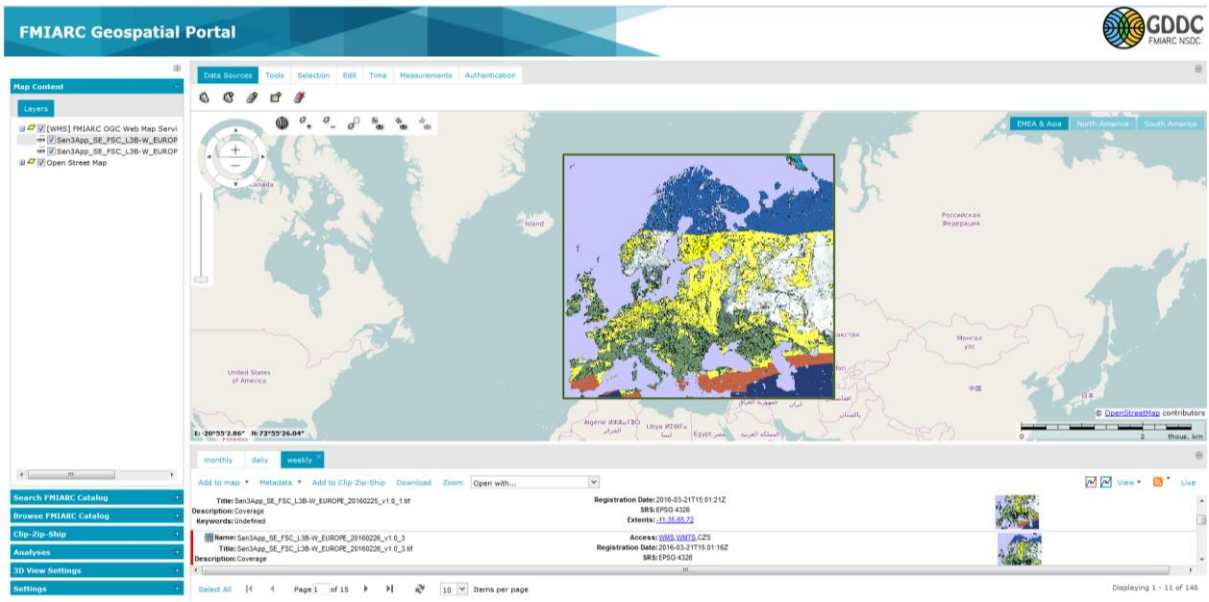

Figure 4.9: An example of the Extended Baltic Sea FSC product, as shown in the FMIARC GeoPortal. This is a weekly composite containing contributions from the last seven days' maps, in this example from 19 to 26 February 2016.

4.5.2 *Performance of products and service*

The service is a fully automatized, ready established operationally running system. Gaps in the spatial map are mostly due to the cloud coverage, although some missing data may occur (with VIIRS).

Products provide sub-pixel Fractional Snow Cover (FSC) with an accuracy < 20%.

5. Documentation of Service Demonstration and Performance for Glacier Products (D5.7)

5.1 Glacier outlines

Service provider: *ENVEO*

5.1.1 Documentation of service demonstration

The glacier outline service is only active on demand for selected regions identified by the interested user. The product is generated with 10 m x 10 m pixel size from Sentinel-2 data acquired as close as possible to the date with maximum ablation area, and at clear sky conditions over the glaciated areas.

The glacier outline products generated within the SEN3APP project meet the internationally accepted standard defined by GLIMS (Global Land Ice Measurements from Space), as well as the INSPIRE standards.

The product is delivered directly to the user requesting the service for a particular region via FTP or per e-mail.

The service characteristics are summarized in Table 5.1.

Table 5.1: Service characteristics for glacier outlines.

Service status	On demand
Service limitations	Satellite image for product generation must be acquired as close as possible to the date with maximum ablation area, with clear sky conditions over the glaciers of interest. Glaciers affected by cloud cover or extensive seasonal snow have to be excluded from product generation. Also rock glaciers are excluded from this service.
Spatial extent	Selected glacier regions, as requested
Spatial resolution	10 m
Temporal resolution	Depends on availability of satellite data meeting the acquisition requirements
Map projection	UTM, WGS-84
Satellite instrument	Sentinel-2 MSI
Latency time	< 3 months
Length of service	Service only active on demand
Service operator	ENVEO
Data access	FTP, e-mail

Figure 5.1 shows an example of the glacier outline product.

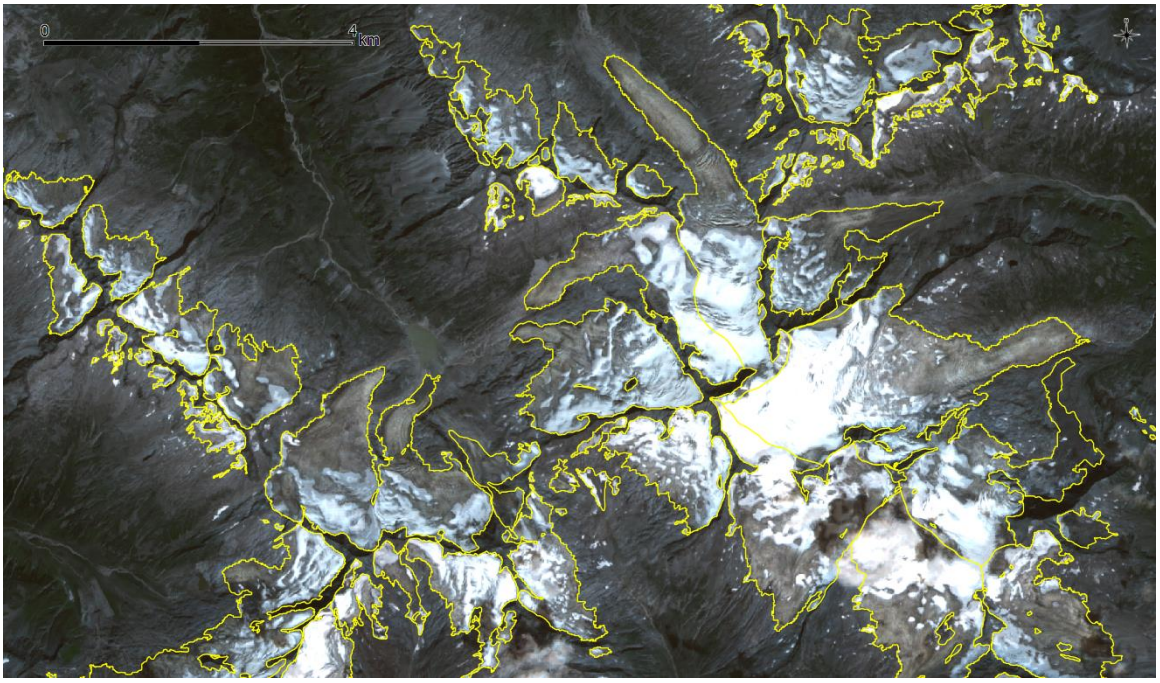

Figure 5.1: Example of glacier outlines mapped from Sentinel-2 scene of 13 August 2015 over the mountain group Venedigergruppe in Austria.

5.1.2 Performance of products and service

The glacier outline products from Sentinel-2 data are generated only on user demand. The service is limited by the availability of useful satellite data, as an image has to be acquired as close as possible to the date with maximum ablation area, and the glaciated areas of interest have to be free of clouds or cloud shadows. During the SEN3APP demonstration phase, one Sentinel-2 scene was available, acquired during the commissioning phase over an user's area of interest in Austria. This scene meets for the most part these requirements, but a few glaciers are affected by clouds and/or cloud shadows, and are thus excluded from any analyses.

The quality of the product can currently only be roughly estimated, due to the lack of usable reference data, although a WorldView-2 scene acquired on the same date as the Sentinel-2 scene was ordered and received by courtesy from the Copernicus Data Warehouse. Unfortunately, the geolocation of the delivered WorldView-2 scene does not match the geolocation of the Sentinel-2 scene, probably due to the usage of different digital elevation models for the orthorectification. But both, the WorldView-2 and the Sentinel-2 scene are only made available as orthorectified data by the providers.

As the service depends strongly on the availability of useful satellite images a reliable annual update of glacier outlines as requested by many users cannot be assured. But, with acquisitions of Sentinel-2A and its twin Sentinel-2B, planned to be launched in mid-2016, the repeat time cycle improves to 5 days. Thus, the chances for getting useful satellite images for more frequent glacier outline monitoring will increase significantly.

5.2 Glacier ice surface velocity over Svalbard

Service provider: *GAMMA*

5.2.1 Documentation of service demonstration

The glacier ice surface velocity service over Svalbard provided by GAMMA is a pre-operational service based on Sentinel-1 C-SAR data. Products are generated every 12 days with 100 m x 100 m pixel size.

The service characteristics are summarized in Table 5.2. Figure 5.2 shows a time series of ice surface velocities over Svalbard derived from Sentinel-1 data from 28 January 2016 till 16 May 2016.

Table 5.2: Service characteristics of glacier ice surface velocity over Svalbard.

Service status	Pre-operational service
Service limitations	N/A
Spatial extent	76.4°N – 80.9°N, 10°E – 30°E
Spatial resolution	100 m
Temporal resolution	12 days, All year around (subject to Sentinel-1 data acquisition)
Map projection	UTM 33N, WGS-84
Satellite instrument	Sentinel-1 C-SAR
Latency time	< 5 days
Length of service	Mid of April 2016 – present
Service operator	GAMMA
Data access	SFTP at dropbox.gamma-rs.ch

5.2.2 Performance of products and service

The product is currently provided within 5 days after satellite data acquisition, but it is planned to improve the latency time to < 1 day after satellite data availability.

Up to the end of May 2016 the reliability of the service on a pre-operational status is very high.

Preliminary validation performed by users with use of in-situ GPS stations and stakes over South Spitsbergen indicate good quality. Details will be reported in the validation report (D4.5).

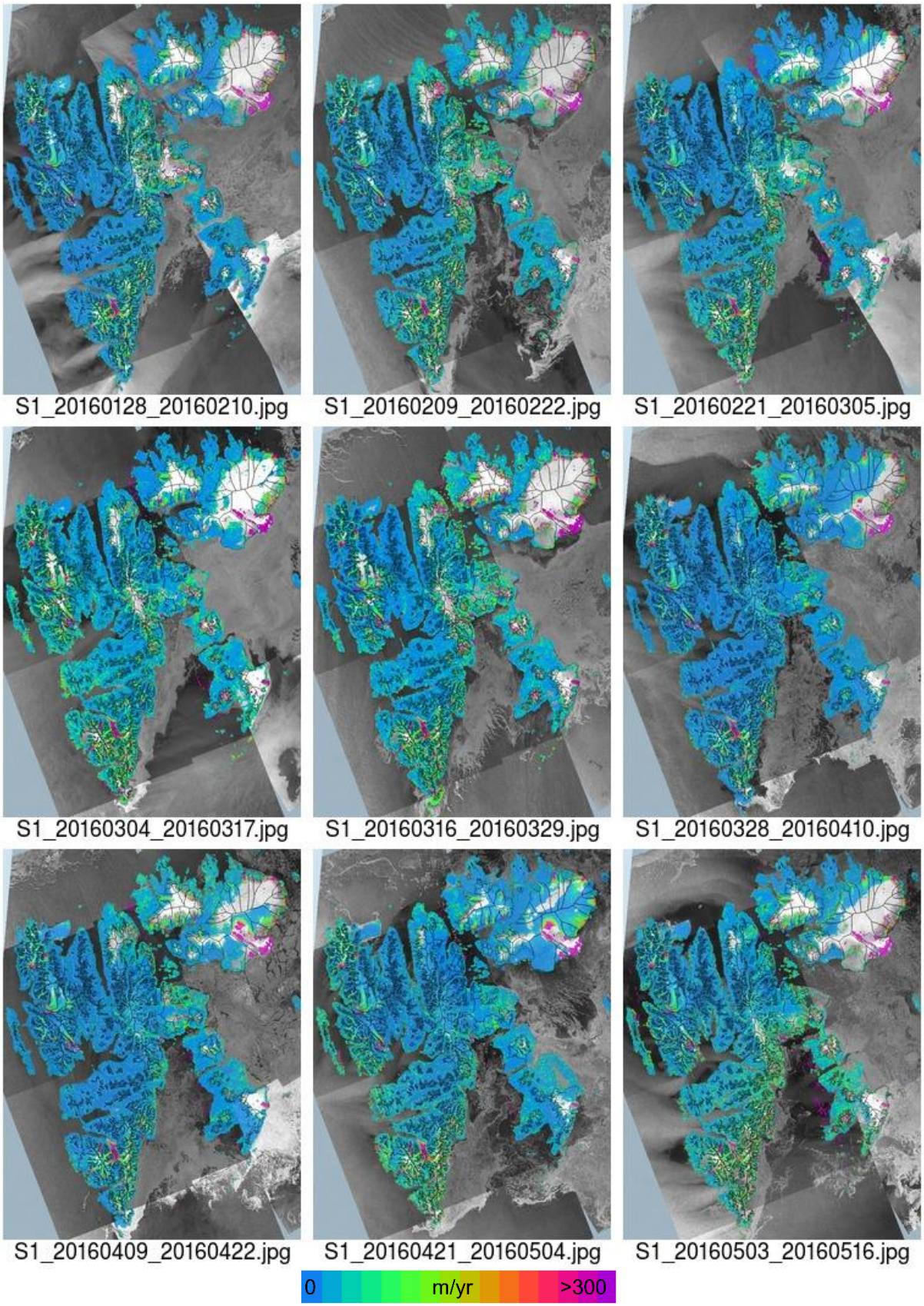

Figure 5.2: Time series of ice surface velocities over Svalbard from Sentinel-1 data.

5.2.3 Product evolution during the demonstration phase

After requests of the users Norwegian Polar Institute (NPI, Tromsø, Norway), Department of Geosciences of the University of Oslo (GUIO, Norway), the Centre for Polar Studies (CPS) and the Faculty of Earth Sciences of the University of Silesia (Katowice, Poland) the relative calibrated backscattering intensity images have been changed during the demonstration phase to absolute calibrated backscattering intensity images, which are provided to the users.

5.3 Glacier ice surface velocity

Service provider: *ENVEO*

5.3.1 Documentation of service demonstration

The glacier ice velocity service is only active on demand for selected regions identified by the interested user. The SEN3APP demonstration products for selected glaciers in northern Greenland were generated with 250 m x 250 m pixel size from repeat-pass Sentinel-1 IW SLC data. The product is delivered directly to interested users via FTP or per e-mail.

The service characteristics are summarized in Table 5.3.

Table 5.3: Service characteristics for glacier ice velocity.

Service status	On demand
Service limitations	The characteristics of the used SAR data (e.g. acquisition mode, temporal base line) determine the detectable glacier size and ice motion. For offset tracking from S1A IW SLC data the size of the observed glacier region (e.g. tongue) should be larger than 1 km in line of sight of the SAR beam, and ice velocity should be minimum 0.10 cm d^{-1}.
Spatial extent	Demonstration for selected glaciers in northern Greenland (79°N – 82°N, 33°W – 70°W)
Spatial resolution	250 m
Temporal resolution	12 days
Map projection	Geographical, WGS-84
Satellite instrument	Sentinel-1A C-SAR
Latency time	< 3 days
Length of service	January 2015 – present, service for other regions active on demand
Service operator	ENVEO
Data access	FTP, e-mail

Figure 5.3 shows an example of the glacier ice velocity product, and Figure 5.4 presents the analysis of a time series for the ice velocity along the flowline of the Petermann glacier in northern Greenland.

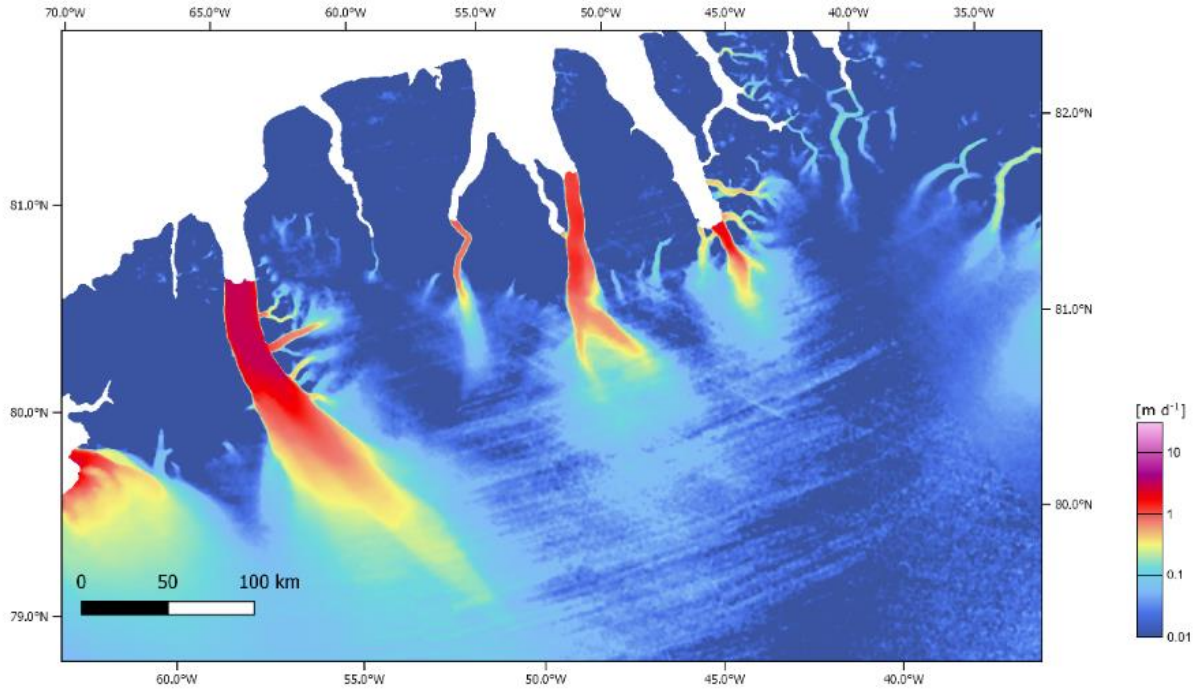

Figure 5.3: Example of glacier ice surface velocity product from multiple Sentinel-1 data of 2015 and 2016 over northern Greenland.

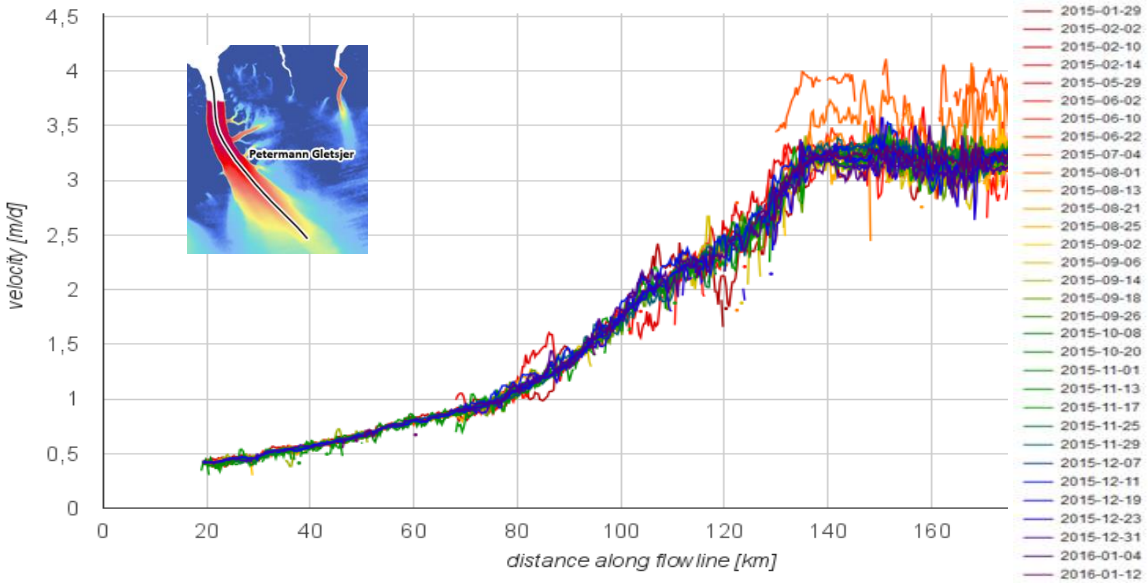

Figure 5.4: Time series of ice velocity along a profile of the glacier tongue of Peterman glacier in northern Greenland.

5.3.2 *Performance of products and service*

The glacier ice velocity products from Sentinel-1 IW SLC data are generated only on user demand. Observed glaciers areas must have a minimum size of about 1 km in line of sight, and a minimum ice velocity of about 0.10 m d^{-1}. During the SEN3APP demonstration phase, a time series of ice velocity products has been generated for outlet glaciers of northern Greenland.

The latency time for the products depend on the area of interest, but can be usually provided in less than 3 days for a selected glacier when repeat pass Sentinel-1 IW SLC data are available.

On user demand, the service can be run every 12 days for a pre-defined area of interest meeting the spatial and motion requirements. Based on experiences made during the SEN3APP demonstration phase generating continuously products for the region around Petermann glacier in northern Greenland as soon as new Sentinel-1 data became available, the reliability of this service is assessed to be high.

Evaluation of the products is still ongoing. Results will be reported in the validation report D4.5.

5.4 Snow / Ice areas on glaciers

Service provider: *ENVEO*

5.4.1 *Documentation of service demonstration*

The snow / ice areas on glaciers service is only active on demand for selected regions identified by the interested user. The product is generated with 10 m x 10 m pixel size from Sentinel-2 data acquired as close as possible to the date with maximum ablation area, and at clear sky conditions over the glaciated areas. Glacier outlines are mandatory input for this product.

The products generated within the SEN3APP project meet the internationally accepted standard defined by GLIMS (Global Land Ice Measurements from Space), as well as the INSPIRE standards.

The product is delivered directly to the user requesting the service for a particular region via FTP or per e-mail.

The service characteristics are summarized in Table 5.4. Figure 5.5 shows an example of the snow and ice areas on glaciers.

Table 5.4: Service characteristics for snow and ice areas on glaciers.

Service status	On demand
Service limitations	Satellite image for product generation must be acquired as close as possible to the date with maximum ablation area, with clear sky conditions over the glaciers of interest. Glaciers affected by cloud cover or extensive seasonal snow have to be excluded from product generation. Also rock glaciers are excluded from this service.
Spatial extent	Selected glacier regions, as requested
Spatial resolution	10 m
Temporal resolution	Depends on availability of satellite data meeting the acquisition requirements
Map projection	UTM, WGS-84
Satellite instrument	Sentinel-2 MSI
Latency time	< 3 months
Length of service	Service only active on demand
Service operator	ENVEO
Data access	FTP, e-mail

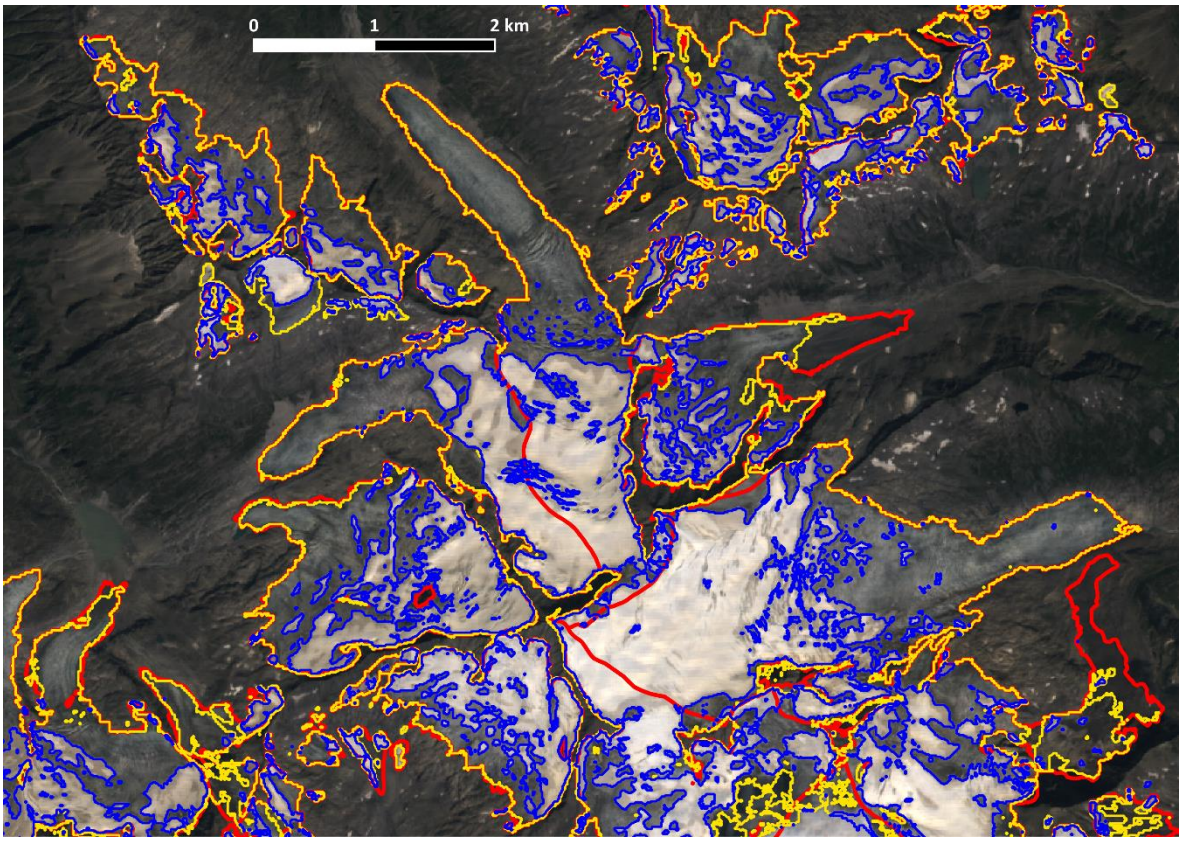

Figure 5.5: Example of snow and ice areas on glaciers from Sentinel-2 scene of 13 August 2015 over the mountain region Venedigergruppe in Austria. Blue: snow; yellow: bare ice; red: debris covered glacier areas.

5.4.2 Performance of products and service

The snow and ice areas on glaciers from Sentinel-2 data are generated only on user demand. The service is limited by the availability of useful satellite data, as an image has to be acquired as close as possible to the date with maximum ablation area, and the glaciated areas of interest have to be free of clouds or cloud shadows. During the SEN3APP demonstration phase, the Sentinel-2 scene over Austria used also for the generation of glacier outlines was used to produce demonstration products. Glaciers affected by clouds and/or cloud shadows are excluded from any analyses.

The quality of the product can currently only be roughly estimated, due to the lack of usable reference data. A WorldView-2 scene acquired on the same date as the Sentinel-2 scene, ordered and received by courtesy from the Copernicus Data Warehouse, will be used to assess the accuracy of the product, although there are shifts in the geolocation of the scenes. Results will be documented in the validation report (D4.5).

As the service depends strongly on the availability of useful satellite images a reliable annual update of the products as requested by many users cannot be assured. But, with acquisitions of Sentinel-2A and its twin Sentinel-2B, planned to be launched in mid-2016, the repeat time cycle improves to 5 days. Thus, the chances for getting useful satellite images for more frequent snow and ice monitoring on glaciers will increase significantly.

6. Documentation of Service Demonstration and Performance for Lake Ice Product (D5.8)

6.1 Lake Ice Extent

Service provider: *SYKE*

6.1.1 Documentation of service demonstration

Lake ice extent (LIE) is an operational product for monitoring the ice coverage on fresh water lakes. Currently the product covers the Baltic Sea drainage area. The main interest groups currently for the product are numerical weather prediction community (Pour et al., 2014), especially in the Finland and Scandinavia, with large number of lakes (from Finnish land cover 10% are lakes).

Industries with some economic value, such as freshwater fishing, reindeer herding and transport are also among the interest groups for lake ice coverage. Especially in Northern Finland, Scandinavia and Northern-Russia are affected by the seasonal ice cover. The ice conditions also have strong effect on leisure activities in these areas (e.g. skiing).

Table 6.1: The main characteristics of the phenology product and service.

Service status	Operational
Service limitations	Cloud cover and polar night (low light conditions)
Spatial extent	Baltic Sea drainage basin [45°N – 71°N, 5°E – 45°E]
Spatial resolution	0.0025° (~250 m)
Temporal resolution	Daily coverage
Map projection	WGS-84
Satellite instrument	MODIS
Latency time	12 hours
Length of service	2011 – ongoing
Service operator	SYKE & FMI
Data access	CryoLand GeoPortal: http://neso1.cryoland.enveo.at/cryoclient/ FMI-ARC GeoPortal: http://saana.nsdc.fmi.fi/fmiarc-geoportal/ (sample products)

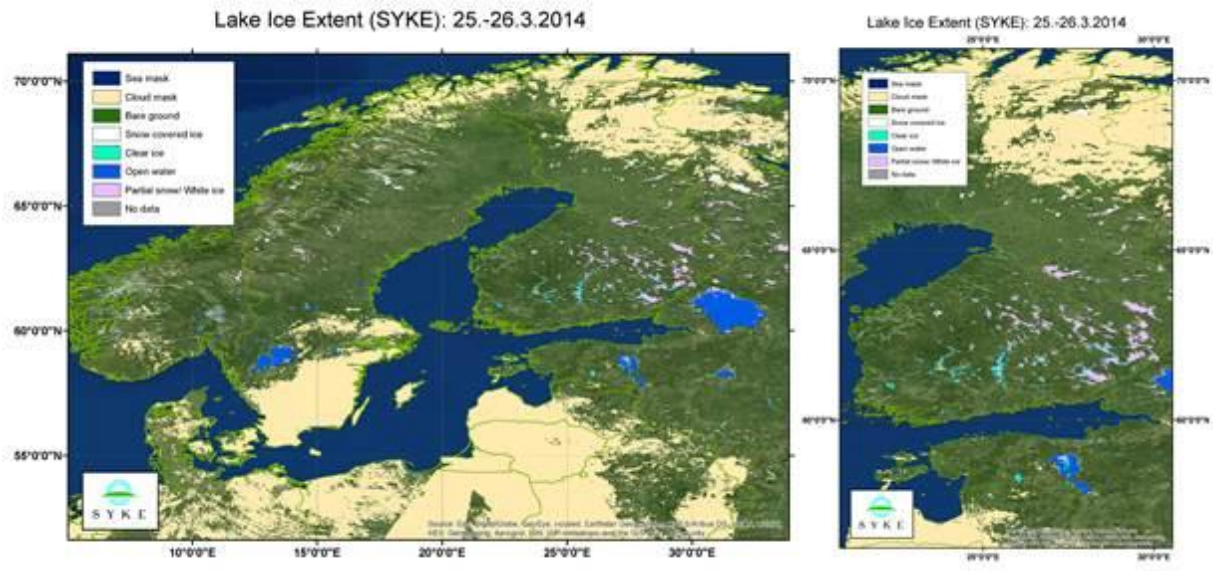

Figure 6.1: Sample LIE -product. Composite of 25th and 26th March 2014.

The product is a 0.0025° raster (e.g. around spatial resolution around 250 m) in WGS-84 coordinate system. This makes the dataset fairly large and therefore requires heavy computing power for applications. The raster can be easily extended to cover larger areas and more lakes. The aim in developing the product is to make selection of lakes and produce focused lake ice maps for these regions, excluded the uninteresting land areas.

The product is currently produced from MODIS satellite data from FMI Sodankylä ground station. The latency time for the product is around 12 hours. This can be considerably reduced, but currently the best overpasses are sought for to generate the product. Sample products are made available through SEN3APP portal (the data is delivered through the CryoLand GeoPortal (http://neso1.cryoland.enveo.at/cryoclient/).

The product is also considered to be included in the Copernicus Global Land portfolio for operative global lake ice detection method.

6.1.2 *Performance of products and service*

The overall performance of the product is satisfying during the active melting period in the spring. The main issue for the product is the clouds, especially late in the melting season. The conditions where the land surface has lost the snow cover from parts of the monitoring area and lakes are still, at least partially ice covered make the conditions for cloud detection challenging. Clouds create easily artificial ice detection on the already open waters.

A low light condition in the Northern-Latitudes during late autumn when the ice cover starts to form is also a challenging time for optical detection of ice cover. This issue is currently tackled in the development of the LIE product.

For the SEN3APP LIE product, there is an accurate lake border dataset available for Finland. For other areas in the Baltic Sea drainage basin are based on GlobCover –dataset (Bontemps et al., 2013). The GlobCover based mask is considerably coarser in resolution and in detection of e.g. land-water mixed pixels.

6.1.3 Product evolution during demonstration/validation phase

The product will go through some evolution during the demonstration and validation phase. The validation data will be divided in two parts, for which one part is used to tune the parameters of the algorithm before validation with independent dataset.

The water body detection will be improved using band ratios (e.g. NDVI) and cloud detection will be improved to reduce the number of misclassifications especially after a lake is already fully open.

The lake/land mask will also be reviewed before final validation.

7. Conclusions

During the SEN3APP demonstration phase (July 2015 – May 2016), twelve services providing products of four categories, land cover and phenology, snow, glaciers, and lake ice, were active. The products are accessible free of charge through two geoportals available at the SEN3APP portal (http://sen3app.fmi.fi/index.php?style=main&page=Products):

- FMIARC GeoPortal (http://saana.nsdc.fmi.fi/fmiarc-geoportal/)
- CryoLand GeoPortal (http://neso1.cryoland.enveo.at/cryoclient/)

7.1 Land cover and phenology services

The crop/vegetation classification product from Sentinel-1, Sentinel-2 and Landsat 8 data for a test area in south-west Finland has been particularly developed for the Agency for Rural Affairs (MAVI) in Finland during the SEN3APP project. After a development phase in 2015, a pilot service is now running during summer 2016.

The phenology product for Finland from MODIS data is developing towards more operational status. Once the end of vegetation active period can be reliably detected the product provides means of following the vegetation activity for boreal areas and is of high interest to global climate research community.

7.2 Snow services

All fractional snow cover services provided within the SEN3APP demonstration phase are operational, providing daily products for different spatial extents and with different spatial resolutions since a couple of years. These near-real time services are currently based on MODIS Terra and NPP VIIRS data, but will use Sentinel-3 SLSTR/OLCI data as input as soon as these data will be available in near-real time.

The Pan-European snow water equivalent service from passive microwave data and ECMWF snow depth data from synoptic stations started as pre-operational service in 2015, and is running operationally since 2016.

The wet snow cover service for the Alpine area based on Sentinel-1 data has been developed during the SEN3APP project, and is currently running as a pilot service during the melting season 2016. Evaluating the products and testing the product generation for other areas of interest identified by users is still ongoing. A pre-operational service is planned for the melting season 2017.

7.3 Glacier services

Glacier services are active on demand for areas of interest identified by users. Demonstration products of glacier outlines, glacier ice surface velocity and snow and ice areas on glaciers were

generated during the SEN3APP project for glaciers in Austria, Svalbard and northern Greenland based on selected Sentinel-1 and Sentinel-2 data. Products are provided directly to interested users.

7.4 Lake ice service

The lake ice extent service providing daily products for the Baltic Sea draining basin based on MODIS data is running operationally since 2011. The seasonal ice cover of freshwater lakes has a strong contribution to the climate research as potential input variable, as well as a role as an indicator for climate change. Early break-up of ice and late freezing are strong indicators for warming climate in the arctic and sub-arctic regions (e.g. Brown and Duguay, 2010). There are clearly also potential users in the general public as well as for some practitioners of reindeer herding and in transports in the Northern latitudes.

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