Description of Service Characteristics Document D5.1 – D5.4

Land Cover and Phenology: Deliverable 5.1

Snow mapping: Deliverable 5.2

Glacier products: Deliverable 5.3

Lake Ice products: Deliverable 5.4

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SEN3APP

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

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Restricted to a group (including the Commission Services) specified by the consortium	
Confidential, only for members of the consortium and for the Commission Services	

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List of Acronyms:

AATSR	Advanced Along Track Scanning Radiometer
AOI	Area Of Interest
API	Application Programming Interface
ASF	Alaska Satellite Facility
CSPP	Community Satellite Processing Package
DB	Direct Broadcast
DEM	Digital Elevation Model
DHMS	Department of Hydro-Meteorological Service, Bhutan
DUE	Data User Element
EEA	European Environment Agency
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
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
GRDH	Ground Range Detected High resolution
IMS	Interactive Multisensor Snow and Ice Mapping System

IW	Interferometric Wide Swath
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
NOAA CLASS	National Oceanic and Atmospheric Administration Comprehensive Large Array-data Stewardship System
NPI	Norwegian Polar Institute
NPP	National Polar-orbiting Operational Environmental Satellite System Preparatory Project
NRT	Near-Real Time
NSDC	National Satellite Data Centre
NWP	Numerical Weather Prediction
OGC	Open Geospatial Consortium
OLCI	Ocean and Land Colour Imager
OLI	Operational Land Imager
PMV	Passive Microwave
RGI	Randolph Glacier Inventory
RSR	Reduced Simple Ratio
RT-STPS	Real-Time Software Telemetry Processing System
SAR	Synthetic Aperture Radar

SCDA	Single Cloud Detection Algorithm
SD	Snow Depth
SLC	Single Look Complex
SLSTR	Sea and Land Surface Temperature Radiometer
SMHI	Swedish Meteorological and Hydrological Institute
SPOT	Satellite Pour l'Observation de la Terre
SSMI/S	Special Sensor Microwave Imager Sounder
SYKE	Finnish Environment Institute
SWE	Snow Water Equivalent
SWIR	Short-Wave InfraRed
ToA	Top of Atmosphere
UK	United Kingdom
VH	Vertical / Horizontal polarization
VIIRS	Visible Infrared Imaging Radiometer Suite
VNIR	Visible and Near InfraRed
VTT	Technical Research Centre of Finland
VV	Vertical / Vertical polarization
WCS	Web Coverage Service
WebGUI	Web Graphical User Interface
WMS	Web Map Service
XML	Extensible Markup Language
ZAMG	Zentralanstalt für Meteorologie und Geodynamik

1. Introduction

In this document the characteristics of the SEN3APP services participating in the demonstration phase are described. In total, eleven products of the following four categories are demonstrated:

- Land cover and phenology (Chapter 2)
- Snow (Chapter 3)
- Glaciers (Chapter 4)
- Lake ice (Chapter 5)

Most of the demonstration services provided in SEN3APP are or will be based on Sentinel-1/-2/-3 data. The Sentinel satellites provide a new data base enabling partly new opportunities for satellite based monitoring. Thus, some of the SEN3APP services are still under development and need further testing and validation activities, and some services are currently running using supplementary satellite data as input. As replacement for Sentinel-3, which was just recently launched on 16 February 2016, data of replacement satellite sensors, such as NPP VIIRS or MODIS Terra are currently used to setup or run services requested by users. Sentinel-2 data are only publicly available since late autumn 2015, so data from Landsat 8 OLI are used additionally to setup some of the services, and to complement the hitherto acquired Sentinel-2 data base. Additional to Sentinel based products, passive microwave (PMW) data are used to generate snow water equivalent products and continue running an existing service.

The demonstration products 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 (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 planned to be 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. But, short summaries of the retrieval of raw data, the processing and product generation are given, in order to show up changes or adaptations in the product processing chain affecting the overall service, e.g. limitation of near-real-time services due to delayed availability of raw Sentinel data.

The SEN3APP services participating in the demonstration phase, 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”. For each of the products provided in the demonstration phase, at least one end-user is identified who is going to test and assess the provided products and services. These users will finally be contacted at a later stage of the project to provide feedback on the SEN3APP products and services.

2. Description of Service Characteristics for Land Cover and Phenology products (D5.1)

2.1 Crop/vegetation classification

Service provider: *SYKE*

2.1.1 General

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 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 has provided the borders of agricultural parcels for whole area, and detailed information for about 1600 parcels which can be used as training data for classification.

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

2.1.2 Raw data for the service

- Sentinel-1: Interferometric Wide swath-product, spatial resolution 5x20m, VV- and VH-polarizations
- Sentinel-2: So far, no images have been used. The preferable image product is atmospherically corrected and orthorectified reflectance (level 2A), but orthorectified ToA reflectance can also be used (level 1C).
- Landsat-8 OLI: Images are pre-processed using ENVIMON-software developed by VTT.

2.1.3 Spatial, temporal and resolution constraints

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

The product is utilizing both optical and microwave images because Finland is usually covered with clouds so that it is very difficult to create monthly gap-free image mosaics using Landsat-8. Therefore, Sentinel-1 radar images have been also used because they are not dependent on clouds or sunlight.

Even with the first satellites from the two-satellite missions of Sentinel-1 and Sentinel-2, the data is likely to be sufficient satellite series.

2.1.4 Product generation

Landsat-8 OLI:

- Automated download can utilize image packages both from Earth Explorer (http://earthexplorer.usgs.gov/) or Libra (https://libra.developmentseed.org/).
- Radiometric and atmospheric correction with cloud masking using Envimon software developed by VTT.
- Computation of Normalized Difference Vegetation Index (NDVI) for images.
- Computation of monthly maximum NDVI-mosaics.
- Computation of average NDVI for agricultural parcels.

Weather was very cloudy during spring and summer 2015. Therefore, the produced monthly maximum NDVI mosaics were full of holes.

Sentinel-1 IW GRDH:

- Download images from Sentinel-1 Scientific Data Hub. Sodankylä receiving station will be used in year 2016.
- Computation of topographically corrected Sigma0 values using Sentinel-1 Toolbox of European Space Agency (ESA).
- Scaling Sigma0 to 16-bit integer
- Resampling to 20 m pixel size
- Transformation to the national ETRS TM35Fin-coordinate system
- Computation of average Sigma0 for agricultural parcels

So far, images from days with both ascending and descending orbit images have been used. Both ascending and descending orbit images are processed and then their average image is computed. This has been done in order to decrease the dependence of Sigma0 from image acquisition direction, decrease the effect of speckle and decrease location errors.

Classification:

NDVI and Sentinel-1 time series of agricultural parcels is classified to agricultural plants and tillage practice classes using nearest neighbour classifier.

A product example and illustrations of intermediate processing steps are shown in Figure 2.1.

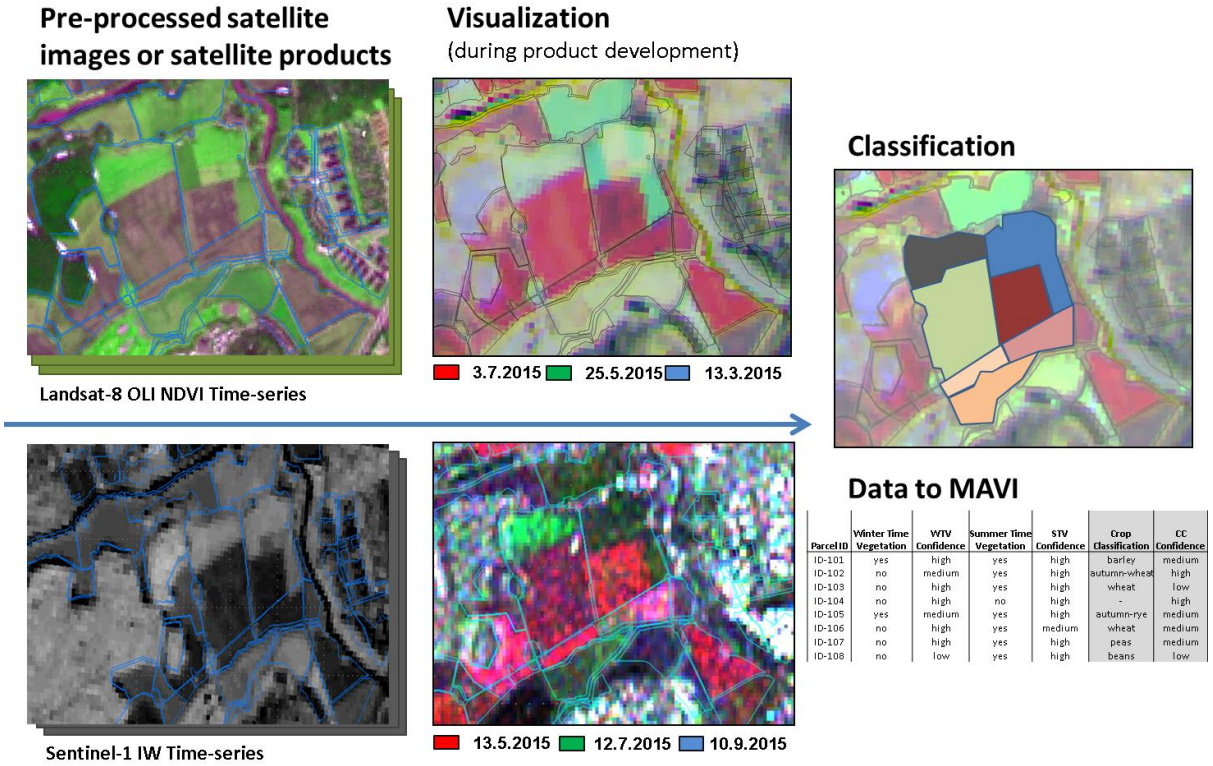

Figure 2.1: The data is delivered to MAVI as table, with unique agricultural parcel-id's linking the existing data and classification and interpretation from time-series of optical and SAR- satellite data. Visualized satellite data can be additionally delivered to MAVI.

2.1.5 *Service status*

The service is still under development together with the end user so it is not possible to say if it fully meets the user requirements. Anyhow, according to MAVI, even at this stage the service is useful for them and they should also do some work to integrate produced information better to their own systems.

The main problem with the service has been availability of cloud-free satellite observations. In order to provide the required information for MAVI a time-series of 3-4 optical, high resolution observations for each agricultural parcel is needed. In summer 2015 this requirement was not met due to cloudy weather conditions in spring and mid-summer. Situation will be improved in summer 2016 when Sentinel-2 is available together with Landsat 8 and Sodankylä facilities are in place.

Usage of Sentinel-1 data in gap filling of optical data is also under development.

2.1.6 Data rights

During the SEN3APP project the products are tailored to specific end-user (MAVI) and will not be distributed openly.

2.1.7 Data access

During the development phase of the product the data transfer is made available to MAVI using FTP. There are plans to use ERDAS Apollo during 2016. The alternative is to set up an own web map service.

2.1.8 End-user

Agency of Rural Affairs in Finland, MAVI (Maaseutuvirasto).

2.2 Phenology Product

Service provider: *SYKE*

2.2.1 General

The vegetation phenology satellite data product of SYKE is in the research and experimental phase. The product is derived from time-series of FSC (Fractional Snow Cover), NDVI (Normalized Difference Vegetation Index) and NDWI (Normalized Difference Water Index) time-series. The use of RSR (Reduced Simple Ratio) index is under development. The phenology products of start-date and end-date of growing season for deciduous and coniferous forests, separately, have been used e.g. in research of carbon cycle modelling and inferring other phenological events (moth peak flight).

2.2.2 Raw data for the service

The time-series used are based on Terra/MODIS satellite data, which spans over 15 years and has the necessary channels for snow-cloud discrimination during winter season. The data sources needed are the time-series of above mentioned satellite derived indices and the fraction of land cover class in each MODIS pixel.

2.2.3 Spatial, temporal and resolution constraints

As the product is currently used mainly in research applications, there are no strict time-lines for data delivery. While the product is based on temporal changes in the satellite indices, the generation of the phenological dates could be estimated once every year.

2.2.4 *Product generation*

MODIS/Terra:

- Data used for time-series generation comes from SYKE's processing line for an operational FSC- service, which uses Terra/MODIS data pre-processed at National Satellite Data Centre (FMI-Sodankylä).
- FSC, NDVI and NDWI time-series are generated and averaged to a coarser grid taking into account the fraction of land cover class
- Phenological dates are extracted for each grid cell of AOI (area of interest)
- Colour coded maps of phenological dates for AOI are generated

A phenology product demonstration example is shown in Figure 2.2.

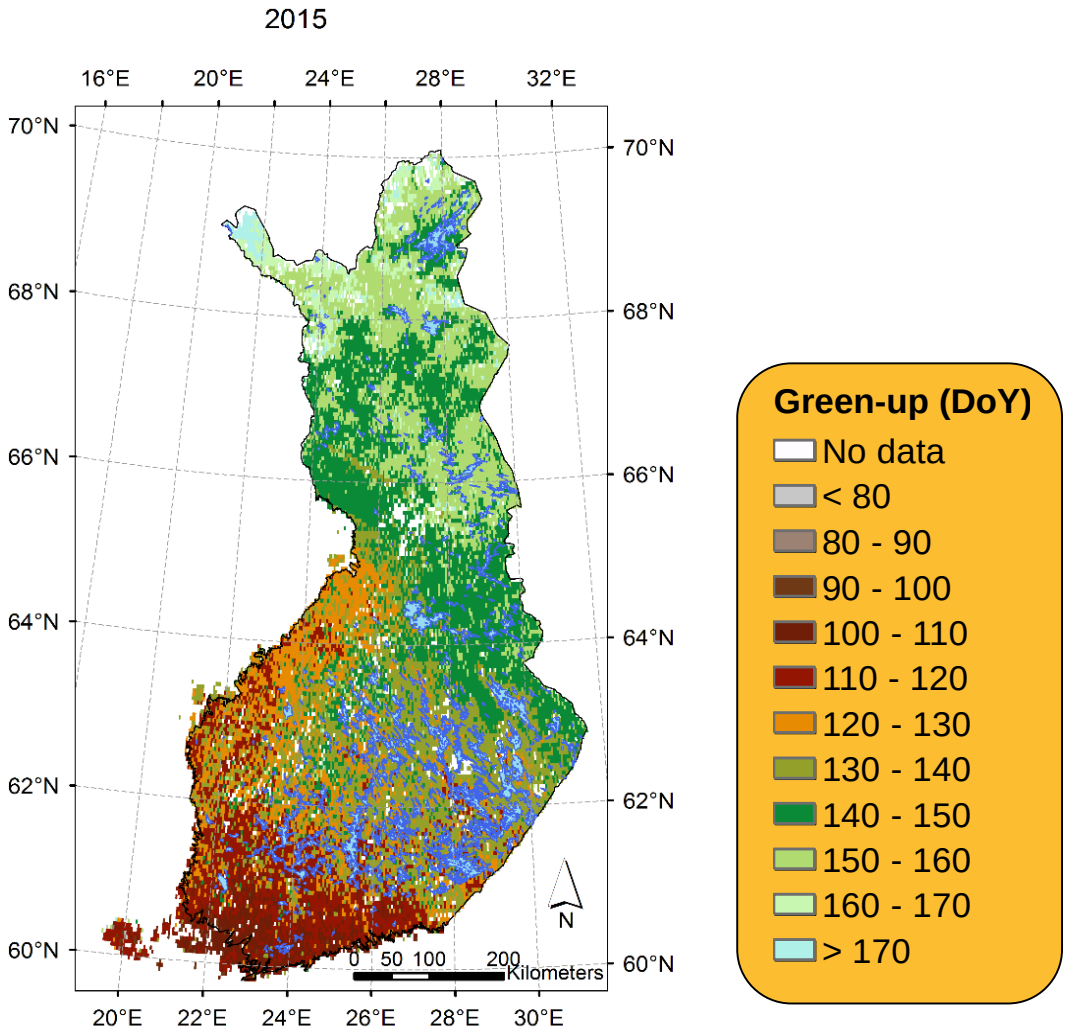

Figure 2.2: SYKE phenology demonstration product. The Green-up day (day of year) of deciduous trees derived from NDWI-time-series for 2015.

2.2.5 Service status

Initially the service will provide only the historical data from 2001-2013, but there are plans to develop the service towards more operational status.

2.2.6 Data rights

Finnish Environment Institute is currently reviewing the CC4.0-BY license to be used in connection with research datasets. The phenology datasets are subjected to the institute's data policy.

2.2.7 Data access

Until now the data has been delivered on request, but the data is foreseen to be placed in a web-service for view and download. The possible options for data delivery are the ERDAS Apollo server at FMI and ArcGIS Online service set-up at SYKE. Alternatively, the data can be provided through both channels.

2.2.8 End-user

Main users are currently internal research partners from Finnish Environment Institute and research project partners from Finnish Meteorological Institute.

3. Description of Service Characteristics for Snow Products (D5.2)

3.1 Fractional Snow Cover extent for Northern Hemisphere from optical data

Service provider: *SYKE & FMI*

3.1.1 Product requirements

The product requirements from the end users indicate the highest interest for a daily, fraction of snow cover extent that preferable would have a complete spatial coverage. This information would be valuable in determining the changes in snow covered area especially during the snow melt season. The target spatial resolution is around 100m (at least better than 1 km); to allow precise delineation of snow cover extent for mountainous regions. This information can be currently derived using satellite-based optical spectrometers, such as the Terra/Aqua MODIS or Suomi NPP VIIRS sensors, both which are currently operational.

The spatial coverage requirement cannot be fully met with optical spectrometers due to their dependence on solar illumination in measuring the surface of the Earth. Observations cannot be made in cloud obscured conditions, during night time, or in high-latitude regions during the mid-winter time (during the polar darkness). However, the optical spectrometers are able to provide a relatively high spatial resolution, for MODIS up to 500m, for VIIRS up to 375m and for the upcoming Sentinel-3 SLSTR up to 500 m. This resolution is adequate for the end users. The limitations regarding spatial extensiveness (the requirement of a full spatial coverage), cannot currently be met with the optical sensors, nor alternative available methods.

In general, the capabilities available (NPP VIIRS) and forthcoming with Sentinel-3, makes the product well suitable for the end-users. Information on FSC can further be utilized to improve the SWE retrieval, by improving the snow mask for the SWE product (the passive microwave radiometer is not as feasible for shallow or wet snow detection as the optical instruments).

3.1.2 Product overview

The Fractional Snow Cover extent product for the Northern Hemisphere has been designed to utilize the ESA Sentinel-3 SLSTR data, once it becomes available. As a precursor to the final Sentinel-3 based product, the Visible Infrared Imaging Radiometer Suite (VIIRS) data on-board the Suomi NPP satellite is applied to produce it within the SEN3App project. The service has been demonstrated within the ESA DUE GlobSnow project where it was run on semi-operational fashion. The legacy GlobSnow VIIRS processing chain will be further updated in the SEN3APP project to allow for a smooth transition to Sentinel-3 data.

The Fractional Snow Cover extent processing system uses VIIRS data retrieved for the NOAA CLASS archive to compute Fractional Snow Cover extent information on a daily basis for Northern Hemisphere. The processing chain applies a Simple Cloud Detection Algorithm (SCDA) to detected and remove cloud obscured regions of Earth. Large water bodies (oceans, lakes and rivers) and glaciers are also masked out, based on auxiliary data layers. The snow cover information is retrieved by the "SCAmod" –FSC retrieval algorithm. The resulting snow cover map is the basis of the generation of the four product types.

3.1.3 Processing chain

The processing system has been designed to operate using various kinds of optical satellite data in order to allow the SEN3App consortium to establish the service using the currently operational Suomi NPP VIIRS data and then seamlessly migrate into using the upcoming Sentinel-3 data, as the satellite has been launched and commissioned.

The processing system is designed for monitoring the snow conditions of the whole Northern Hemisphere. The utilized VIIRS data are downloaded from the NOAA CLASS central data dissemination archive. An automated script connects to NOAA CLASS, downloads all available VIIRS data for the given day for the necessary sensor channels for Northern Hemisphere. Currently the SCAmod retrieval algorithm applies the VIIRS M4 (555 nm) data for the FSC determination, and the M10 (1,61 µm), M12 (3,7 µm), M15 (10,76 µm) and M16 (12,0 µm) channels are utilized for cloud discrimination. All these above mentioned channels are downloaded to Sodankylä satellite processing centre as input data for the FSC retrieval processor. The FSC processor reads the VIIRS data, all swaths from the geographical domain monitored, within the corresponding target day. All the data available for a given day are processed and combined into an orthorectified one-day reflectance mosaic. The local solar illumination geometry and a digital elevation model (DEM) are applied to compute a terrain illumination model which is applied for radiometric topography correction in the classifier. For regions with overlapping coverage, the cloud-free satellite data with the optimal viewing geometry is used (i.e. each overlapping pixel is evaluated for clouds and its viewing geometry is noted, the cloud-free pixel with optimal viewing geometry is picked for final FSC retrieval). Cloud detection is carried out using a SYKE developed SCDA algorithm. The final FSC retrieval is carried out by the SCAmod algorithm. The final output is a daily FSC composite.

The product file assembly includes exporting of the generated information to appropriate layers in the NetCDF and Geotiff file format (layers and metadata).

In the future, once Sentinel-3 SLSTR data becomes available, the processing chain will remain equal, except for the initial satellite data retrieval steps. The future Sentinel-3-based processing chain will retrieve corresponding channels from the Sentinel collaborative ground segment for Northern Hemisphere. The Sentinel-3 data will be read into the geo-rectification

block of the processing chain and the rest of the processing chain will function as with VIIRS data, modifications are needed for final metadata and naming of the Sentinel-3 product.

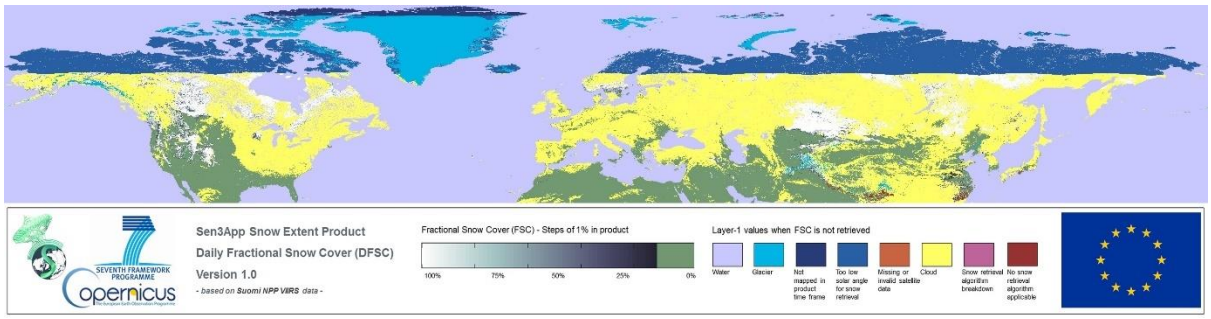

Figure 3.1: Sen3App Northern Hemisphere FSC product for 25 February 2016.

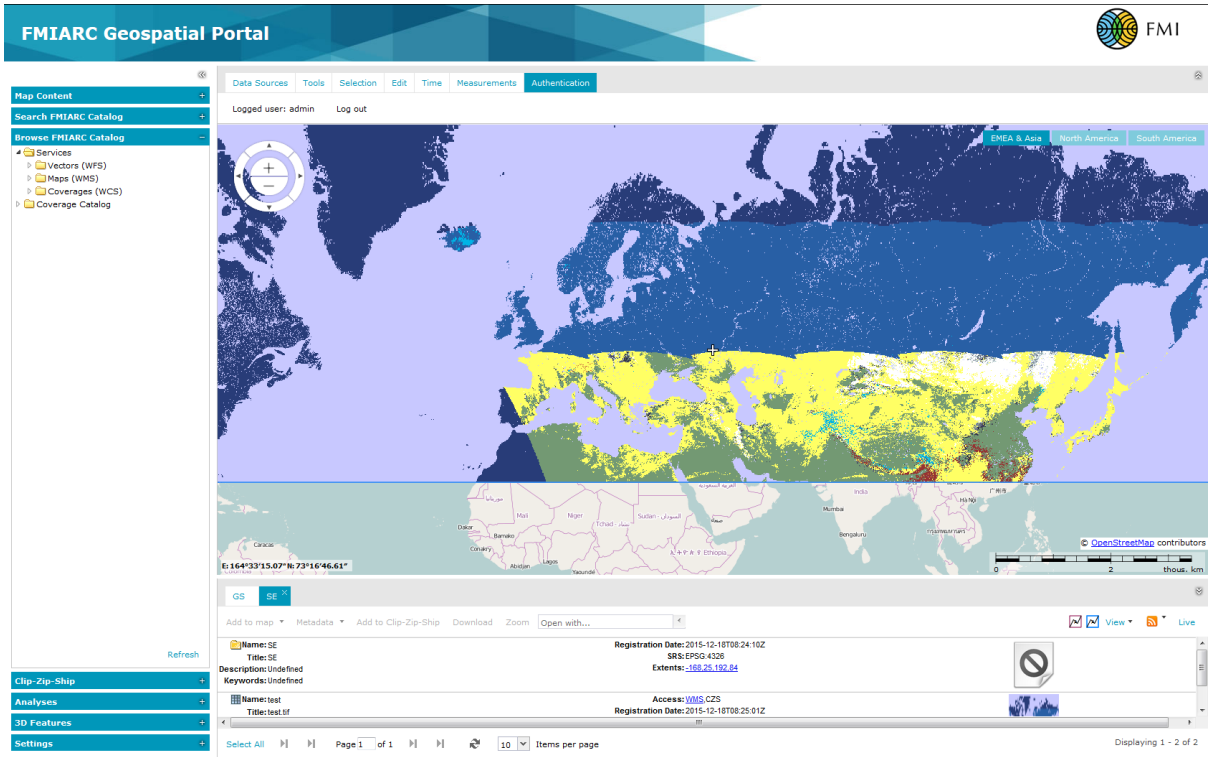

Figure 3.2: FMIARC-geoportal- screenshot http://saana.nsdc.fmi.fi/fmiarc-geoportal/.

While waiting for the launch and commissioning phase of Sentinel-3 to occur; the Sen3App "Fractional Snow Cover extent for Northern Hemisphere from optical data" processing system will be demonstrated using simulated Sentinel-3 SLSTR data. Demonstration of the system using simulated SLSTR data should allow for seamless transition of service to utilize Sentinel-3 data, once they become available. Additionally, the already existing operational VIIRS processing chain can be operated side-by-side the new upcoming Sentinel-3 chain, thus

providing a backup functionality, in case of satellite data gaps in temporal and spatial coverage.

Possibilities to combine information from Suomi NPP VIIRS and Sentinel-3 SLSTR products will be considered. Combination of information from several sources can be readily done, by applying the uncertainty information hardcoded into the products. Basically, a combined product, picking the least uncertain cloud-free estimate, or alternatively, creating a product where both input data sources are considered, by weighing their observations by their respective uncertainties could be generated.

3.1.3.1 Geo-correction

The Suomi NPP VIIRS (and in the future also the Sentinel-3 SLSTR) data are transformed from the original VIIRS coordinate system to the latitude- longitude grid based on the provided geolocation grid tie points. Bi-linear resampling is applied. The geo-correction module reads the data in native VIIRS (HDF5) format. A file reading functionality for the Sentinel-3 SLSTR data will be added to the Geo-correction module, once final Sentinel-3 SLSTR data is available.

3.1.3.2 Cloud detection

Clouds are detected by a cloud-cover retrieval algorithm, Simple Cloud Detection Algorithm (SCDA), developed in the GlobSnow project by SYKE. Alternative available cloud-detection algorithms and products were investigated in the initial assessment phase of the project but found inferior to the SCDA approach that has been demonstrated in e.g. the ESA GlobSnow framework and in the EU FP7 CryoLand project. The latest version of the SCDA algorithm (v2.0), released during the ESA GlobSnow-2 project is applied for the product generation.

3.1.3.3 SCAmod snow retrieval algorithm

The SCAmod algorithm is based on a semi-empirical reflectance model, where reflectance from a target is expressed as a function of the snow fraction. The average generally applicable reflectance values for wet snow, forest canopy and snow-free-ground serve as model parameters. A transmissivity map provides the amount of reflected sunlight that could be observed from a satellite in forest areas. The transmissivity is an expression of the effect of forest on local reflectance observations. FSC can then be derived from observed reflectance based on the given reflectance constants and the transmissivity values. The method is described in detail in (Metsämäki et al. 2005, Metsämäki et al. 2012).

3.1.4 Auxiliary data

Static thematic masks are used in the processing system as input to the retrieval algorithm and to label areas where Snow Extent processing is not applied, such as seas and glaciers. The following masks were generated for the Snow Extent domain:

- Digital Elevation Model (GETASSE30 DEM)
- Open water mask
- Glacier mask
- Optical Transmissivity mask (for SCAmod algorithm)
- Bare ground reflectance mask (for SCAmod algorithm)

The primary data sources for generating the masks are

- Land-cover maps from the ESA GlobCover project (about 300 m pixel size; Bicheron et al. 2008).
- Digital elevation model GETASSE30 DEM (made by ESA and made available by Brockmann Consult: http://www.brockmann-consult.de/beam/doc/help/visat/GETASSE30ElevationModel.html).

The data sets have been resampled to the resolution and projection of the FSC product.

3.1.5 Service status

The service is currently pre-operational. The product is being operationally processed in daily near-real time (NRT) fashion but the dissemination via the Sen3App portal is still being finalized.

3.1.6 Data access

The products are distributed using ftp service and FMIARC-geoportal (an ERDAS Apollo server, providing WMS and WCS interfaces and functionality).

3.1.7 End-users

In general, the whole community using snow cover information in hydrological, numerical weather prediction (NWP) and climate change studies. Fortum is more interested in regional products (Extended Baltic region FSC and Super resolution SWE), but could use the northern hemisphere (NH) product, if there are gaps in the regional product due to Sodankylä direct broadcast data availability.

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

Service provider: *FMI*

3.2.1 Service requirements

Concerning Snow Water Equivalent (SWE) products hydrologists demand a higher spatial resolution than space borne radiometer instruments nominally (pixel size ~ 25 km) have. This product provides SWE in 5 km grid daily with 24h timeliness.

3.2.2 Product description

SWE is provided for the Pan European region on daily basis. SWE is provided in millimetres. Product is estimated for non-mountainous areas only and mountains are masked out from the final product. In addition, water bodies and bare ground without snow are also masked out. Together with SWE value an estimate of the SWE error will be provided.

Data is available as Geotiff and can be packaged to NetCDF format if necessary. The underlying grid is latitude-longitude-grid in WGS84. Products are disseminated through OGC WMS and WCS interfaces at FMI.

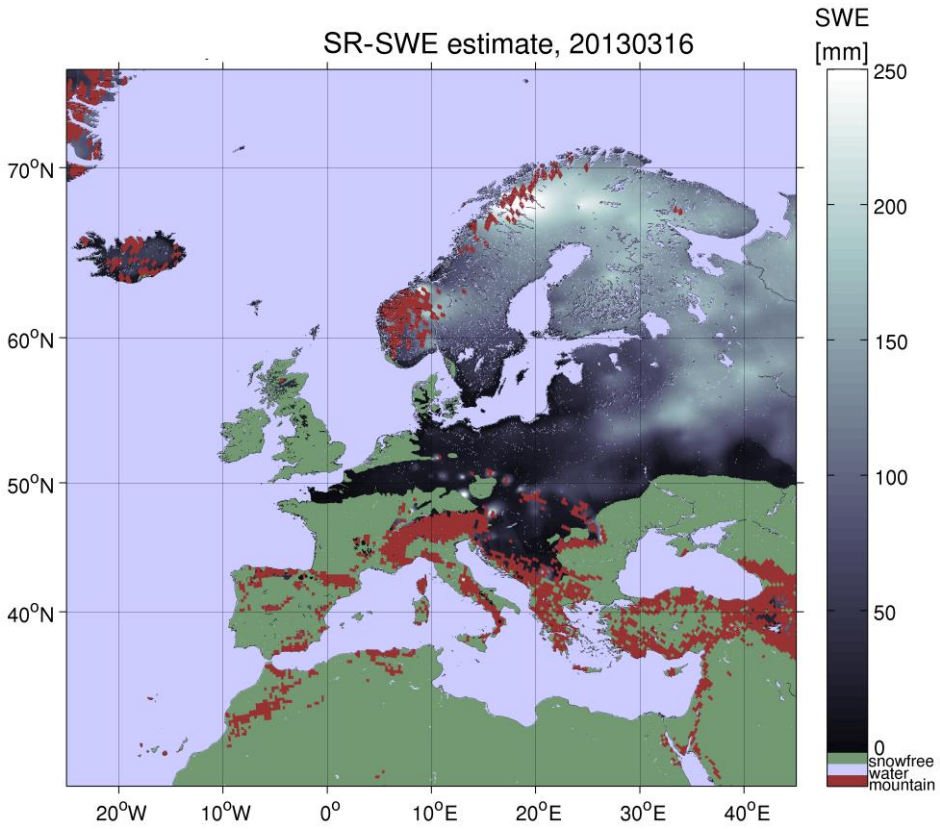

Figure 3.3: Example of a High Resolution SWE product for the Pan-European domain.

3.2.3 Data base for the service

Pan European SWE product is based on assimilation of Synoptic Snow Depth (SD) observations and space borne radiometer data from SSMI/S instrument(s). FMI real time weather observation database provides SD data to the processing system in comma separated values (csv) format. If necessary, the SD observation dataset can be augmented using open data from Sweden (SMHI).

SSMI/S data is provided as swaths by Servizio Meteorologico Aeronautica Militare. Swath data is resampled into Pan European grid using Pyresample tool from PyTroll software package.

Auxiliary data:

- Land use map is derived from ESA GlobCover 2009 300 m data (Bontemps et al. 2009)
- Forest stem volume map is derived from Northern Hemisphere-scale forest transmissivity map (Metsämäki et al., 2015)
- Snow cover is determined using IMS mask (National Ice Center 2008) in 4 km resolution, re-gridded to the Pan European Grid. IMS mask is augmented with VIIRS derived Snow Extent
- Water mask is from Global Raster Water Mask at 250 meters Spatial Resolution MOD44W (Carroll et al., 2009)
- Mountain mask is based on ETOPO5 data

3.2.4 Product generation

Once Pan European region is resampled and available together with the synoptic SD observation data file the processing system starts. First, SD data points are kriging interpolated to the grid. Second, the snow grain size and variance are determined at the station locations using forward emission model and auxiliary data as input. Third, snow grain size and variance estimates are interpolated with nearest neighbour interpolation over the grid. On the fourth step the assimilation of space borne derived SWE estimates together with SD observations and auxiliary data fields generated in previous steps is performed. Once the SWE and SWE error estimates are derived a post processing step is applied including masking and packaging. A Geotiff file together with XML metadata is generated and copied to data archive. A crawler reads the files and adds them to the catalogue of WMS and WCS services.

3.2.5 Service status

Experimental NRT processing system is currently running as a preoperational service. The main components of the processing chain are already in place and the validation results in

Finland show a good performance. On the other hand, changes to the system and end products are expected in a short notice.

3.2.6 Data rights and access

SWE products are made available in public and products are provided free of charge for non-commercial usage.

Data are disseminated through OGC WMS and WCS services at FMIARC- geoportal (http://saana.nsdc.fmi.fi/fmiarc-geoportal). Data can be downloaded either machine readable interface or using Web-GUI. FTP push can be implemented on user request.

3.2.7 End-users

Energy company Fortum has been test user for the high resolution (5 km) Pan-European SWE product. User feedback has been used in developing the experimental version. Hydrologists at Finnish Environment Institute SYKE are interested in using remote sensing SWE products. This product will be provided to them once file conversion to specific format (SWE per drainage basin) is available. MetOffice UK and ECMWF have also expressed interest in the product.

3.3 Regional wet snow cover from Sentinel-1 data

Service provider: *ENVEO*

3.3.1 Service requirements

The users ZAMG, MetOffice UK and Hydrological Service Tyrol (Austria) requested weekly high resolution maps of wet snow cover for the Alps and for the Pan-European area during the melting season. For the SEN3APP demonstration a pilot service for the Alpine area based on Sentinel-1A data is set up.

3.3.2 Product description

The wet snow cover products from SAR data provide wet snow in open land focusing on mountain regions above the tree line. Forests, urban areas and open water bodies are masked out using auxiliary information.

The products are provided in Geographic Map projection (Latitude / Longitude grid, WGS84), in Geotiff or optionally NetCDF file format. The product coding follows the instructions defined in the EU FP7 project CryoLand including INSPIRE compatible metadata information.

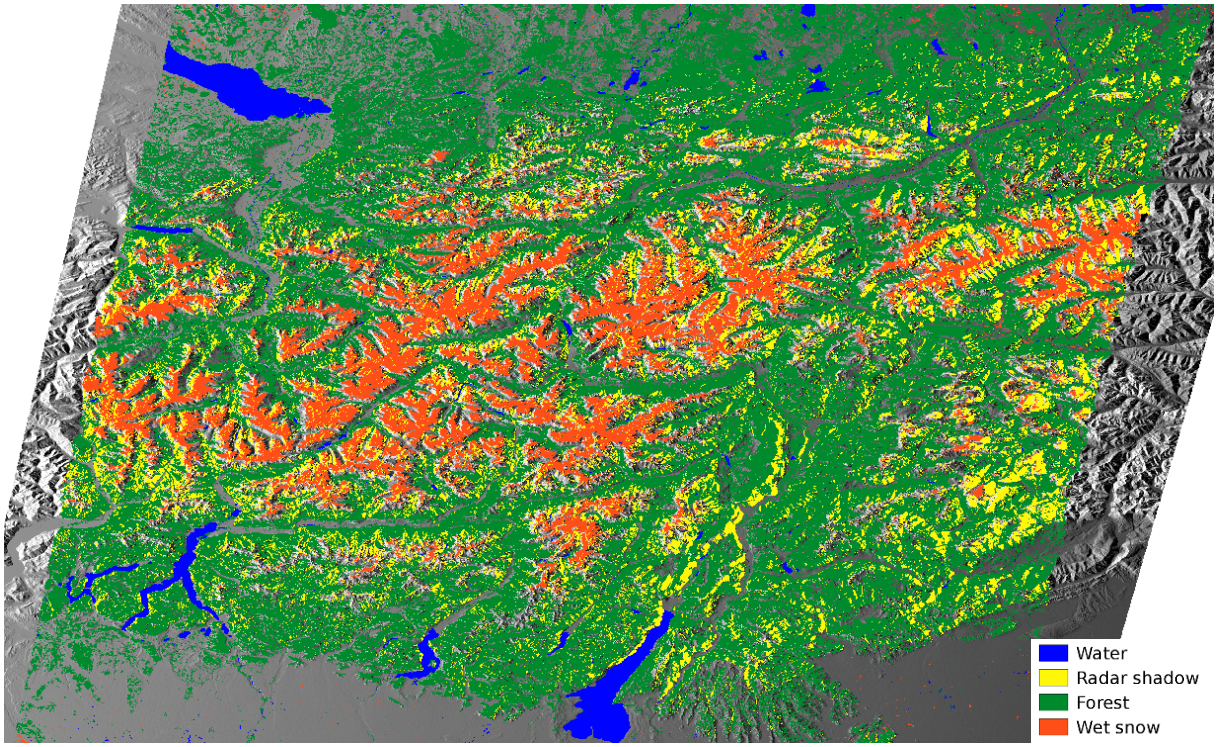

Figure 3.4: Wet snow cover from Sentinel-1 data (track 168) of 09 May 2015 over the alpine area.

3.3.3 Data base for the service

The wet snow cover pilot service for the Alpine area is based on Sentinel-1A Interferometric Wide Swath (IW) level-1 single look complex (SLC) VV and VH polarized data. The receiving station at Sodankylä, providing Sentinel data for many other SEN3APP products, does not cover the area of interest (AOI), so the raw data for this service are downloaded from ESA's Sentinels Scientific Data Hub.

Additionally, the following static ancillary data are used for the product generation:

- Digital elevation model over Europe (EU-DEM) with 30 m pixel size, provided by the European Environment Agency (EEA), available from http://www.eea.europa.eu/data-and-maps/data/eu-dem
- Permanent water body map and forest mask, each with 30 m pixel size from Hansen et al. (2013), available from http://earthenginepartners.appspot.com/science-2013-global-forest/download_v1.2.html

3.3.4 Spatial, temporal and resolution constraints

The wet snow cover pilot service is provided for the Alpine area during the demonstration phase of SEN3APP.

Currently, Sentinel-1A data for the same track is available every 12 days. Four to five tracks, acquired within 5 days, are needed to cover the Alps. Thus, the wet snow cover map cannot be provided for one day for the full Alpine area, but as soon as a new acquisition of a track is available the data are downloaded and processed. With Sentinel-1B (launch planned in Q2/2016), the acquisition of repeat tracks will be reduced to 6 days, which allows a higher temporal sampling of the snow pack conditions. Using overlapping tracks the repeat observation is further reduced depending on the track coverage.

The baseline wet snow cover product is prepared with 100 m pixel size. High resolution products with 50 m pixel spacing will be prepared for selected regions requested by users in the future.

3.3.5 Product generation

The wet snow cover product from Sentinel-1 is based on change detection. Wet snow significantly reduces the backscatter signal compared to bare ground or cold and dry snow. Therefore, Sentinel-1A SLC images acquired either during very cold winter days in 2015 or in midsummer 2015 were used to generate a reference data base.

Sentinel-1 data are downloaded from the Sentinel Science Hub, which provides the data sets about 24 h to 36 h after image acquisition. To match the requested latency time of the users of 24 h, a near real time access to Sentinel data is required (e.g. data should be accessible about 6 h after image acquisition).

After downloading the Sentinel-1 data, the processing starts, as described in D3.2 – D3.7. Products generation for one track over the Alps (2 Sentinel-1 slices) takes about 3 hours.

3.3.6 Service status

The wet snow cover maps for the Alpine area are provided as pilot service during the demonstration phase of SEN3APP. The wet snow cover maps of the melting season 2015 are currently processed and will be provided to users for testing purposes. A pre-operational service providing wet snow maps within the current latency time is planned for the melting season 2016. For assessing the product quality, the generated pilot products of the melting season 2015 are validated with selected reference data. Extended ongoing validation of the products and the service is needed.

3.3.7 Data rights

Pilot wet snow cover products are provided to the key users showing interest in the service. When the service is running operationally, products will be made available to the public. Products are provided free of charge for non-commercial usage.

3.3.8 Data access

Key users have currently dedicated access to a FTP server established at ENVEO, hosting also the products accessible through the CryoLand GeoPortal. The pilot wet snow cover products are provided to the key users via this FTP. When the service is running as planned during the melting season 2016, products are planned to be made freely available to the public for non-commercial usage through the CryoLand GeoPortal. Data are thus accessible through a WebGUI, EO-WMS/EO-WCS or can optionally be manually or automatically downloaded. The ERDAS Apollo System is planned to be linked with CryoLand GeoPortal in order to reach a broader user community.

3.3.9 End-user

The meteorological service of Austria, ZAMG and the Hydrological Service of Tyrol in Austria are end users for the wet snow cover service for the Alpine area. The meteorological service of United Kingdom, MetOffice UK, is mainly interested in a wet snow cover service for United Kingdom and for the Pan-European area, each with a higher temporal resolution than weekly. Anyway, the MetOffice UK will get the pilot wet snow cover products for testing purposes.

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

Service provider: *ENVEO*

3.4.1 Service requirements

Users requested daily Fractional Snow Cover (FSC) maps for the Alps and for the Pan-European area, extending from 72°N/11°W – 35°N/50°E with medium spatial resolution. Users request products provided in near-real time all the year round.

FSC services for the Alps and the Pan-European area are currently based on MODIS Terra data, but will be using Sentinel-3 data in future. For the SEN3APP demonstration FSC products are generated from selected archived Envisat MERIS and AATSR, used for simulating Sentinel-3 SLSTR and OLCI data. Additionally, the existing services for Alpine and Pan-European FSC maps are continuously running.

3.4.2 Product description

The fractional snow cover (FSC) products from optical satellite data provide information on snow fraction per pixel in percentage (0 % - 100 %) for cloud free land cover pixels. Water bodies, cloud covered pixels and any invalid input pixels are masked. The Pan-European product provides FSC information for open land and forested areas with about 500 m pixel

size. The alpine product provides FSC information for open land, and binary snow information for forested areas, each with about 250 m pixel size.

The baseline products are provided in Geographic Map projection (Latitude / Longitude grid, WGS84), in Geotiff or optionally NetCDF file format. The product coding follows the instructions defined in the EU FP7 project CryoLand including INSPIRE compatible metadata information.

For the users ZAMG and Hydrological Service Tyrol the products are transformed to national map projections and products are tailored to their particular needs.

3.4.3 Data base for the service

The alpine and Pan-European FSC services are currently based on daily MODIS Terra data, available in near-real time from NASA. Retrieving FSC maps from synergistic Sentinel-3 SLSTR and OLCI data was successfully tested with selected archived Envisat MERIS and AATSR scenes in the Alpine area, the Baltic Sea region, Scandinavia and west Russia. Product processing from Sentinel-3 is planned to start as soon as data will be available.

Additionally, the following static ancillary data are used for the products generations:

- Digital elevation model over Europe (EU-DEM) with 30 m pixel size resampled to pixel size of snow products, provided by the European Environment Agency (EEA), available from http://www.eea.europa.eu/data-and-maps/data/eu-dem
- CORINE Land Cover 2006 and 2012 data, provided by Copernicus Land Monitoring Services, available from http://land.copernicus.eu/pan-european/corine-land-cover

3.4.4 Product generation

The Sentinel-3 instruments SLSTR and OLCI are built on the heritage of the Envisat AATSR and MERIS instruments. As Sentinel-3 will only be launched in Q1/2016, archived Envisat AATSR and MERIS data were downloaded for selected areas in Europe for generating FSC demonstration products within SEN3APP. The demonstration FSC maps were generated following the processing line described in D3.2-D3.7.

The operational alpine FSC service providing products with 250 m pixel size from MODIS Terra data are also based on the multi-spectral un-mixing approach. The operational service providing daily Pan-European FSC maps from MODIS Terra data with 500 m pixel size uses a strict NDSI based binary pre-classification followed by the SCAmod (Metsämäki, 2012) algorithm applied on all pixels identified as snow. For the daily Pan-European FSC product a daily uncertainty information providing the Root Mean Square Error per pixel is provided. Additionally, snow maps generated from high resolution optical satellite data are regularly used to evaluate the alpine and the Pan-European FSC product.

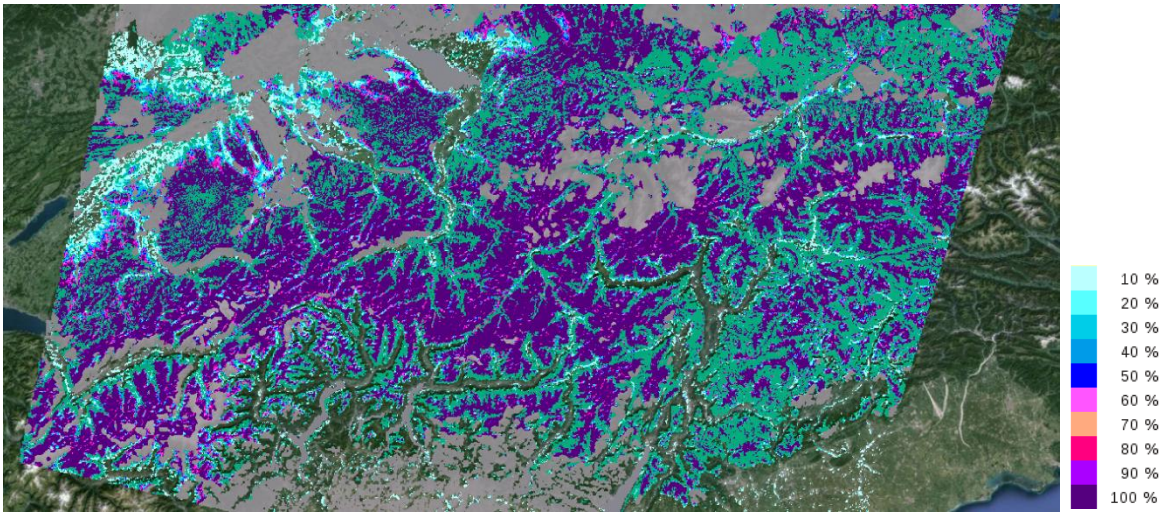

Figure 3.5: Fractional snow cover retrieved from synergistic usage of MERIS and AATSR data of 25 October 2003 over alpine area. Semi-transparent grey areas indicate cloud cover. Snow in forest is classified binary, and is shown in teal.

3.4.5 Service status

Operational services for daily FSC maps for the Alpine (250 m resolution) and the Pan-European (500 m resolution) areas currently based on MODIS Terra data installed within the EU FP7 project CryoLand are continuously running. Example of the products as shown in the CryoLand GeoPortal are shown in Figure 3.6.

Sentinel-3 SLSTR and OLCI data are planned to be used as new long-term data base for the alpine and the Pan-European FSC products, as the MODIS Terra instrument is already working much longer that originally foreseen, and could fail at any time. As soon as Sentinel-3 data will be available testing the FSC product generation will start.

3.4.6 Data rights and access

The alpine and Pan-European FSC products are accessible through the CryoLand GeoPortal. Users can get products using the WebGUI, EO-WMS/EO-WCS or via manual or automated download. Data available at the CryoLand GeoPortal can be downloaded free of charge for non-commercial usage. The users ZAMG and Hydrological Service Tyrol get the alpine and Pan-European products tailored to their particular needs via FTP.

3.4.7 End-users

Key users within SEN3APP of the Pan-European FSC products are the meteorological services ZAMG, Austria, and MetOffice UK. The alpine FSC products are used by the SEN3APP key users ZAMG and the Hydrological Service Tyrol. Beside these SEN3APP key users, many other users regularly access and download the alpine and Pan-European FSC products available through the CryoLand GeoPortal.

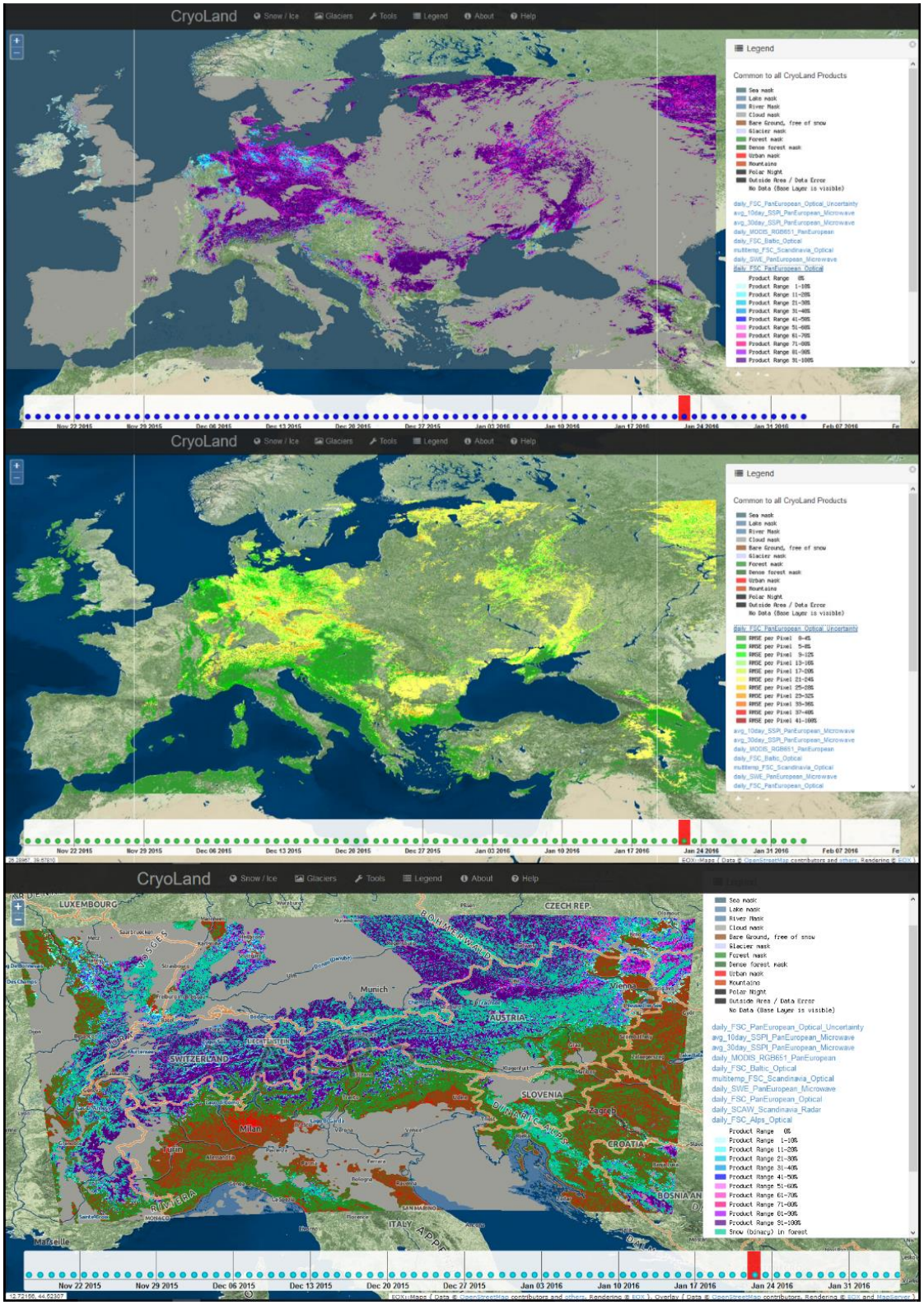

Figure 3.6: Currently active fractional snow cover service from MODIS Terra data (top) and associated uncertainty layer per pixel (middle) for the Pan-European area, and the fractional snow cover service from MODIS Terra data for the Alpine area. All products are provided daily through the CryoLand GeoPortal (http://neso.cryoland.enveo.at/cryoclient/).

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

Service provider: *FMI & SYKE*

3.5.1 Product description

The Extended Baltic Sea FSC service will work on the legacy of the GlobSnow NRT product for Europe, based on Suomi/NPP VIIRS Direct Broadcast data. Several advancements will be carried out, however. The basic algorithm (for snow and for cloud detection) will retain (*SCAmod*, Metsämäki et al. 2005, 2012, 2015). However, the areal coverage will be re-defined, and it is also planned to go for 500 m resolution as this will be the nominal resolution for the up-coming S3-SLSTR anyhow. VIIRS data does not provided 500m bands but deficiency this will overcome by sampling techniques.

3.5.2 Data base for the service

The NRT snow products at the moment are based on VIIRS Direct Broadcast (DB) data downlinked from Suomi NPP at FMI Sodankylä National Satellite Data Center. The VIIRS snow products will be amended with Sentinel-3/SLSTR based products once the Sentinel-3 data becomes operationally available for the Collaborative Ground Stations. As there are several suitable overlapping spectral bands, transition from VIIRS to SLSTR from algorithms point-of-view should be feasible. The Sodankylä Collaborative Ground Station will mirror and disseminate the Sentinels' NRT data from ESA's COLHUB or, if activated on Sentinel-3, use its DB capability for local reception.

In the demonstration phase of Sen3app the Baltic Sea FSC will be carried out employing direct broadcast VIIRS-data. The VIIRS data is processed using NASA's Real-time Software Telemetry Processing System (RT-STPS) for decoding and frame syncing the live satellite data stream and University of Wisconsin's Community Satellite Processing Package (CSPP) for Level 1 processing. The total processing time from downlink stop to L1 is in maximum of 15 minutes depending on the duration of satellite's visibility over Sodankylä. VIIRS L1 data is used as an input for FSC processor.

3.5.3 Product generation

The Extended Baltic Sea service will be provided as a daily basis. A mosaic product combining several overpasses is generated within few hours after the day's last planned satellite overpass covering the defined Area of Interest (AOI). The covered area in products can vary on daily basis as Suomi NPP has occasionally conflicts with other higher prioritized satellites. Usually these conflicts occur with satellites flying on or close to so called dawn-dusk orbit. In general, this means that the day time overpasses with better illumination conditions are secured but early morning and evening overpass can be lost because of conflicts. However, this has only

minor effect on the Baltic Sea Service as the Sodankylä satellite visibility cone is larger area than just the AOI. The service is running/can be run through the year but due to the limitations of optical remote sensing capabilities during the Polar Night, the data is valid only for period from 1st of February to 31st of October in the Baltic Sea drainage/Polar region. Southern parts of Europe will have a longer period of valid data. Considering these limitations, the product will be run throughout the year.

The areal coverage will be 11W-65E, 38N-72N.; so the areal coverage will be clearly more extensive than the current Baltic Sea Service.

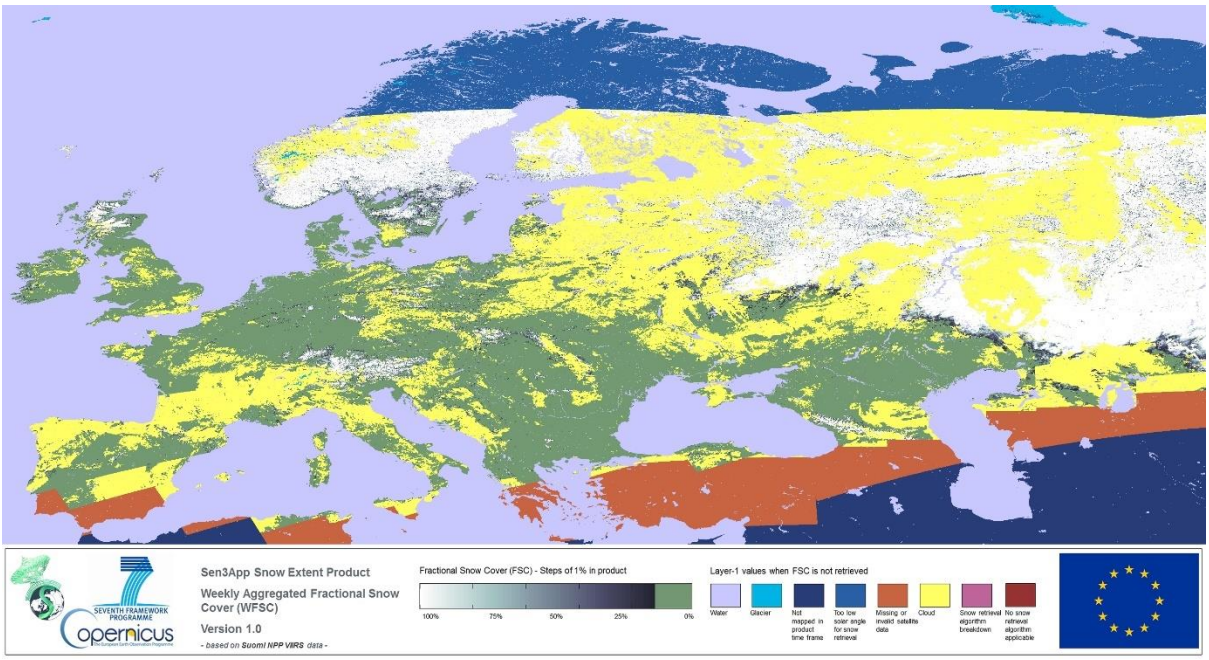

Figure 3.7: The latest example of the Extended Baltic Sea FSC product. This is weekly composite (contributions from last seven days' maps, so 22-28 Feb, 2016) to visualize the contents better, owing to reduced cloud cover. The spatial resolution is still ~1000 m, but will be soon switched to ~500 m as planned. Daily maps are provided on regular basis however, in addition to composites.

3.5.4 Service status

As this product is only in demonstration phase, the existing Copernicus-CryoLand Baltic Sea area product (based on MODIS) will be retained in production as a joint effort by SYKE/FMI. It serves as a backup and is also valuable to the users until a proper (full) validation to the new product can be conducted (this needs an appropriate number of reference data).

3.5.5 End-user

At the moment, the major use is for hydrological forecasting. This product also has potential as a Copernicus service, as the same algorithm for snow map production is directly applicable for Sentinels-3 SLSTR data. In the absence of SLSTR so far, this product is substitutive to SLSTR-based product and as such would be suitable for Copernicus-service.

4. Description of Service Characteristics for Glacier Products (D5.3)

Glacier products are generated only on user demand. The SEN3APP users identified regions with high priority for getting Sentinel based glacier products in Austria, Norway, Himalaya and Greenland. Secondary selected regions for glacier products were identified by users in Patagonia, Alaska and the Arctic.

4.1 Glacier outlines

Service provider: *ENVEO*

4.1.1 Service requirements

The users ZAMG, Hydrological Service Tyrol and MetOffice UK requested annually updated glacier outlines for selected regions from high resolution satellite imagery. Products should be prepared following the GLIMS (Global Land Ice Measurements from Space) standards.

4.1.2 Product description

The glacier outline product from high resolution optical satellite data contains closed polygons identifying features such as glacier outlines, internal rocks, pro-glacial lakes or debris cover. All polygons mapped from one scene can be stored as multiple entries in one vector file, following the internationally accepted standards of GLIMS. Additionally, INSPIRE conformal metadata information are prepared for each product.

4.1.3 Data base for the service

Glacier outline products are based on high resolution optical satellite data. Freely available scenes of Sentinel-2 MSI and Landsat 8 OLI are the main data base. Optionally, other (very) high resolution optical satellite data, as SPOT or Pleiades, respectively, can be used for mapping glacier outlines, but such data are usually only available at a charge.

For the SEN3APP demonstration of the glacier outline product only one Sentinel-2 MSI scene meeting the requirements for mapping glacier parameters is available in an area of interest identified by users. The scene was acquired during the commissioning phase, on 13 August 2015 over the region Hohe Tauern in Austria, and was provided by ESA only to expert users. This data set is (still) not available through the Sentinel Science Hub, which will be used for all future Sentinel-2 scene selections.

Further, a high resolution digital elevation model (DEM) is needed for the processing. For Austria, a national high resolution DEM with 10 m pixel size from airborne laser scanning data is available.

A high resolution water body mask would be helpful, but currently available masks have in many cases only coarser resolutions (30 m or more), and do not include small water bodies as often occur in mountain regions nearby glaciers.

If previous glacier outlines are available this is a helpful ancillary data set to be used, as many glaciers have stable extents in the accumulation area, but main changes can be observed at the glacier tongue. Anyway, this ancillary data set is not mandatory.

Currently available Sentinel-2 data accessible through the Sentinel Science Hub are processed in Level 1C, which means that data are radiometrically and geometrically corrected. The DEM used for the geometric correction is not available to the public. This is a critical for processing data in mountainous areas, where many glaciers are located. As a pre-processing step for retrieving glacier parameters a topographic correction is applied on the data using a DEM preferably with the same resolution as the selected Sentinel-2 bands. The used DEM is in most cases different from the DEM used by ESA for generating the Level 1C product. This can introduce significant side effects, especially beside and below mountain ridges where many glaciers have a part of their accumulation area. For retrieval of glacier parameters from Sentinel-2, Level 1B raw data would be preferred, as the same DEM can then be used for orthorectification and further processing steps.

4.1.4 Spatial and temporal constraints

For the product generation a high resolution optical satellite image acquired in late summer, close to the date with maximum ablation areas on glaciers is needed. Seasonal snow from the last winter remaining partly until the mid of the summer season, can significantly affect the quality of the mapped glacier outlines. As scenes have to be acquired at clear sky conditions at least over the glacier areas and surrounding areas, it can take sometimes several years to get a useful image for a particular area of interest.

The coverage of an area of interest for glacier products depends on the availability of Sentinel-2 or other high/very high resolution data for the defined region, and is limited by the swath width of the used satellite sensor. In case of Sentinel-2 the swath width is 290 km, while that of Landsat 8 OLI is only 185 km, and recent SPOT satellites have only 60 km.

4.1.5 Product generation

The glacier outline product from Sentinel-2 is based on the different reflectance properties of ice and snow compared to other surface classes. Preliminary glacier outlines are generated applying the NDSI and additional thresholds on VNIR and SWIR bands. Afterwards, manual correction is needed, especially at debris covered glacier tongues, which often cannot be separated automatically from the surrounding environment. Also small and patchy snow areas outside glaciers or small water bodies having similar reflectance properties as snow and glacier ice in the used VNIR and SWIR bands have to be removed manually. The detailed processing

is described in D3.2 – D3.7. A product example from Sentinel-2 MSI data of 13 August 2015 is shown in Figure 4.1.

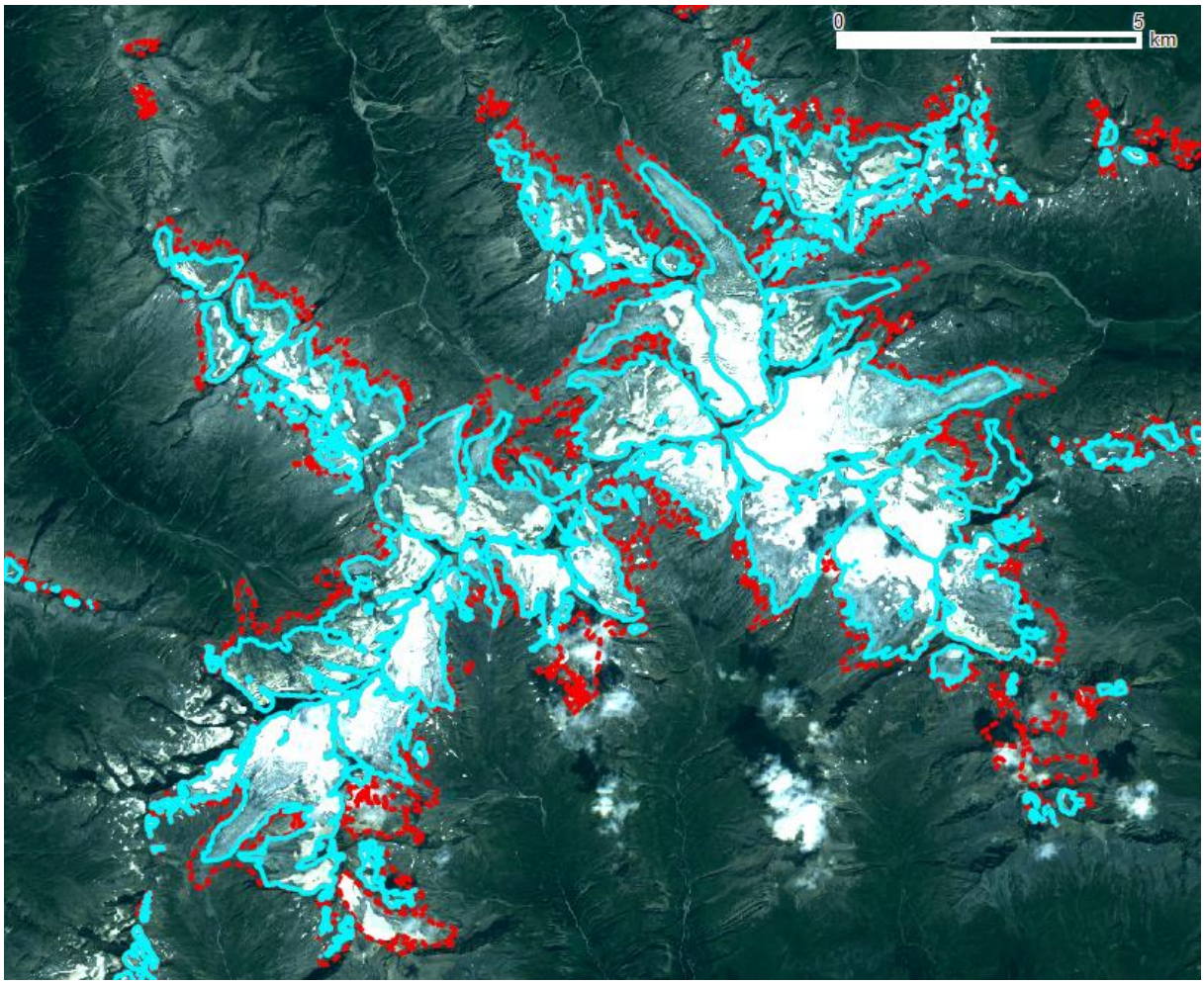

Figure 4.1: Glacier outlines of Venedigergruppe, Hohe Tauern, Austria, mapped from Sentinel-2 MSI L1C data of 13 August 2015 (cyan). Additionally, the outlines of the Austrian glacier inventory of 1999 are shown (red dotted outlines) to illustrate the changes of glacier areas.

Products are prepared as vector files in Shapefile format following the standards of GLIMS. The shapefile, associated metafiles and a preview image of the product are stored in a compressed tar-archive (.tar.gz).

Products are generated on demand and depend on the availability of usable satellite imagery. The latency time for the glacier outline product is 3 months after user request, as especially the manual correction can be time consuming.

4.1.6 Service status

The service is only active on user demand. Validation of the glacier outline products from Sentinel-2 data is needed, but depends on availability of usable reference data. Orthophotos or very high resolution optical satellite imagery acquired (nearly) at the same date as the scenes used for the product generation are the preferred reference data sets. Such data enable an areal evaluation of the product, not only a point-wise validation as with rarely available in-situ observations. Several very high resolution satellite images are planned to be ordered in 2016 through the Copernicus Data Warehouse, but the current status of accepted quota is unclear.

4.1.7 Data rights

Products are generated only on demand of users, and are made freely available to the interested user for non-commercial usage.

4.1.8 Data access

Products (stored as compressed tar-archive) are sent via mail to the interested user or put on a dedicated FTP accessible by the user.

4.1.9 End-users

The SEN3APP users ZAMG, Hydrological Service of Tyrol, MetOffice UK and DHMS are interested in glacier outline products in selected regions.

4.2 Ice velocity

4.2.1 Ice velocity over Svalbard Archipelago

Service provider: *GAMMA*

4.2.1.1 Service requirements and end users

The Norwegian Polar Institute (NPI), Tromsø (Norway), the Department of Geosciences, University of Oslo (Norway) and the University of Silesia, Katowice (Poland) are interested in ice velocity products over the Svalbard Archipelago.

4.2.1.2 Raw satellite input data

Sentinel-1 SLC data acquired every 12 or 24 days over Svalbard since mid-August 2015 meet the user requirements with respect to spatial coverage and temporal resolution (i.e. frequency of image acquisitions). However, the spatial resolution of products still needs to be assessed

by the engaged users. There are no problems with Sentinel-1 data availability in near-real-time with images available within a few hours (best case) to days (in case of problems in data distribution). The data is either ingested from the Copernicus API Hub or the ASF ground segment using the GAMMA Sentinel-1 download mechanism, or from the FMI ground segment in Sodankylä. Availability of new data triggers the GAMMA IC processor as described in the Products and Algorithm/Processing Line Specification Document.

4.2.1.3 Product generation

The ice velocity product is retrieved from image pairs of Sentinel-1 IW SLC data using offset tracking as baseline method. The repeat time of the Sentinel-1 image acquisitions is 12 days in most of the cases, 24 days in a few situations. The processing line with offset tracking is described in detail in D3.2 – D3.7 and includes:

- task track and frame in SEN3APP processor
- pre-processing of TOPS SLC products (extract SLC data, generate SLC_tab and mosaic of TOPS burst SLC data)
- co-registration of mosaicked SLC image pair with previously selected reference SLC (matching refinement only, no spectral diversity refinement)
- computation of differential interferogram
- offset tracking between SLC images using intensity cross-correlation
- post-processing of displacement fields
- product geocoding
- internal product assessment
- generation of final products for database.

The final product shows ice surface velocity in m/day or m/year. Products are prepared as raster in files format Geotiff and as ascii tables.

Figure 4.2 shows examples of ice velocities at different seasons. Gaps in the product occur if there are no acquisitions in one of the two orbits, if there was a problem with one or the other frame, or if the noise is very high (wet conditions). The sea is not masked because the Randolph Glacier Inventory (RGI) used as auxiliary data is from the early 2000's and thus not updated with regard to the recent speed-up of some of the glaciers.

4.2.1.4 Service assessment

The service was running in development level with 12 days Sentinel-1 image pairs of ascending orbits from August to December 2015 and will run in pre-operational level starting from

January 2016. The latency time for the ice velocity product is a few days after acquisition of a new imagery.

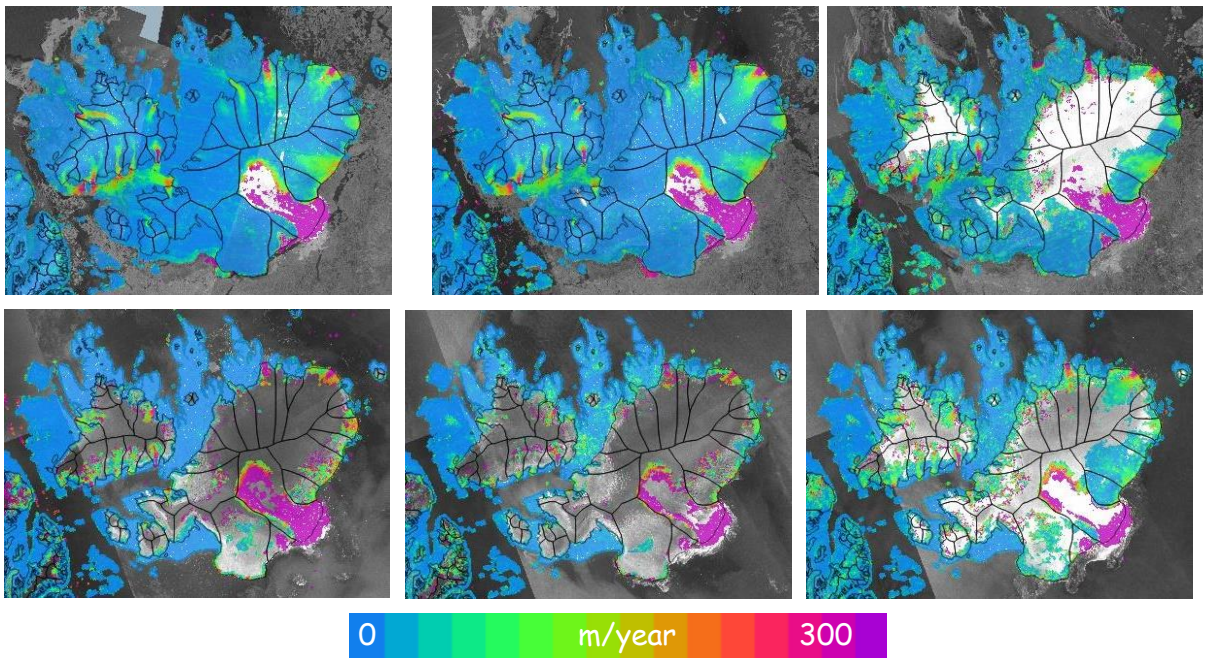

Figure 4.2: Ice velocity maps on Nordaustlandet, Svalbard, Norway from multiple Sentinel-1 image pairs. Top: ice velocity in winter, S1 image pairs acquired in Jan/Feb 2015; bottom: ice velocity in summer, S1 image pairs acquired in Aug/Sept 2015.

4.2.1.5 Product assessment

The delivery includes an ascii table with displacement values in Northing, Easting and vertical direction together with the cross-correlation as quality measure computed on a grid of 100 m spatial resolution together with a meta data file description, a Geotiff of the displacement magnitude and of a quicklook image as main product. As side products, the differential interferogram, the two intensity images and a coherence image are computed with 20 looks in slant-range and 4 looks in azimuth and geocoded at 50 m resolution.

Assessment of weather the provided products fully meet the user requirements is ongoing. If the product is not meeting the user requirements, the differences between the user requirements and the available service will be described. Weather the service has to be improved or if it is anyway useful for the end-user right now will be also assessed.

4.2.1.6 Product availability

Products are generated on user's demand and are made freely available to the interested users for non-commercial use.

4.2.1.7 Product provision

After production is completed and automated product verification is successful, the data are made available to the users on the GAMMA dropbox with a notification by mail. Alternatively, and depending on the user, the products are made available on the SEN3APP products portal (ERDAS Apollo System). The product is made available free of charge at this time but could be run commercially in the future.

4.2.2 Ice velocity

Service provider: *ENVEO*

4.2.2.1 Service requirements and end users

The users ZAMG, MetOffice UK and DHMS are interested in annually updated ice surface velocity maps for selected glacier from high resolution SAR satellite data.

4.2.2.2 Product description

The glacier ice velocity product shows the displacement of the ice surface on selected glaciers in m/day. The baseline method for the product generation is offset tracking using image pairs of Sentinel-1 SLC data, as described in detail in D3.2 – D3.7. The product is provided as raster in file format Geotiff or NetCDF.

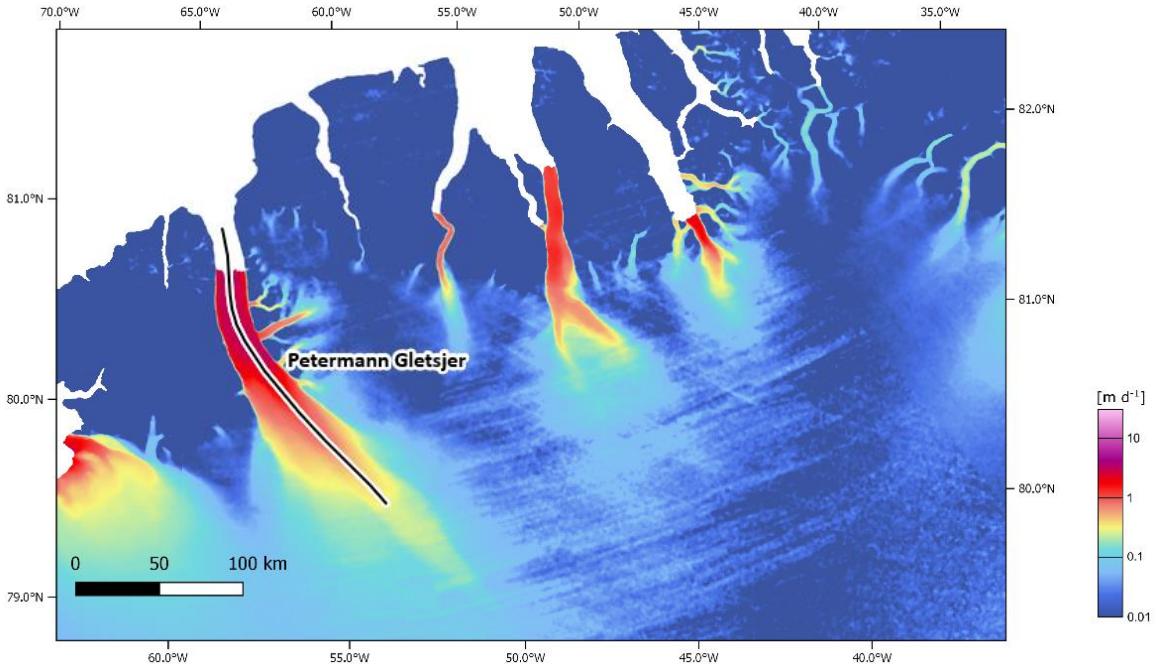

Figure 4.3: Ice surface velocity on large outlet glaciers in North Greenland from multiple Sentinel-1 data of 2015. Ice velocity analyses along the flowline of Petermann Glacier are shown in Figure 4.4.

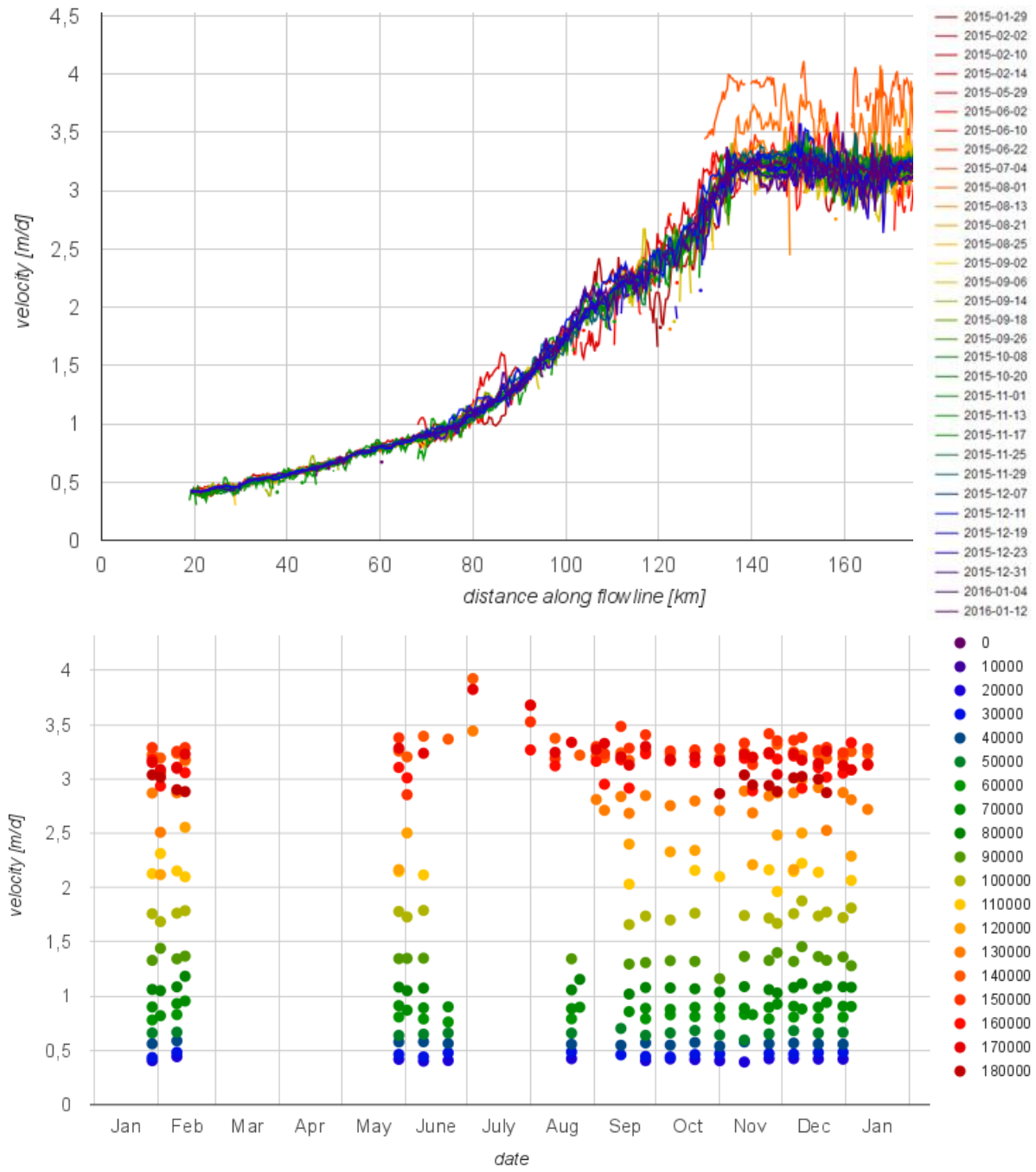

Figure 4.4: Top: Ice velocity of multiple dates in 2015 and 2016 in dependence of the distance along the flowline of Petermann Glacier (cf. Figure 4.3); Bottom: Mean ice velocity of 12 days scaled to m/day in dependence of the time. The coloured dots show the distance along the flowline of Petermann Glacier.

4.2.2.3 Data base for the service

Ice velocity products are based on Sentinel-1 SLC data. For large and fast moving outlet glaciers, as occur in Greenland or Antarctica, data acquired at IW mode are used.

For smaller glaciers, or glaciers with steep surrounding slopes, very high resolution radar data are needed for the product generation.

Additionally, a high resolution DEM is needed for geocoding the ice velocity product.

4.2.2.4 Spatial and environmental constraints

For retrieving usable ice velocity maps on glaciers by means of Sentinel-1 IW SLC with 20 m azimuth resolution, the minimum transverse of the observed glacier must be at least several hundred meters. For smaller glaciers, as in the Austrian Alps, Sentinel-1 scenes acquired with SM mode with 5 m azimuth resolution would be needed, but such scenes are currently only acquired over small islands and not over glaciated areas.

Beside the size of the glacier the ice surface must also have a minimum motion in the range of about 60 meters/year in azimuth resolution to be detectable by means of offset tracking from Sentinel-1 IW data. For very slow glaciers with ice velocities in the order of centimetres or a few meters per year the offset tracking method shows no motion at all. Using instead interferometry to retrieve ice surface velocity for very slow glaciers from Sentinel-1 IW SLC data might be an option in future, but is still under development.

4.2.2.5 Product generation

The ice velocity product is retrieved from image pairs of Sentinel-1 IW SLC data using offset tracking as baseline method. Repeat time of the Sentinel-1 image acquisitions is 12 days. The detailed processing with the baseline method offset tracking is described in D3.2 – D3.7. The final product shows ice surface velocity in m / day. Products are prepared as raster in file format Geotiff or NetCDF.

Products are generated on demand and depend on the availability of satellite imagery. The latency time for the ice velocity product is 3 months after user request.

4.2.2.6 Service status

The service is only active on user demand.

4.2.2.7 Data rights

Products are generated only on demand of users, and are made freely available to the interested user for non-commercial usage.

4.2.2.8 Data access

Products are sent via mail to the interested user or put on a dedicated FTP accessible by the user.

4.3 Snow / Ice areas on glaciers

Service provider: *ENVEO*

4.3.1 Service requirements and end users

The SEN3APP users ZAMG, Hydrological Service Tyrol, MetOffice UK and DHMS requested annually updated snow / ice areas on selected glaciers from high resolution satellite imagery. Products should be prepared following the GLIMS (Global Land Ice Measurements from Space) standards.

4.3.2 Product description

The snow / ice area on glaciers product from high resolution optical satellite data provides a rasterized snow map on glaciers in file format Geotiff or NetCDF, and additionally closed polygons outlining all snow areas on glaciers, relating the snow information via attributes to the overall glacier outline data base following the standards of GLIMS. An example is shown in Figure 4.5. Additionally, INSPIRE conformal metadata information are prepared for each product.

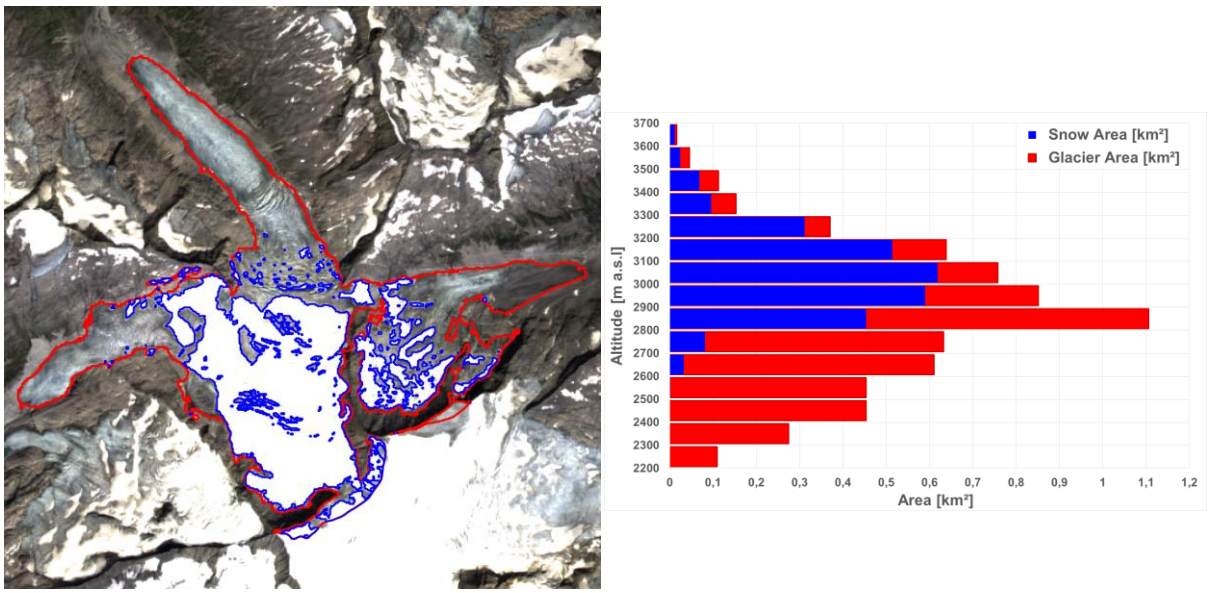

Figure 4.5: Snow areas (blue outlines) on a selected glacier (red outlines) of Venedigergruppe, Hohe Tauern, Austria, derived from Sentinel-2 L1C MSI data of 13 August 2015. The overlaid box plot shows the area altitude distribution of the total glacier area and the snow areas on the glacier.

4.3.3 Data base for the service

Snow / ice area on glaciers are mapped from high resolution optical satellite data. Freely available scenes of Sentinel-2 MSI and Landsat 8 OLI are the main data base. Optionally, other

(very) high resolution optical satellite data, as SPOT or Pleiades, respectively, can be used for mapping snow / ice areas on glaciers, but such data are usually only available at a charge.

For the demonstration within SEN3APP the snow / ice areas are mapped on selected glaciers covered by the Sentinel-2 MSI scene of 13 August 2015 over the region Hohe Tauern in Austria, which is also used for generating the demonstration product of glacier outlines. Also for mapping snow / ice areas on glaciers Sentinel-2 level 1B data would be preferred, for the same reason as described for the glacier outlines.

Additionally, the same DEM as used for the processing of the glacier outlines is used for the processing of the snow/ice areas on glaciers. Further, outlines of the glacier(s) of interest are mandatory to reduce the analysed area and avoid the detection of snow fields outside glaciers.

4.3.4 Spatial and temporal constraints

For the product generation a high resolution optical satellite image acquired in late summer, as close as possible to the date with maximum ablation areas on glaciers is needed. The same restrictions as for glacier outline mapping are valid for detecting snow / ice areas on glaciers.

4.3.5 Product generation

The baseline product snow / ice areas on glaciers from Sentinel-2 uses the different reflectance properties of snow and ice in the near infrared spectral range to detect snow areas on glaciers. The detailed processing is described in Bippus (2011) and in D3.2 – D3.7. The final product shows snow areas on glaciers.

Products are prepared as raster in Geotiff or NetCDF format and as vector files in Shapefile format following the standards of GLIMS. Optionally, also wet snow can be detected on glaciers using Sentinel-1 data and applying the processing line as for the baseline wet snow cover product, but reducing the analysed area to selected glaciers.

Products are generated on demand and depend on the availability of usable satellite imagery. The latency time for the product snow / ice areas on glaciers is 3 months after user request.

4.3.6 Service status

The service is only active on user demand. Validation of the snow / ice areas on glaciers from Sentinel-2 data is needed, but depends on availability of usable reference data. Orthophotos or very high resolution optical satellite imagery acquired on the same date as the scenes used for the product generation are the preferred reference data sets. Depending on the weather conditions a maximum delay of 5 days between the image acquisitions is acceptable. Such data enable an areal evaluation of the product, not only a point-wise validation as with rarely available in-situ observations. Several very high resolution satellite images are planned to be ordered in 2016 through the Copernicus Data Warehouse for validation purposes.

4.3.7 Data rights

Products are generated only on demand of users, and are made freely available to the interested user for non-commercial usage.

4.3.8 Data access

Products are sent via mail to the interested user or put on a dedicated FTP accessible by the user.

5. Description of Service Characteristics for Lake Ice Product (D5.4)

5.1 Lake ice Extent

Service provider: *SYKE*

5.1.1 General

Lake ice extent has currently main user internally at Finnish Environment Institute, SYKE for seasonal and long-term monitoring of lake ice cover in Finnish lakes. There is also interest for the product in weather forecasting. Some trials have been carried out in previous projects, with the products predecessors, but the product needs improvement before further implementation to the models.

The product is currently produced for Northern-Europe covering an area of 45° - 71° latitude and 5° - 45° longitude.

Aim: provide information on lake ice extent (and snow cover on ice) for long-term monitoring.

5.1.2 Raw data for the service

- MODIS: The LIE- data production relies on Terra/MODIS- data until the Sentinel-3 SLSTR and OLCI data become available
- Sentinel-2: The method can also be applied to high resolution data of Sentinel-2. The initial development and testing period is the spring 2016, when the data becomes first time available.
- Landsat-8 OLI: Images are used for validation purposes.

5.1.3 Spatial, temporal and resolution constraints

The spatial extent of valid daily observations is restricted by clouds and polar night in the northern latitudes (e.g. Finland), where the period of coverage is from end of February to disappearance of ice cover. In the context of SEN3APP demonstration phase package of data is offered from last 5 years (2010-2015).

Development of an operational service to Sodankylä NSDC is on-going and is worked towards NRT-service, i.e. data product being available around 6 hours after image acquisition.

With the initiating Sentinel- satellite series the product generation for medium and high resolutions are well covered.

5.1.4 *Product generation*

- MODIS Data is acquired from NSDC Sodankylä (FMI) receiving station.
- Radiometric and atmospheric correction are done using Envimon software developed by VTT.
- SYKE developed algorithm is used for cloud generation.
- The product is generated at NSDC Sodankylä (FMI) processing facilities with control at SYKE.

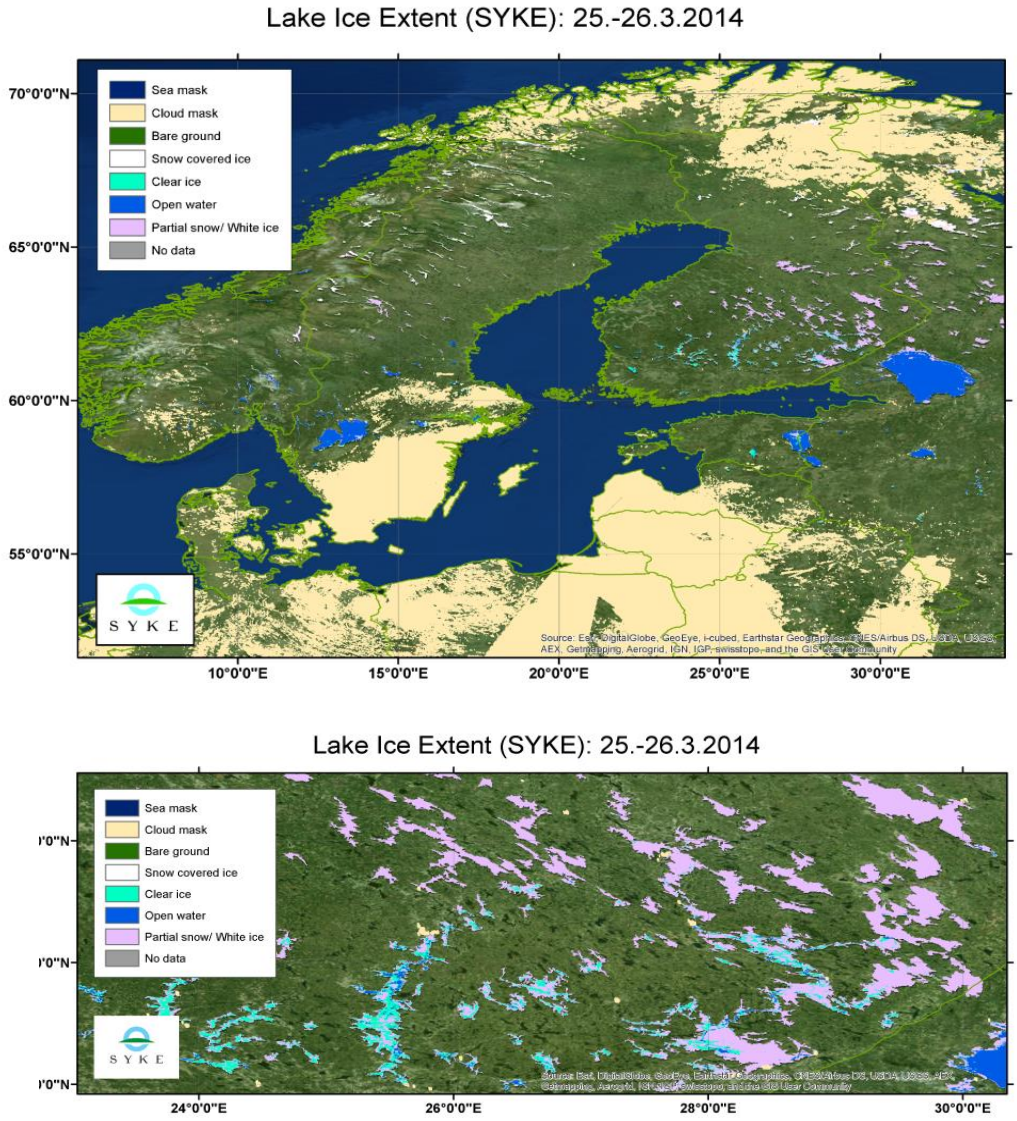

Figure 5.1: SYKE Lake Ice Extent classification [snow covered ice, partial snow/white ice cover, open water] demonstration product.

5.1.5 Service status

The service is still under development together with the end user so it is not possible to say if it fully meets the user requirements. Anyhow, according to MAVI, even at this stage the service is useful for them and they should also do some work to integrate produced information better to their own systems.

5.1.6 Data rights

The products will be made openly available. The SYKE data policy is currently under review and therefore the exact data usage conditions will be refined later.

5.1.7 Data access

In the demonstration phase the data package will be made available via ERDAS Apollo service at NSDC Sodankylä. Later the distribution of the data will be also extended to SYKE open data service.

5.1.8 End-user

SYKE Freshwater centre.

6. SEN3APP Products excluded from Demonstration Phase

For some of the originally planned products to be provided within SEN3APP not enough end-users could be found within the project, other products are still under development and not ready yet for demonstration. The following products were originally planned, but will finally not be provided within the SEN3APP demonstration phase:

- Water Body map (service planned by GAMMA)
- Freeze / Thaw maps (service planned by GAMMA)
- Combined (2-layer, 25km) Northern Hemisphere snow cover product with optical FSC and PMW SWE –layers (service planned by SYKE & FMI)
- Pan-European wet snow cover map (service planned by ENVEO)
- Lake Ice State (service planned by GAMMA)

Anyway, work on these products and associated services is in progress, and might be available in future after the project period.

Although the combined Northern Hemisphere snow cover product with optical FSC and passive microwave radiometer SWE layers is not included in the demonstration phase, the separate NH FSC product (Section 3.1) and the Legacy GlobSnow NH SWE products are available. The combined product is not included, as no significant user demand has been identified. The end users either need only one of the products or are satisfied using them independently.

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