Global Snow Monitoring for Climate Research

GlobSnow Snow Extent Product Guide
Product Version 1.0

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1 OVERVIEW OF THE PRODUCTS

The European Space Agency (ESA) Data User Element (DUE) GlobSnow Snow Extent (SE) product set version 1.0 for the Northern Hemisphere represents information on snow coverage retrieved from ERS-2 ATSR-2 and Envisat AATSR from 1995 until present. There are four product types:

- **Daily Fractional Snow Cover** (DFSC), snow fraction (%) per grid cell for all satellite overpasses of a given day
- **Daily 4-classes Snow Cover** (D4SC), snow cover classified into four categories per grid cell for all satellite overpasses of a given day
- **Weekly Aggregated Fractional Snow Cover** (WFSC) for all satellite overpasses within a 7-day period based on aggregation of daily products. Available for each day based on a 7-day sliding time window giving most recent observations highest priority
- **Monthly Aggregated Fractional Snow Cover** (MFSC) for all satellite overpasses within a calendar month period providing the average, standard deviation, minimum and maximum FSC for the period

The goal of the ESA GlobSnow project is eventually to produce SE products for the whole seasonally snow covered Earth from 1995 until present, which also means that the product time series is updated in near real time. The data set is freely available and can be downloaded via a web or FTP interface.

2 DESCRIPTION OF THE PRODUCTS

The SE products are available in a geographical (latitude/longitude) coordinate system based on the reference ellipsoid WGS 84 and with a grid resolution of 0.01 × 0.01 degrees. The geographical area covered is the Northern Hemisphere 25°N-84°N (the seasonally snow covered part of the hemisphere). The sensors applied are ERS-2 ATSR-2 for the period from 1 August 1995 until 31 July 2002 and Envisat AATSR for the period from 1 August 2002 until present. The product set is produced and made available as a historic time series and updated daily.

Each product type includes a set of layers. Layer 1 is always the (main) thematic layer with a colour legend as explained in Figure 2.1. The encoding schemes applied in each layer are described in Section 3.

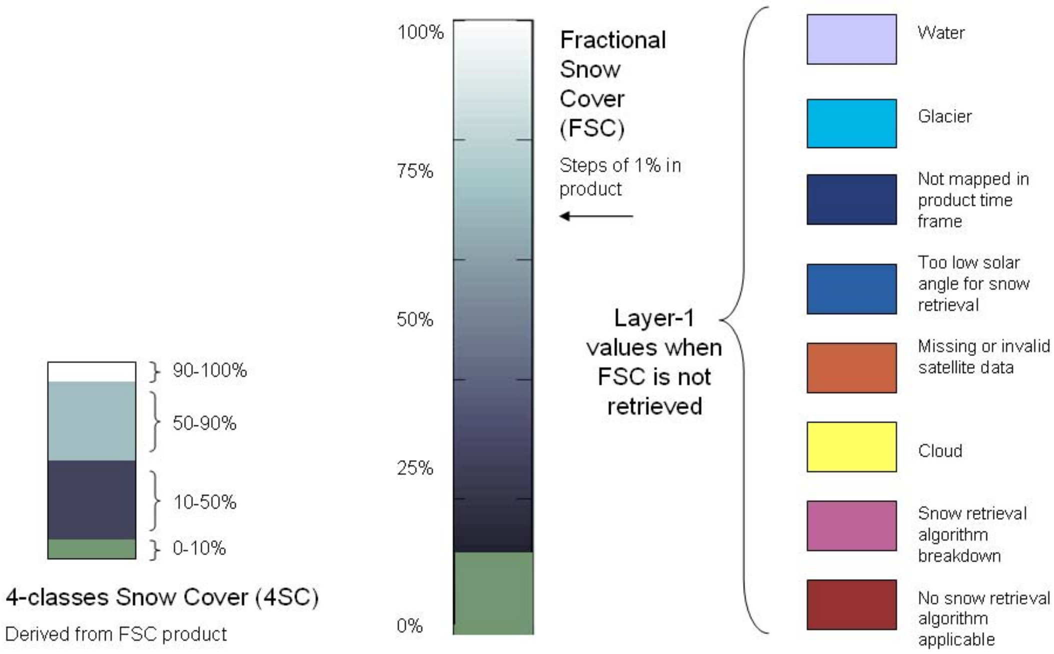

Figure 2.1: Colour legend for Layer 1 (thematic layer) for the snow products

2.1 Daily Fractional Snow Cover (DFSC)

The Daily Fractional Snow Cover (DFSC) product provides the fractional snow cover (FSC) in percentage (%) per grid cell for all satellite overpasses of a given day. The product represents the best estimate of today's snow cover, given the sensor capabilities (ATSR-2 or AATSR). If there are multiple snow observations (only far north within a day), the satellite observations applied are those giving best solar illumination (highest solar elevation). The product is generated for each day based on a 24 hours time window limited by sunlight. The product is produced and made available for each day in near real-time.

Layers:

- Layer 1: FSC if any cloud-free observation (flagged *cloud* if cloudy observations only; *not mapped in product time frame* if none)
- Layer 2: Uncertainty estimate of FSC retrieval (not implemented yet; the layer is empty)
- Layer 3: Bit flags (see explanation in Section 3.3)

Figure 2.2: Example of Daily Fractional Snow Cover product for 10 April 2003

2.2 Daily 4-classes Snow Cover (D4SC)

The Daily 4-classes Snow Cover (D4SC) product provides snow cover classified into four categories per grid cell for all satellite overpasses of a given day. In terms of FSC, the four classes represent:

- 0% ≤ FSC ≤ 10%
- 10% < FSC ≤ 50%
- 50% < FSC ≤ 90%
- 90% < FSC ≤ 100%

The product is derived from the DFSC product and has, therefore, the same general characteristics.

Layers:

- Layer 1: SE class if any cloud-free observation (flagged *cloud* if cloudy observations only; *not mapped in product time frame* if none)
- Layer 2: Uncertainty estimate of FSC retrieval (not implemented yet; the layer is empty)
- Layer 3: Bit flags (see explanation in Section 3.3)

2.3 Weekly Aggregated Fractional Snow Cover (WFSC)

The Weekly Aggregated Fractional Snow Cover (WFSC) product is based on all satellite overpasses within a seven-day period. The product represents the best estimate of the current snow cover. It is generated daily based on DFSC products within a sliding 7-days time window including the past seven days. The product is made available each day in near real-time.

If a calendar week product is needed, use the last product in each calendar week (each 7th product). Bit flags (see below) refer to day of snow observation (*n*). If there are no snow observations in period, but clouds are observed, bit flags and *n* represents the most recent cloud observation.

Layers:

- Layer 1: FSC for most recent cloud-free observation (flagged *cloud* if cloudy observations only; *not mapped in product time frame* if none)
- Layer 2: Uncertainty estimate of FSC retrieval (not implemented yet; the layer is empty)
- Layer 3: Bit flags (see explanation in Section 3.3)
- Layer 4: Relative day number for observation (*n* in *t – n,* where *t* is the product date)

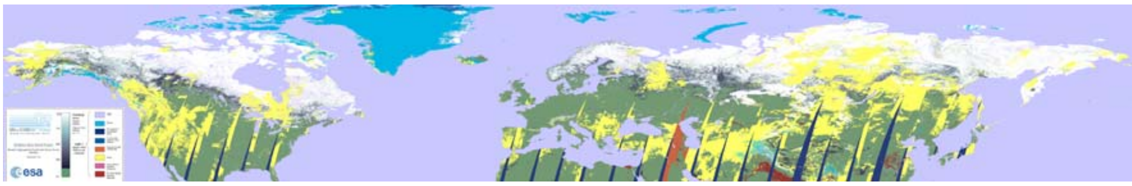

Figure 2.3: Example of Weekly Aggregated Fractional Snow Cover product for 19 April 2003

2.4 Monthly Aggregated Fractional Snow Cover (MFSC)

The Monthly Aggregated Fractional Snow Cover (MFSC) product is based on all satellite overpasses within a calendar month period. The product provides statistics for cloud-free observations of FSC within the period. It is based on DFSC products for the given calendar month. The bit flags are based on the flags of the corresponding day products. The product is generated and made available immediately when a new calendar month starts.

Layers:

- Layer 1: Average FSC of days with cloud-free observations) (flagged *cloud* if cloudy observations only; *not mapped in product time frame* if none)
- Layer 2: Combined uncertainty estimate of FSC retrieval (not implemented yet; the layer is empty)
- Layer 3: Bit flags (see explanation in Section 3.3)
- Layer 4: Number of days with snow observations
- Layer 5: Standard deviation of FSC retrieved
- Layer 6: Minimum FSC retrieved
- Layer 7: Maximum FSC retrieved

Figure 2.4: Example of Monthly Aggregated Fractional Snow Cover product for April 2003

3 PRODUCT ENCODING SCHEMES AND METADATA

The encoding scheme applied in each layer and the metadata are explained in the following.

3.1 Thematic information (Layer 1)

The encoding scheme applied to the thematic layer (Layer 1) is explained in Table 3.1. There are two encoding schemes for snow cover, one for FSC and one for the 4-class representation. Additionally, there are codes for other thematic classes and exceptions.

Table 3.1: The encoding scheme for Layer 1

Code	Explanation
	Snow information in the all three FSC products (DFSC, WFSC and MFSC):
100	100: FSC = 0%
101	101: FSC = 1%
…	…
200	200: FSC = 100%
	Snow information in 4-classes daily product (D4SC):
6	0% ≤ FSC ≤ 10%
7	10% < FSC ≤ 50%
8	50% < FSC ≤ 90%
9	90% < FSC ≤ 100%
	General thematic class codes applied in all products:
0	No data
20	Cloud
30	Glacier
40	Water body
	Exception codes applied in all products:
51	Outside mapping area
53	Not mapped in product time frame
54	Too low solar angle for snow retrieval (< 17°)
55	Missing or invalid satellite data
57	Snow retrieval algorithm breakdown
58	No snow retrieval algorithm applicable

3.2 Uncertainty (Layer 2)

Uncertainty of the retrieved snow cover represents important information in many applications of snow products. In the current version of the GlobSnow SE products uncertainty estimation is not implemented. Work is ongoing for development of an uncertainty model, and this layer will be included when then the model is implemented and evaluated. Currently, Layer 2 is empty.

3.3 Bit flags (Layer 3)

The bit flags provide supplemental information to the thematic layer (Layer 1). The flags are explained in Table 3.2.

Weekly product (WFSC): Bit flags correspond to day of snow observation (n in $t - n$, where t is the product day number). If there are no snow observations in period, but clouds are observed, bit flags and n represents the most recent cloud observation.

Monthly product (MFSC): The bit flags are based on the flags of the corresponding day products.

Table 3.2: Explanation of bit flags

Bit #	Explanation, if bit set (= 1)	Specific explanation for the monthly aggregated product
1	Snow cover retrieved by SCAmod	Same
2	Snow cover retrieved by NLR	Same
3	Too low solar elevation for snow retrieval (< 17°)	Set if sustained too low solar elevation (for the whole period)
4	Low solar elevation, warning for snow retrieval (≥ 17°; < 30°)	Set if there is a snow observation in the period with low solar elevation
5	Forest density near crown closure (t^2 < 0.33, where t is the forest transmissivity applied in the SCAmod algorithm), warning for snow retrieval (for coniferous forest only)	Same
6	Saturation in thermal band (B), max value applied ($B_{3.7\,\mu m}$ → 311.78 K; $B_{11.0\,\mu m}$ → 321.0 K; $B_{12.0\,\mu m}$ → 318.0 K)	Set if there is any occurrence of saturated thermal band in the period for snow or cloud observations

3.4 Metadata

Table 3.3 explains specific metadata for SE products. Most of the attributes are self-describing. Note that day products are defined as Level 3A, while the aggregated products are defined as Level 3B. The average uncertainty attribute is the average of all per-pixel uncertainties in the product (not implemented in the current version). For the aggregated products, the data date attribute is the last day of the 7-days period for the weekly product. For the monthly product, the day (dd) is skipped.

Table 3.3: Specific SE product metadata. Other attributes are self-describing and according to the netCDF CF conventions (see Section 4.1). The column *Product* refers to which products each attribute is valid for

Attribute	**Contents**	**Product**
title	'GLOBSNOW PS SE/AATSR'	all
data_content_field_1	'Level 3A Fractional Snow Cover (%)'	DFSC
data_content_field_1	'Level 3A 4-class Snow Extent (CATEGORY)'	D4SC
data_content_field_1	'Level 3B Fractional Snow Cover (%) Aggregated Weekly '	WFSC
data_content_field_1	'Level 3B Fractional Snow Cover (%) Aggregated Monthly '	MFSC
data_content_field_2	'Uncertainty of FSC retrieval (%)'	all
data_content_field_3	'Bit Flags'	all
data_content_field_4	'Relative day number of observation'	WFSC
data_content_field_4	'Number of days with snow observations'	WFSC
data_content_field_5	'Standard deviation of FSC retrieved'	MFSC
data_content_field_6	'Minimum FSC value retrieved'	MFSC
data_content_field_7	'Minimum FSC value retrieved'	MFSC
processing_date	<yyyy-mm-dd hh:mm:ss>	all
data_date	<yyyy-mm-[dd]>	all
coordinate_system	'Lat/Lon WGS 84'	all
latitude_range	'25N-84N'	all
longitude_range	'168E-192W'	all
spatial_resolution	'0.01 × 0.01 degrees'	all
average_uncertainty	<dd.dd>	all
processing_software_name	'GLOBSNOW PS SE/AATSR PROCESSOR'	all
processing_software_version	'1.0'	all
processing_organisation	'FINNISH METEOROLOGICAL INSTITUTE'	all
retrieval_algorithm_mountains_name	'NLR FSC ATSR'	all
retrieval_algorithm_mountains _version	'0.9.3'	all
retrieval_algorithm_forests_name	'SCAmod FSC ATSR'	all
retrieval_algorithm_forests_version	'3.1'	all
cloud_detection_algorithm_name	'SCDA'	all
cloud_detection_algorithm_version	'1.4.2'	all
auxiliary_data_open_water_mask_name	'GLOBCOVER ENVEO water mask'	all
auxiliary_data_open_water_mask_version	'1.1'	all
auxiliary_data_unforested_mountain_mask_name	'GLOBCOVER ENVEO unforested mountain mask'	all
auxiliary_data_unforested_mountain_mask_version	'1.1'	all
auxiliary_data_glacier_mask_name	'GLOBCOVER ENVEO glacier mask'	all
auxiliary_data_glacier_mask_version	'1.1'	all
auxiliary_data_digital_elevation_model_name	'GETASSE30'	all
auxiliary_data_digital_elevation_model_version	'3.0'	all
auxiliary_data_transmissivity_map_name	'GLOBCOVER SYKE transmissivity map'	all
auxiliary_data_transmissivity_map_version	'1.2'	all

4 PRODUCT FORMAT, STORAGE AND ACCESS

The file format of the products, the data types of the product layers, the file name convention and the storage catalogue structure are explained in the following.

4.1 File format

The GlobSnow SE products are stored in the netCDF CF format. NetCDF (Network Common Data Form) is a self-describing, machine-independent data format that supports the creation, access, and sharing of array-oriented scientific data. That the data format is "self-describing" means that there is a header which describes the layout of the rest of the file, in particular the data arrays, as well as arbitrary file metadata in the form of name/value attributes. The CF conventions define metadata that provide a definitive description of what the data in each variable represents, and of the spatial and temporal properties of the data. This enables users of data from different sources to decide which quantities are comparable, and facilitates building applications with extraction, regridding and display capabilities. Software libraries providing read/write access to netCDF files, encoding and decoding the necessary arrays and metadata are supplied by University Corporation for Atmospheric Research (UCAR) and others (http://www.unidata.ucar.edu/software/netcdf/). A convenient viewer is Panople (http://www.giss.nasa.gov/tools/panoply/). Users preferring the Hierarchical Data Format (HDF) might use conversion tools available at http://www.hdfgroup.org/HDF-FAQ.html#convnetcdf.

The 3-7 layers in the SE products are represented by data types as given in Table 4.1.

Table 4.1: Data types for the SE product layers. SHORT is signed short integer (two bytes), FLOAT is signed floating number (four bytes).

Layer #	DFSC	D4SC	WFSC	MFSC
1	SHORT	SHORT	SHORT	SHORT
2	FLOAT	FLOAT	FLOAT	FLOAT
3	SHORT	SHORT	SHORT	SHORT
4			SHORT	SHORT
5				SHORT
6				SHORT
7				SHORT

4.2 File name convention

The SE product files are named according to the following convention:

GlobSnow_SE_<type>_<level>_<region>_<date>_<version>.<extension>

where

<type> is 'FSC' for Fractional Snow Cover and 'CL4' for 4-snow-classes system
<level> is:
'L3A' for the daily products

'L3B-W' for sliding-window weekly (7-days) aggregated product
'L3B-M' for fixed-window monthly aggregated products
<region> is 'NH' for Northern Hemisphere
<date> is the observation date in the format yyyymm[dd]
<version> is the product version
<extension> is 'nc'

Example: 'GlobSnow_SE_FSC_L3A_NH_20030131_v1.0.nc'
is the daily SE FSC product for 31 January 2003, product version 1.0 in netCDF CF format

4.3 Repository

The products are stored at a file server with the Finnish Meteorological Institute (see Section 4.5 for access information). There is one catalogue for each product version (e.g., SE_v.1.0). There is one sub-catalogue for each year, each with the following sub-catalogues:

- DFSC: Daily Fractional Snow Cover products
- D4SC: Daily 4-classes Snow Cover products
- WFSC: Weekly Aggregated Fractional Snow Cover products
- MFSC: Monthly Aggregated Fractional Snow Cover products
- DFSC_ql: Quick-look pictures for DFSC products
- D4SC_ql: Quick-look pictures for D4SC products
- WFSC_ql: Quick-look pictures for WFSC products
- MFSC_ql: Quick-look pictures for MFSC products

The quick-look pictures are provided for quick and easy browsing in Portable Network Graphics (PNG) format. They come in two versions, one in full spatial resolution and the other sub-sampled to 8% spatial resolution. They are stored in separate sub-catalogues for easy handling of multiple files. One might download a whole year of the 8% quick looks and browse the time series conveniently by stepping ('clicking') through them all using a standard photo viewer.

The products are stored at the Finnish Meteorological Institute and made freely available through both web and FTP interfaces:

- The web pages can be accessed at http://www.globsnow.info
- For login access to the FTP server, contact kari.luojus@fmi.fi

5 PRODUCT PROCESSING AND ALGORITHMS

The GlobSnow SE processing system applies optical measurements in the visual-to-thermal part of the electromagnetic spectrum acquired by the ERS-2 sensor ATSR-2 and the Envisat sensor AATSR. Clouds are detected by a cloud-cover retrieval algorithm (SCDA) and masked out. Large water bodies (oceans, lakes and rivers) and glaciers are also masked out. The snow cover information is retrieved by two algorithms, one for high-mountain areas of steep topography above the tree line (NLR) and another for forested and open areas (SCAmod). The domains of the algorithms are determined by the thematic masks, and the retrieval results are merged. The resulting snow cover map is the basis of the generation of the four product types.

The algorithms, processing chains and products have been developed jointly by the Norwegian Computing Center (NR), Finnish Environment Institute (SYKE), ENVEO IT GmbH (ENVEO), Finnish Meteorological Institute (FMI) and GAMMA Remote Sensing AG (GAMMA). NR has had the coordinating role of the SE development, developed the laboratory processing chain and had the responsibility of the NLR algorithm. SYKE has developed the SCDA and SCAmod algorithms, while ENVEO has evaluated the performance of the algorithms and collaborated in improvements of the SCDA. GAMMA has implemented the operational processing system. FMI is the prime contractor of GlobSnow and responsible for operating the processing system.

5.1 Processing chain

The processing scheme is briefly explained in the following. The system can be imagined as composed of three sub-systems:

1. Pre-processing
2. FSC retrieval
3. Post-processing

Pre-processing is composed of geo-correction, mosaicing of top-of-atmosphere radiance data, cloud detection, general mask assembly and illumination modelling. Geo-correction is done by the BEAM software reprojecting and resampling the image data to SE grid. All orbits within the product domain (geographic area) available within a day are processed at a time and combined into one day mosaic. A 'background mask' for the product (outside mapping area, water, glacier, not mapped in product time frame, too low solar angle for snow retrieval, missing or invalid satellite data) is generated. 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 NLR algorithm. A cosine correction is computed for application by SCDA and SCAmod to compensate for variable solar elevation.

FSC retrieval is based on the output of the pre-processing: TOA reflectance day mosaic, masks, illumination model and auxiliary data. FSC retrieval for terrain above the tree line in the mountainous is carried out by the NLR algorithm. FSC retrieval in all other areas (defined by a transmissivity mask) is carried out by the SCAmod algorithm. The output is a FSC day mosaic with uncertainty grid and bit flags.

The post-processing includes aggregated product generation and assembly of the product files. Aggregation is based either on a sliding window approach (weekly product) or a static window (monthly product). The product file assembly includes exporting of the generated information to appropriate layers in the file format (layers and metadata).

5.2 Geocorrection and drift calibration

Geo-correction is performed by the BEAM open-source software toolbox developed by Brockmann Consult for ESA (http://www.brockmann-consult.de/cms/web/beam/). The data are transformed from the original ESA Level 1 B files in swath geometry to the GlobSnow SE latitude-longitude grid. Bi-linear resampling is applied.

Long-term radiometric drift analysis has been performed by the Rutherford Appleton Laboratory (RAL). Results from Smith and Poulsen (2008) show that ATSR-2 has excellent long term stability, while for AATSR the drift measurements suggest that thin-film interference explain the observed effects. RAL has implemented a drift-correction table that is based on the observations themselves. As new satellite data are acquired, updated correction tables are published by RAL (http://www.aatsrops.rl.ac.uk/performance.html). The latest published drift-correction table is applied by the GlobSnow production system. For near real-time products, they are re-processed when a new drift-correction table becomes available. For shorter periods, the deviation between NRT and re-processed products are ignorable.

5.3 Cloud detection

Clouds are detected by a cloud-cover retrieval algorithm, Simple Cloud Detection Algorithm (SCDA), developed in the GlobSnow project by SYKE. Other available cloud-detection algorithms and products were tested in the project but found insufficient to discriminate well between snow and clouds. The algorithm applies bands 1, 3, 4, 5 and 6. The first order cloud detection is based on the brightness-temperature (BT) difference between 11 µm and 3.7 µm, which shows large negative values for clouds (strong reflection of solar energy at 3.7 µm). A set of additional rules are applied to remove clouds under certain conditions. The SCDA-based cloud mask has been evaluated visually against colour composite AATSR images for various test sites worldwide by ENVEO.

5.4 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. The algorithm has been developed and is intended for forested and non-forested, non-mountainous regions, particularly for the boreal forest zone and tundra belt. Currently, band 1 (555 nm) and 4 (1.6 µm) is used by the algorithm.

The SCAmod algorithm requires generation of *a priori* forest canopy transmissivity map for the whole target area, which has previously been based on the use of clear-sky optical imagery acquired under full (dry) snow cover conditions. The generation of the transmissivity map thus limits the applicability of SCAmod to the regions which have at least few weeks of seasonal snow cover. The model parameters are adjustable and are currently based on image sampling and in situ spectrometer measurements (Salminen et al. 2009). To mitigate the limitation given by observing the actual transmissivity, an approach using a forest map from the ESA GlobCover project to estimate the transmissivity has been developed in GlobSnow.

5.5 NLR snow retrieval algorithm

The NLR algorithm is based on the assumption that there is a linear relationship between snow coverage and measured top-of-atmosphere (TOA) reflectance (or radiance). When this relationship is established, the fractional snow cover percentage value of each pixel can be calculated. The relationship is established by an automatic calibration procedure using calibration targets. Populations of 100% snow covered pixels are identified and determine the reflectance for 100% snow coverage. A corresponding procedure is followed for 0% snow coverage. The algorithm is often referred to as the Norwegian Linear-Reflectance-to-snow cover (NLR) algorithm, and is actually a two-endmember case of linear spectral unmixing. The algorithm was originally developed for analysis of NOAA AVHRR data (Solberg and Andersen, 1994), and has later been tailored to MODIS data (Solberg et al. 2006). A special version of the NLR algorithm has been developed for the GlobSnow project. Currently, band 2 (670 nm) is used by the algorithm.

For topographic correction (‘terrain normalisation’) C-correction is applied. Teillet et al. (1982) developed this semi-empirical method based on a modified variant of the cosine correction in their attempt to correct for topographic effects that could not be overcome by means of the conventional cosine correction method. They incorporated in its formulation a semi-empirical parameter (*C*) obtained from the satellite data to be corrected. Later called ‘the C-correction method’ by Meyer et al. (1993), this methodology has been used extensively by many researchers.

5.6 Auxiliary data

Static thematic masks are used in the processing system to support the selection of suitable algorithms for specific land-cover types (forested, non-forested) and to label areas where SE processing is not applied, such as seas and glaciers. The following masks were generated for the SE domain:

- Open water mask
- Glacier mask
- Mask of mountainous areas (> 2° local slope)

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 were resampled to the resolution and projection of the SE product.

6 PRELIMINARY EVALUATION RESULTS

The work on Fractional Snow Cover (FSC) evaluation of the Full Production Set (FPS) Version 1.0 has focussed on a inter-comparison of GlobSnow SE and MODIS Fractional Snow Cover products for the northern hemisphere in order to identify systematic differences between the two products. Additionally, snow maps from high-resolution optical sensors (Landsat) were generated for different environments and climate zones in order to study the capabilities and limitations of the GlobSnow algorithms. The following main conclusions were drawn:

- The analysis of several statistical parameters, e.g. bias, root-mean-square difference, correlation coefficient and total snow coverage (in terms of pixels) of the inter-comparison of the two products showed good overall agreement and confirms the performance studies carried out for the pan-European domain. In the calculations the pixels which are cloud-free in both products, are included
- During the mid winter the limitation of the GlobSnow algorithms to solar zenith angles above 72° limits the evaluation to lower latitudes
- During June it seems that GlobSnow SE 1.0 product is overestimating the snow extent for mountains. Especially snow-free areas are classified as partly snow covered (up to about 20 %)
- The concept of applying different algorithms in the product requires further improvement in the inter-calibration of the two algorithms, as in several areas a discrepancy in the calculated snow fraction along the mountain mask boundary is observed.

In summary, SE mapping at the northern hemispheric coverage is successful and demonstrate that maps of FSC can be retrieved at this scale from data from the ATSR-2 and AATSR sensors. The correspondence between GlobSnow products and NSIDC MODIS snow maps as well as snow maps derived from Landsat 7 seems to be quite good in general.

Cloud-snow discrimination has been one of the key foci of the SE work in GlobSnow Phase 2. As an algorithm for accurate cloud detection over snow-covered surfaces could not be found, the project developed an own algorithm – Simple Cloud Detection Algorithm (SCDA). Based on visual comparison of the SCDA cloud mask with colour composite AATSR images as reference data on a global domain, the main findings were:

- The dynamic threshold for the difference between brightness temperature in the 11 µm and the 3.7 µm channel is an effective way to detect cloud cover over a very cold snow-covered surfaces
- SCDA does not completely detect cold, high cloud tops
- The use of the maximum value for a band in the case of saturation proved to be a good solution to reduce the areas which were not analysed previously
- In certain cases SCDA detects clouds along the snow line, probably caused by mixed pixels.

Overall, the evaluation results reveal that SCDA provides a predominately reasonable cloud mask for most ground surfaces and is also suitable for an operational environment due to the low computational costs. The misbehaviour described above will cause some false detection only for small areas.

7 KNOWN ISSUES WITH THE PRODUCTS

As can be expected for such a very first version of a hemispherical geophysical satellite product, there are certain issues that will need improvement. This will be the focus in upcoming new releases of the SE product when a more comprehensive evaluation of the current product time series has been carried out. The know issues are briefly mentioned in the following.

Both FSC retrieval algorithms have been developed for application in the boreal zone. Using the algorithms down to 25°N means that also other types of land cover will be present than what the algorithms were developed for. The SCAmod algorithm uses fixed reference reflectance values for the understory ground surface, the forest and the snow. In particular the ground surface reflectance should be set to values representative for the actual local surfaces present. The NLR algorithm, applied in mountainous terrain, overcomes in principle these problems by the use of local reflectance calibration targets. This means that both variability in bare ground reflectance and snow reflectance due to metamorphosis and impurities may be compensated for. However, a preliminary simplification of the reflectance calibration process was done when moving from pan-European snow mapping to the entire Northern Hemisphere. The reflectance target values were fixed based on mean annual statistics for snow and bare ground reflectance for the whole Northern Hemisphere. This may result in retrieval of low FSC values (5-20%) for bright bare ground surfaces (typically arid terrain, like mountainous deserts). The reference reflectance issues for both algorithms are planned to be mitigated in later versions of the SE products (probably based on global land-cover information and spectral libraries).

The forest transmissivity (a measure of how transparent the forest is seen from above) map used by the SCAmod algorithm has been derived from the GlobCover land cover map. Preliminary analysis shows that very dense and very sparse forests are typically not correctly represented in the map. The effect of dense boreal forests in, e.g., Siberia and North America, can easily be seen as 'water masked' into the snow maps under winter conditions. This means that FSC is underestimated for very dense forest. Mitigation of this effect is currently planned by improvements of the transmissivity map.

The latest version of the cloud masking algorithm seems to work quite well. The algorithm provides a predominately reasonable cloud mask for most surfaces. However, some cases of misbehaviour have been identified and will cause some false detection in the snow map. The algorithm does not completely detect cold high cloud tops, and in certain cases it detects clouds along the snow line, probably caused by mixed pixels. Additionally, the cloud frequency seems to increase somewhat with low solar elevations (an effect that can be seen close to the mapping limit in the north during winter conditions). Other misbehaviours might also be discovered when a larger dataset is evaluated. These issues will be further investigated and probably to some degree mitigated (e.g. by the use of an estimated ground surface temperature field to detect truly snow-free conditions).

8 DATA ACCESS AND CONTACT INFORMATION

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- For login access to the FTP server, contact kari.luojus@fmi.fi
- For technical questions about SE products, contact rune.solberg@nr.no
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Additional information on the ESA DUE GlobSnow project and the products can be found at the web-site http://www.globsnow.info.

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