

SNOW SERVICES FROM GSE POLAR VIEW - FIVE WINTERS OF OPERATIONAL SERVICE AND THE EXTENSION TOWARDS A PAN-EUROPEAN SERVICE

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ABSTRACT

Snow plays a major role in the flow patterns of many rivers - not just in the Northern Regions and in the mountains, but also extending far downstream to the large rivers of the densely populated lowlands of Central Europe. Knowledge on snow distribution, area, volume and changes are essential for a wide range of users.

Polar View's snow service partners located in Norway, Finland and Germany, provide EO based, near-real-time information on snow coverage for a variety of users. These pan-European institutes, water resources authorities, flood forecast centres, research institutes, local associations and private companies receive dedicated products for their requirements of planning and decision making. Areas covered by the services are Scandinavia, the Baltic Sea basin and Central Europe, including the Alps.

In this paper, the current services and the recent extension towards a consolidated snow service are described. The common, consolidated information on snow covered area, derived from the detailed EO products of each service provider, fulfils the demands for are larger user group, e.g. the global change community and gives stronger recognition and publicity to Polar View. Polar View will provide a "one-stop-shop" for Earth Observation services offering integrated monitoring and forecasting services in polar and mid-latitude regions affected by ice and snow. www.polarview.org

1. INTRODUCTION – THE GSE POLAR VIEW

The presented Snow Services are part of Polar View, a successful, ESA funded, international consortium of government agencies, research institutes and service providers across Europe and Canada in the scope of GMES. Polar View services were designed to meet clearly defined user requirements, concerned with policy, the environment, the economy, and safety. Besides the Polar Regions, all areas in the European mid-latitudes that are significantly affected by snow and ice were targeted. The services enclose sea ice and icebergs, river and lake ice, glaciers and snow monitoring. Since 2005 the Polar View network, with

more than 80 partners from 17 countries, serves as one of the largest user of EO data that provide reliable services and products to users.

The continuing support from ESA (extension towards 2012) enables to continue to provide high-quality Earth Observation products, and to establish new products, services and collaborations.

2. SNOW SERVICES WITHIN POLAR VIEW

Within Polar View three snow service providers, located in Norway, Finland and Germany were involved. They provide EO based, near-real-time information on snow coverage to an increasing number of users. Each of these companies and institutes (represented by the authors of this paper) has large experience in snow monitoring and other EO based services.

To cover the specific needs of the mainly locally operating users and give consideration to the specific geographic aspects of the covered regions, near-real-time EO observation from optical (MODIS / AVHRR) and C-Band SAR (ENVISAT ASAR), different dedicated algorithms, automated processes and distributed ways of product delivery were implemented. All of the snow cover products, ranging from weekly snow cover fraction analysis to daily snow line derivation, were developed and specified with respect to consolidated requirement of the involved users.

An overview of the individual services is given in the following sections.

2.1. Scandinavian Snow Cover Area Service

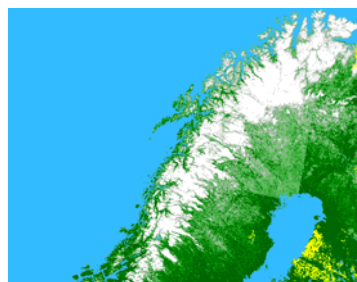


Figure 1:
Scandinavian Snow
Cover Area Service

Fractional snow
cover

(section of KSAT
product)

The objective of the Scandinavian sub-service was to develop a sustainable satellite-based snow monitoring service providing products tailored to the Scandinavian region. The basic service has been developed and demonstrated by Norut and NR within a series of projects. The service chain was already demonstrated pre-operationally for hydropower companies in southern Norway and Western Sweden during EnviSNOW. For the operational phase of this service within Polar View, the coverage area was expanded to the whole of Norway and Sweden.

Optical data provides the highest confidences, but are often hampered with cloud coverage. SAR data are independent of daylight and clouds, but are less accurate in determining the snow cover fraction and can only be used when wet snow is present. The final product delivered to the users is a mosaic combining the pixels with highest confidence from the time series of images obtained over the previous few days before the last acquisition (up to the previous 7 days). The service is automated and runs operationally at KSAT with manual inspection and quality assessment of the final products. The final product provides a percentage of snow cover per pixel based on a multi-temporal mosaic of optical and SAR data, and is produced by KSAT after each data acquisition during the snowmelt season (1 April – 1 July).

Table 1: Summary EO product specifications

EO Input	ENVISAT ASAR & Terra MODIS
Snow Map Product	Fractional Snow Coverage raster (mountainous areas)
Coverage	57°-72° N; 0°-32° E
Resolution	250m UTM 33
Delivery	Daily product, including information of EO observations of last 7 days
Access	FTP directory for users
Service Provider	Kronsberg Satellite Services KSAT, Norway www.ksat.no

2.2. Snow Monitoring Baltic Region

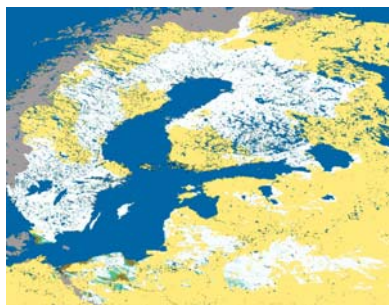


Figure 2:
Snow Monitoring
Baltic Region

Fractional snow
cover

(section of SYKE
product)

The aim of the Baltic region snow map service is to provide near real time (NRT) information on fractional snow coverage for the Baltic Sea drainage area during

the snow melting period. SYKE snow mapping service uses input Earth Observation data provided by Terra/MODIS. SYKE's automated processing flow starts right after data has been received at the server. After preprocessing, including calibration, geocorrection and cloud-masking, (the cloud mask is visually verified and corrected by human operator if necessary) the automated snow algorithm, using a transmissivity map, is launched, ending up with a snow map. Finally the data is uploaded to SYKE's snow map website with free access to the users.

Table 2: Summary product specifications

EO Input	Terra MODIS
Snow Map Product	fractional snow coverage (in forests and in open areas)
Coverage	45°-71° N; 5°-45° E
Resolution	0.05° × 0.05° (WGS-84)
Delivery	Daily product < 6 h after EO acquisition
Access	Service providers web site
Service Provider	Finnish Environment Institute SYKE, Finland www.environment.fi

2.3. Snow Service Central Europe

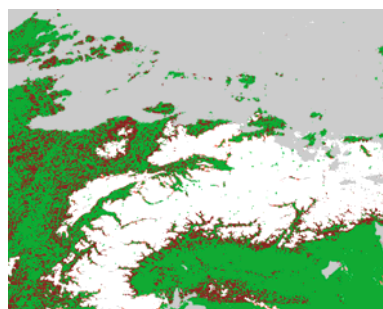


Figure 3:
Snow Service
Central Europe

Alpine snow cover

(section of VISTA
SCA product)

The service consists of snow cover mapping and snow line estimation using optical and microwave EO data for major catchments in Central Europe and the Alps. The produced snow covered area maps give raster based information on snow, wet snow, snowline, snow-free areas and unclassified areas (e.g., clouds, unsuitable geometry) for appointed catchments. This snow information from EO is delivered daily, shortly after EO data availability, for optical EO data, depending on cloud situation. The availability of snow cover and wet snow information from microwave data depends on ENVISAT WSM mode availability.

The provision of Snow Water Equivalent (SWE) using the physically based snow- and hydro-model PROMET requires meteorological station-data, land-use and topography as input. The spatial distribution of Snow Water Equivalent is calculated physically based, regarding all components of mass and energy transfer. Observed snow cover information from EO is assimilated for improved results. [1] [2]

Table 3: Summary EO product specifications

EO Input	ENVISAT ASAR & NOAA AVHRR
Snow Map Product	Binary Snow Map, Location of Snow Line and Wet Snow Areas raster
Coverage	44°-56° N; 3°-15.5° E Product dedicated to catchment areas (e.g. Upper Danube)
Resolution	1km
Delivery	Daily product, 1 h / 6 h after EO acquisition
Access	password protected FTP service, including backup server
Service Provider	VISTA Remote Sensing in Geosciences GmbH, Germany www.vista-geo.de

Table 4: Summary SWE product specifications

Input	Metrological station data, EO bases snow map
SWE product	SWE distribution, daily, raster
Resolution	1km
Delivery	Daily product
Access	On request

3. OPERATIONAL SERVICE PROVISION

The operational service provision is targeted to the needs of the users. Most of the users of Polar View services are strongly involved in the project. They contribute to the continuing development of services by participating in trials and defining requirements

3.1. Users of the Snow Service

The services are used by a span of pan-European institutes, water resources authorities, flood forecast centres, research institutes, local associations and also private companies. They receive dedicated products for their requirements of planning and decision making for their areas in Scandinavia, the Baltic Sea basin and Central Europe, including the Alps.

The focus of the Scandinavian service is largely on commercial companies, working in the field of hydropower / water resources management.

On the other hand, the Baltic Region SCA-product addresses primarily the needs of governmental activities related to water management (e.g. flood prevention) but also the hydropower industry. In the longer term, this service will likely provide beneficial information for use in climate studies.

In addition to the Northern services from KSAT and SYKE, dedicated to monitoring of the yearly snow melt season, the service for Central Europe obtains important information also during snow accumulation phase. For the areas in Southern Germany, close to the Alps, a dynamic behaviour of the snow cover is predominant. Alternating processes of accumulation and melting,

often in interaction with rain fall, produce the risk of local flood events. The flood forecast and early warning is the duty of most of the involved users in this service. As example, the flood forecast centre of the state of Baden-Wuerttemberg / Germany uses the Polar View snow products operational to control and update their runoff calculations and forecasts.

3.2. Service Performance

During the last 5 years of service a massive number of EO datasets had been received, processed and delivered as value-added products.

For the snow services an annual quota of 250 ENVISAT ASAR datasets was assessed. In addition to that, auxiliary optical EO datasets (Terra MODIS / NOAA AVHRR) were integrated in the service chains twice a day. Altogether, an annual number of about 1200 snow maps for the different areas and users could be achieved.

Within the operation of the last 5 year period, no appreciable service gap or failure could be reported

4. EXTENSION TO CONSOLIDATED SERVICE

The three described services cover the specific needs of the mainly locally operating users and give consideration to the specific geographic aspects of the covered regions. They use different sensors and dedicated algorithms and distribute the products in different ways. Within the continuing scope of Polar View, a consolidation of the products of the service partners, and a combined product (covering the complete pan-European service area) was inducted. These products, characterized by lower spatial and temporal resolution is now made public available on the Polar View Snow Service Portal.

4.1. Concept of the Snow Service Portal

Common, consolidated information on the snow covered area fulfils the demands for are larger user group, e.g. the global change community and gives stronger recognition and publicity to Polar View. Polar View wants to offer a "one-stop-shop" for Earth Observation services offering integrated monitoring and forecasting services in polar and mid-latitude regions affected by ice and snow.

To reach this, the creation of an access point, were interested parties get snow products from Polar View, and all information about the service providers involved, was targeted. The concept of the portal was developed under the consideration of an intuitive usability by interested parties, the application of most

common web technologies, no need of any software installations and fair data transfer rates.

Under review of other existing web services and portals (e.g. IPY Ice Logistics Portal, NSIDC websites, etc.) a user interface using Google Map technology was set up and continuously improved after internal discussions with the partners.

The new Snow Service Portal (starting summer 2010) now gives access to recently enhanced 10 day composite products of each service in with consolidated specifications and the derived Combined product. Details on the products consolidation can be found in section 4.2.

In addition the portal provides direct the link to the service providers and contact persons for the snow products. Mechanism of feedback and tracking of user requests are under development and will be made available soon. According to Polar View's objectives, the evaluation of user requirements and the approach of new user groups are the main targets of the portal.

The snow portal is reachable via the Polar View Web page www.polarview.org or directly at www.snowsense.de.

4.2. Product consolidation

To overcome the situation that the three service providers only generate highly individual products (different algorithms, different classes, different geometry), a concept of a common product specification was developed. Using the inputs from each service provider and each service area, a multiday composite product, as common denominator product, was introduced. To achieve best conformity with user requirements and technical aspects, the specifications were chosen:

- Multiday-Product (10days mean of snow)
- Snow Cover Fraction, divided in 5 classes
- Spatial Resolution of 0.05 degree
- Geographic projection (Lat / Lon)

These specifications are also in analogy with projected GlobSnow and H-SAF products. For the products presented on the portal, the most common data format was selected (PNG & KML) to allow easy access, download and viewing using e.g. Google Earth.


The available high resolution products from the partners, which up now were only delivered to directly involved users, serve as input for the 10d day composite product. The main technical details for the generation and presentation of the consolidated products for each area / service provider are summarized in table 5a/b.

Table 5a: Technical details of consolidated products

Spatial aggregation & geometric projection		
Scandinavia use of 2500m UTM product (based on 250m original) reprojection using nearest neighbor	Baltic Region 0.05° product directly available	Central Europe / Alps 0.0125° binary product sampled to 0.05° resolution
Temporal aggregation		
All available products within 10d period are sampled *		
$10dFSC = \text{sum of } FSC(n) / n$ if $n < 2$ then 10dFSC = set to no data flag $n =$ number of snow or snow free info each pixel		
* The KSAT products comprise the EO data of the last 7 days. For the 10d periods only the last 4 products were considered for the calculation		
Definition of 10d periods		
Period I	1. to 10. of each month	
Period II	11. to 20. of each month	
Period III	21. to 28.-31. of each month	
Classification rules		
calculated fractional snow cover	naming	
0%	snow free	
1% - 25%	slightly snow covered	
26 - 50%	partly snow covered	
51% - 75%	mainly snow covered	
76% - 100%	fully snow covered	

Having access to the original products, all steps of processing for the consolidated products were performed at Vista's facilities after each 10 day period. A central processing of the products ensures comparable products. The quality / accuracy of the 10d products provided via the Snow Service Portal is of course dependent of the quality / accuracy of the initial datasets provided by each service provider.

Table 5b: Details of presentation of consolidated products on the Snow Service Portal

<u>Color coding</u>		
	RGB	HEX
snow free	255 153 000	FF9900
slightly snow covered	217 229 242	d9e5f2
partly snow covered	188 214 244	bcd6f4
mainly snow covered	102 153 255	6699FF
mainly snow covered	000 51 102	003366
Clouds or no data	180 180 180	b4b4v4
		
<u>Masked out areas</u>		
Water bodies		
Countries outside snow mapping purpose		
Areas outside applicability of classification algorithm		
<u>Transparency settings</u>		
Snow Free: Alpha value = 30		
Snow / No Data: Alpha value = 64		
Masked areas: Alpha value = 127		

Concept of the portal was the easy display of the Polar View snow products in the above described specifications. For this purpose, also taking download volume / speed in account, all products were made exclusively available as PNG (Portable Network Graphics) format datasets. This format allows lossless and well-compressed distribution of raster images and provides full capability with Google Maps and Earth application. An important feature of the PNG datasets is the option of selective transparency for different colours. This allows the improved display of the snow covered areas using Google Maps technologies.

The detailed specifications of the presented raster products are listed in in table 5b.

According to the characteristics of each region and product algorithm, services and products are only available for a certain time span. On the one hand snow cover for the Alpine regions are of nearly half-year interest (starting November), on the other hand the snow melt processes in the Northern areas are of large interest in the spring to summer. Since for Central Europe also the irregularly snow fall and melt process in the low lands already in autumn are of interest, the long lasting snow coverage in Norway and Finland demands intense observation starting lately in April. In addition the low sun elevation for the areas north of $\sim 55^\circ$ N disables an earlier start of the local services. Due to this situation,

the period of the single Polar View snow services shows large temporal spread. The mean space of time for the three services is illustrated in table 6.

Table 6: Temporal coverage of the service during the winter months (N)ovember to (J)une

Service / Month	N	D	J	F	M	A	M	J
Scandinavia						x	x	x
Baltic Region				x	x	x	x	
Central Europe	x	x	x	x	x	x	x	

4.3. The Combined Product

The generated 10d day composite product from each region serves as direct input for the additionally 'Combined Product'.

For this first available pan-European product, representing the overall snow situation ($44^\circ - 72^\circ$ N), a number of overlaps between the original products had to be treated.

For some cases, (e.g. Poland) where only small overlaps between the services occur, the consolidated product is calculated using mosaic techniques, using the information of the more assigned / closer service provider. In case of large key areas, like the mountainous areas of Scandinavia (located in Norway and Sweden), where two service providers (KSAT & SYKE) have outreaching coverage, a more sophisticated method is applied. Overview on key areas and spatial overlap is listed in table 7. Considering the fact that both services have different focus, the more specialised algorithm / service was chosen. Therefore, the mountainous areas of Sweden, Sweden and Norway ($> 500\text{m a.s.l.}$) were covered by results from the multi-sensoral & multi-temporal algorithm developed NR & NORUT [3], while the non-mountainous and forested areas were covered by results from the SYKE [4] algorithm. To keep the original results from the different service providers (different algorithms), the user can obtain the map results from all sources within the portal for overlapping areas. A detailed overview on the functionality of the portal is given in section 5.

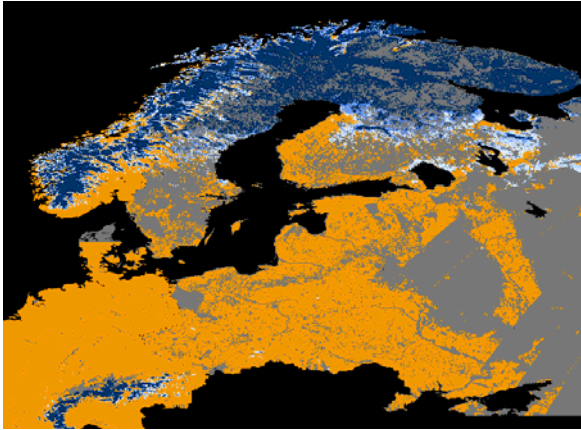


Figure 4: Combined Product for the period of 21- 30 April 2010, optimized to be display at the Snow Service Portal

Table 7: Areal coverage by service provider for key areas

Key Area / Provider	KSAT	SYKE	VISTA	Combined Product
Norway	fully	none	none	KSAT
Sweden	mostly	fully	none	KSAT > 500m SYKE < 500m
Finland	partly	fully	none	KSAT > 500m SYKE < 500m
Baltic & Eastern European States etc.	none	fully	none	SYKE
Poland Czech Republic	none	fully	partly	SYKE
Germany	none	partly	fully	VISTA
Austria	none	partly	partly	VISTA (western part) SYKE (eastern part)
Switzerland	none	none	fully	VISTA
Italy and France	none	none	partly	VISTA

5. USE OF THE SNOW SERVICE PORTAL

During the development of the Snow Service Portal, an easy to understand layout was intended. Users following the link to the portal, or directly browsing to www.snowsense.de, will find a graphical user interface (GUI) as illustrated in figure 5. From the start, the GUI will present the map section on the right (labeled C) and the basic functionality of 'Area / Service' selection (A) and the selection of the displayed period (B) on the left. Auxiliary functions and access to more information is placed in the lower part (D).

5.1. Basic map functions

All selected maps are displayed on a Google Map window with fixed background to 'Terrain Mode'. (Within the map window the user can zoom using mouse wheel or buttons and navigate the map individually. The snow information overlay the map layer with different adapted levels of transparency. (see details in table 5b).

An overlay of two or more map products is not possible within the map window of the portal. To apply such features e.g. Google Earth must be used. Please find more information on that in the 'Download' chapter of this document.

5.2. Selection of Area / Service Provider

Choose Area / Service

At the start of the portal (also using the 'Home' function) the latest available 'Combined Product', generated from inputs of all service providers of the snow map (details see 4.3.) are displayed. By the selection of an other area (Central Europe / Baltic Region / Scandinavia) – area of box A in figure 5 – the latest available associate product of the responsible service provider will be displayed. The background map will automatically be centred to the selected area. Changing the selected area will change the origin (service provider) of the products.


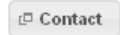
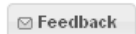
5.3. Selection of Period

Choose Period

All available 10 days composite snow maps (starting from winter 2009 / 2010) were made available to the portal. Using the drop-down menu – area of box B in figure 5 – the desired period can be selected. Only available datasets are indicated. Note that the service periods depend on the service area (see table 6). The combined product is only available if at least two regional maps are available.


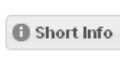
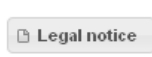
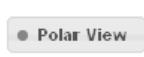
5.4. Fundamental functions

Beyond the basic selection of area and period, the user of the portal has access to three more significant functions, located in the center lower area of the portal (area of box D in figure 5). Activating one of the functions using the buttons, an additional small window appears. This one can be positioned freely.

	<p>The menu for the product download shows up a table, including thumbnail quicklooks, with the available datasets for the combined product and respectively the local service providers.</p> <p>A click on the filename (e.g. PV_SC100531.kml) will open a pop-up menu for the selection to open it directly in Google Earth (if installed on local computer) or download the file to a local directory.</p> <p>The naming of the files consists of 5 characters indicating the service provider or the Combined Product (PV_SC = Polar View Snow Cover) and 6 characters of the date (yymmdd). The date refers the last day of the 10d period (cf. table 5a)</p> <p>Note: The downloaded KML file will contain the geolocation of the product and the link / location of the dataset, not the raster data itself.</p>
	<p>The Access and Contact window provides the user the appropriate contact persons and the link to more detailed informations (and snow products if available) on the services at service providers' websites.</p>
	<p>For the improvement of the portal and the approach to new user groups, feedback is very much welcome.</p>

5.5. Other functions

For the convenience of the user additional functions and information are given by activating the buttons.

	<p>Reloads the portal, all map functions and product selections will be set back to starting-point</p>
	<p>Gives brief information on the origin and the specifications of the products. Links to more detailed references are provided here in a small window.</p>
	<p>Important information on terms of use, warranty and disclaimer for the provided information. The selection opens a new browser window.</p>
	<p>Link to the Polar View main website www.polarview.org. The selection opens a new browser window.</p>

6. CONCLUSIONS

The Polar View snow portal provides easy access to the public on services and achievements of the GMES initiative Polar View. It provides map based visualisation of the snow cover in Europe and its change with time. A consolidated snow product combines the regional service products of a set of providers to a single product which covers already a large part of Europe. Thus the Polar View snow portal can be understood as a window to and baseline of a GMES core service on snow.

7. ACKNOWLEDGEMENT

The Polar View snow services and the development of the Snow Service Portal are support by ESA within the GMES Services Element (GSE) activities.

8. REFERENCES

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A Combined Map
Central Europe
Baltic Region
Scandinavia

B Choose Period
21 May 10 - 31 May 10

C Polar View

D Download Data

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Figure 5: Overview of the snow service portal GUI, showing areas of user functionalities (A, B, D) and Google Maps window (D).