GLOBSNOW

Newsletter

no. 7 / 2010

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Topics of the Newsletter

GlobSnow NRT service demonstration
Special Issue covering GlobSnow SE
SWE development update

esa

FINNISH METEOROLOGICAL INSTITUTE

European Space Agency
DUE - GlobSnow (2008–2011)

Development of Global Snow Monitoring Services

Demonstration of the GlobSnow NRT Processing System commenced:

- The GlobSnow near-real time (NRT) processing system has been successfully set up and started operations on 1 October 2010
- GlobSnow NRT data is available through the GlobSnow website at www.globsnow.info

Preparations for the GlobSnow Near-Real Time (NRT) demonstration production system have been completed. The final GlobSnow NRT system that will produce the NRT SWE and SE products passed the On-Site Acceptance testing in late September and was turned on to produce the SE and SWE near-real time products in the beginning of October.

15 years of snow extent data under processing

A hectic period in the development of the GlobSnow Snow Extent (SE) product and implementation of the SE processing system has take place the last several months. In the period July-September parallel work on algorithm improvements, product evaluation, and implementation of the production system has been undertaken. The final prototype product and lab processing chain version (0.9.5) has worked as a reference for the implementation of the operational processing system. The on-site acceptance test for the operational system took place on 21 September, and the production of the 15 years (1995-present) of continuous snow products based on the ERS-2 and Envisat satellites is ongoing. The release of the first version of this snow-observations time series will take place in October.

The products

There are now 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** (4CL), 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 seven 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 passes within a calendar month period providing the average, standard deviation, minimum and maximum FSC for the period

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. The file format is NetCDF CF (Network Common Data Form with Climate and forecast (CF) Metadata Convention).

The SE 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 www.globsnow.info
- For login access to the FTP server, contact kari.luojus@fmi.fi.

Each product type includes a set of layers. Layer 1 is always the (main) thematic layer with a colour legend as explained in Figure 1.

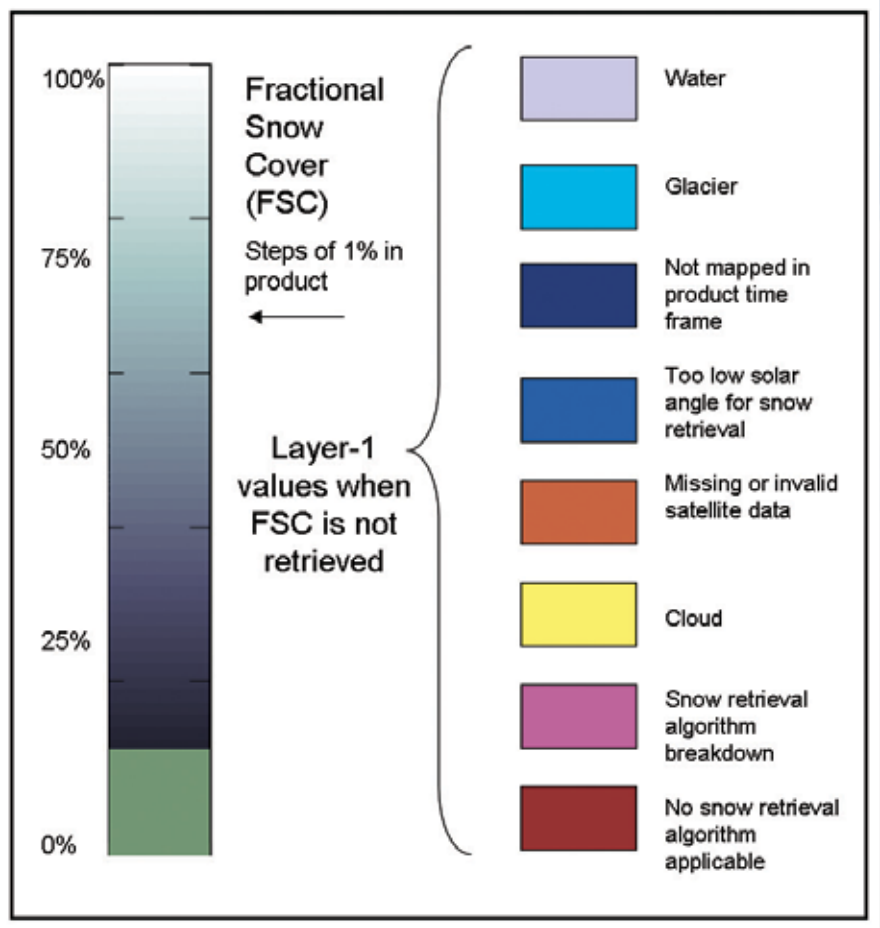


Figure 1: Colour legend for Layer 1 (thematic layer) for the snow products.

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 sensors (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; layer is empty)
- Layer 3: Bit flags

Figure 2: Example of Daily Fractional Snow Cover product for 10 April 2003.

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; layer is empty)
- Layer 3: Bit flags

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 (n) of snow observation. If 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; layer is empty)
- Layer 3: Bit flags
- Layer 4: Relative day number for observation (n in t – n, where t is the product date)

Figure 3: Example of Weekly Aggregated Fractional Snow Cover product for 19 April 2003.

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 a fixed time window of one calendar month. 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; layer is empty)
- Layer 3: Bit flags
- 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 4: Example of Monthly Aggregated Fractional Snow Cover product for April 2003.

The processing system

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 / Ref.: Solberg R. and T. Andersen, 1994. An automatic system for operational snow-cover monitoring in the Norwegian mountain regions. Proceedings of the International Geoscience and Remote Sensing Symposium, 8-12 August 1994, Pasadena, California, USA: 2084-2086.) and another for the non-mountainous areas (SCAmod / Ref.: Metsämäki, S., Anttila S., Huttunen M. and Vepsäläinen J., 2005. A feasible method for fractional snow cover mapping in boreal zone based on a reflectance model. Remote Sensing of Environment, Vol. 95 (1):77-95.)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.

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. 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 post-processing includes aggregated product generation and assembly of the product files.

Preliminary evaluation results

The evaluation done so far of the product quality has been based on SE products generated by the laboratory processing chain developed by NR. The laboratory chain worked as a reference for the implementation and validation of the operational processing system implemented by GAMMA. The long-term time series product quality from the operational processing system will be investigated by the project team in the near future.

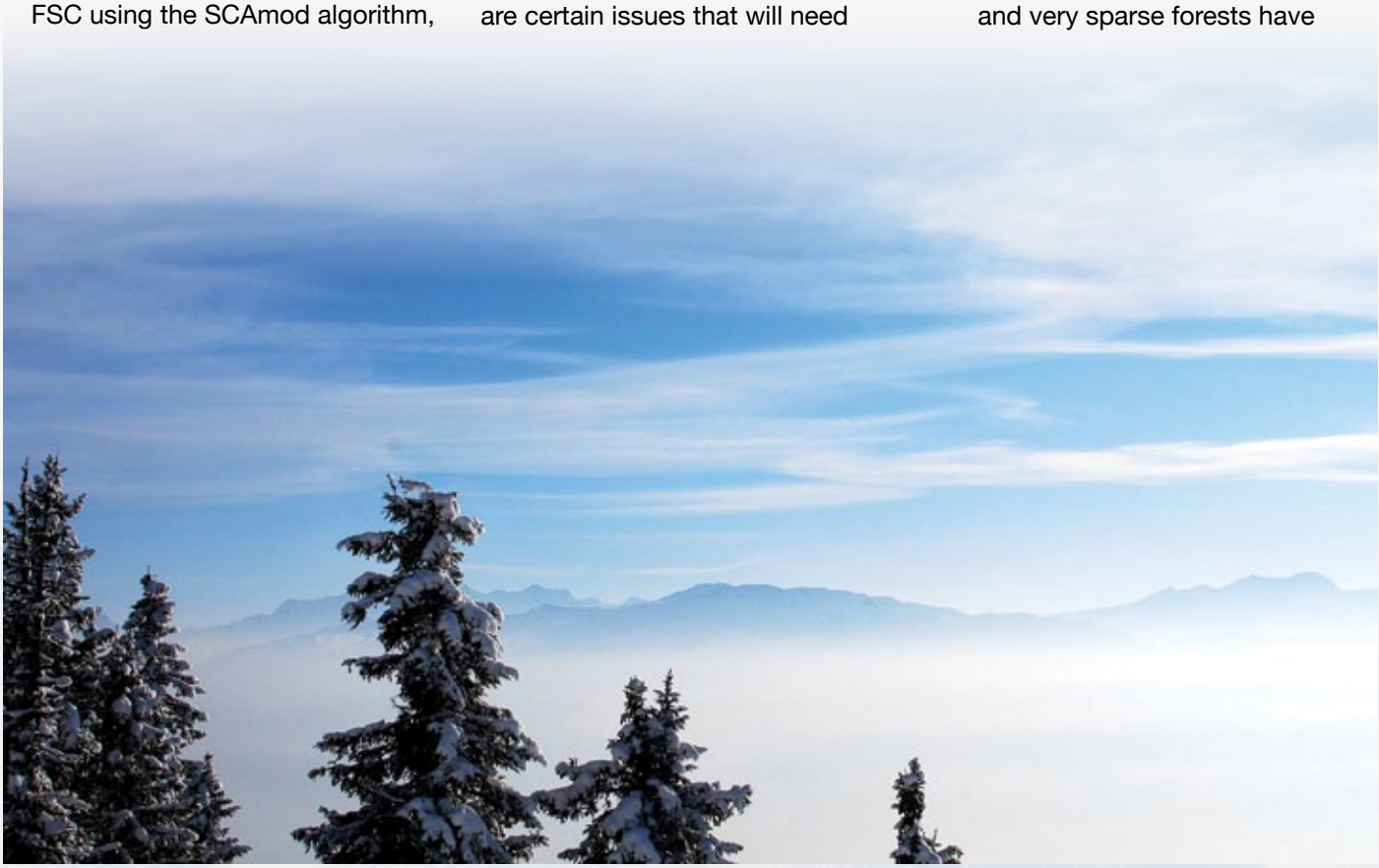
Thematic quality evaluation of retrieved FSC has focussed on 1) a set of dedicated experiments to investigate algorithm performance etc., 2) a pan-European experiment in order to obtain experience with SE mapping on a larger scale (as a stepwise approach to global SE mapping), and 3) evaluation of the performance for the full Northern Hemisphere at a selection of sites spanning climate, terrain and land-cover variability. Envisat AATSR data from 2003-2006 has been applied in the evaluation work. For non-mountainous terrain and FSC using the SCAmod algorithm, the root-mean-squared deviation (RMSD) were typically between 10-25% depending on the forest density. For mountainous terrain and NLR algorithm the RMSD values for the summer months were typically in the interval 10-15%, and around 15-25% in the winter (dark months).

The cloud masks generated by the SCDA algorithm have been evaluated visually against colour composite AATSR images. This process has been repeated several times as the algorithm has been incrementally improved. For the current Northern Hemisphere SE product, the evaluation has taken place for several sites on North America, South America, Europe and Asia. The algorithm provides a reasonable cloud mask for most surfaces. Some issues remain with the cloud masking algorithm and work to improve it is still on-going.

Further development and improvements

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 the upcoming release 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 other types of land cover will be present than what the algorithms were developed for. This may, e.g., result in retrieval of low FSC values (5-20%) for bright bare ground surfaces (typically arid terrain, like mountainous deserts). The reference reflectance issues might be mitigated in later versions of the SE products by the use of global land-cover information and spectral libraries.
- The forest transmissivity map (a measure of how transparent the forest is when observed from above) used by the SCAmod algorithm has been derived from the ESA GlobCover land cover map. Preliminary analysis shows that very dense and very sparse forests have



tendency for under- and over-estimation, respectively, in the calculated transmissivity map. The effect of dense boreal forests (caused by the under-estimation of the transmissivity) is represented as underestimation of snow cover within FSC retrieval. 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. Other issues might also be discovered when a larger dataset is evaluated. These 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).

The mentioned current weaknesses of the product are already quite well understood by the SE project team, and we are confident that they to a high degree will be mitigated in the next releases of the SE products. In any case, the first version of 15 years of snow extent products should give a clear indication of the potential for climate change analysis at the local, regional and hemispherical scale.

Recent developments for the SWE product:

- Acquisition of temporally and spatially continuous weather station data set for 1979 – 1992 completed, all data for 1979 – 2009 are now available
- Release of the GlobSnow long term SWE dataset is expected during October 2010

The GlobSnow SWE development has continued with acquisition of supplementary weather station data to provide a temporally and spatially extensive data coverage for the years 1979 to 1992. The data that were available through ECMWF had serious spatial and temporal gaps in coverage and hindered the production of reliable SWE estimates for northern Eurasia for the years prior to 1992. The supplementary data to cover the gaps in data have now been successfully acquired. The current efforts have focused on merging the ECMWF weather station data with the new data acquired from Russia. Once the weather station data have been homogenized, the production of the long term SWE data, covering years 1979 to 2009 for Northern Hemisphere, can continue. The production of the 30 year SWE data set will start in the beginning of October 2010 and the data is expected to be available for the User community by late October 2010.

The currently available SWE data set v.0.9.2 covers the years 1992 to 2009. An example SWE product is shown in Figure 5.

- Full data set will cover Northern Hemisphere for 1979 to 2009
- SWE products calculated for daily, weekly and monthly intervals
- Spatial resolution of 25 km, information on accuracy included with the products

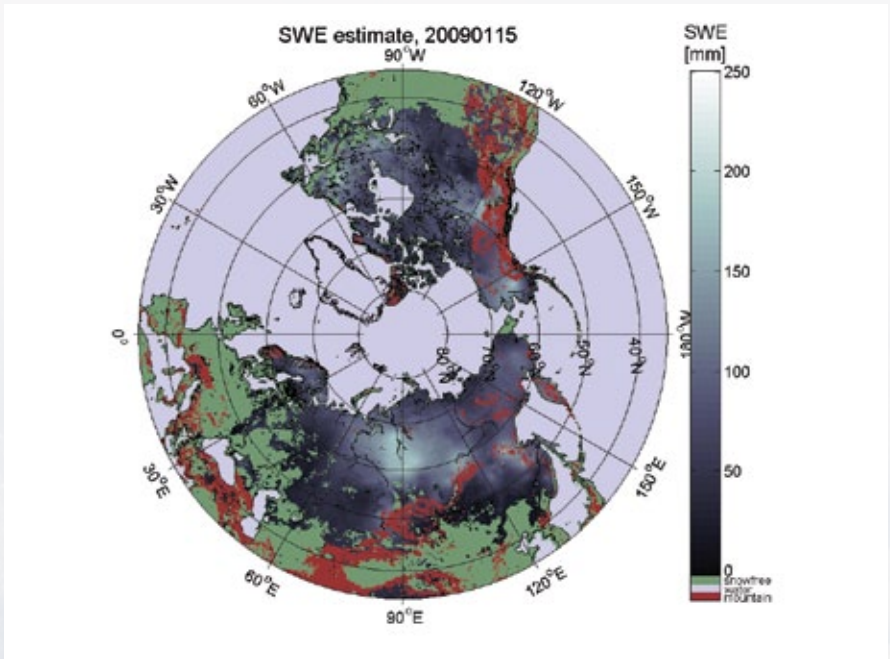


Figure 5: An example SWE product.

Project overview

The European Space Agency (ESA) funded GlobSnow project aims at creating a global database of snow parameters for climate research purposes. In addition to a historical data set comprising of 15 to 30 years of snow data an operational near-real time snow information service will be constructed. Information on two essential snow parameters: snow water equivalent (SWE) and areal snow extent (SE) will be provided. The archive and the demonstrated snow service will be based on data acquired from active and passive, optical and microwave-based spaceborne sensors combined with ground-based weather station observations.

GlobSnow consortium

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Environment Canada (EC)
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Finnish Environment Institute (SYKE)
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