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GLOBSNOW

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Topics:

- Release of the GlobSnow SE & SWE v2.0 datasets
- GlobSnow SWE v2.0 data
- GlobSnow SE v2.0 data
- GlobSnow User Consultation Meeting, 3-6 February 2014 @ Bern, Switzerland
- GlobSnow white paper

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FINNISH METEOROLOGICAL INSTITUTE

The GlobSnow SE & SWE v2.0 datasets released!

The European Space Agency (ESA) Data User Element (DUE) funded GlobSnow-2 project has released Version 2.0 snow dataset for the Northern Hemisphere. The dataset, intended for climate research purposes, provides information on two essential snow parameters: snow water equivalent (SWE) and areal snow extent (SE), for a period of 34 years and 17 years, respectively. The SE dataset is based on optical data from Envisat AATSR and ERS-2 ATSR-2 sensors covering the Northern Hemisphere between 1995 to 2012. The SWE record is based on the time series of measurements by two different space-borne passive microwave sensors (SMMR and SSM/I) spanning 1979 to 2013.

The objective of the v2.0 product development within GlobSnow-2 was further enhancement of the retrieval methodologies for SE and SWE products and a re-processing of the long term datasets utilizing the improved retrieval algorithms. For the SE-product, these improvements are related to the selection of a single SE-retrieval method to be applied for the entire Northern Hemisphere, the improved parameterization of the method and enhanced auxiliary data. Further development of the SWE product focussed on the improved quantification of product uncertainty characteristics and the improvement of overall product accuracy, especially in terms of consistency between different years. The data are available via the GlobSnow (www.globsnow.info) website. For direct data access, browse to: (www.globsnow.info/se/) and (www.globsnow.info/swe/).

GlobSnow SWE v2.0 data

The ESA DUE GlobSnow Snow Water Equivalent (SWE) product set version 2.0 for the Northern Hemisphere represents information on snow water equivalent retrieved from SMMR and SSM/I sensors combined with ground-based weather station data from 1979 until 2013. The dataset provides coarse resolution (25 km) daily information on SWE for Northern Hemisphere complemented with information on snow extent. The SWE product is calculated for terrestrial regions excluding mountains and glaciers.

The SWE products are distributed in both NetCDF-CF and HDF-formats: a single file contains the data for a single day; each file containing two fields 1) the SWE estimate and 2) an error estimate (Statistical Standard Deviation of the SWE estimate).

The aim in the further development of the SWE product was the improved quantification of product uncertainty characteristics and the improvement of overall product accuracy, especially in terms of consistency between different years. This is essential for the employment of the GlobSnow-2 SWE product as a hemispheric Climate Data Record (CDR) for the period 1979 - 2013. The main advancement includes the following topics: (a) estimation of systematic error characteristics in addition to statistical error, (b) homogenization of the multiple-year synoptic weather station observation data sets on snow depth input to the SWE estimation algorithm, (c) regional treatment of statistical error characteristics of applied synoptic snow depth data and (d) use of a new forward model version to describe the space-borne observed microwave brightness temperature (e) enhanced temporal range for the dataset, starting from September 1979 and extending to May 2013.

Concerning product accuracy characteristics the new GlobSnow-2 SWE product provides a total error that includes the contribution of statistical (random) error and the systematic error, the latter being evaluated from an extensive data set of independent SWE observations available for Eurasia covering different years. The homogenization of applied weather station observations includes the filtering of outliers and selection of stations that report the snow depth uniformly through the time period of the SWE product. In the case of the statistical accuracy of weather station observations different RMS errors are assigned depending on whether the site and region represents open areas or forested landscape. As a result, the new SWE product version provides a more reliable time-series of the hemispheric behavior of snow mass than the earlier product versions.

The development work algorithm investigated the usage of dynamic,

spatially varying and temporally evolving snow density for SWE retrieval. Several iterations for SWE retrieval using a dynamic snow density scheme were implemented and evaluated. In the end the constant snow density consideration from GlobSnow-1 project was retained for the final SWE v2.0 algorithm as a sufficient and consistent improvement to the overall retrieval process was not found with the dynamic snow density scheme. This will be the focus of continued research and development.

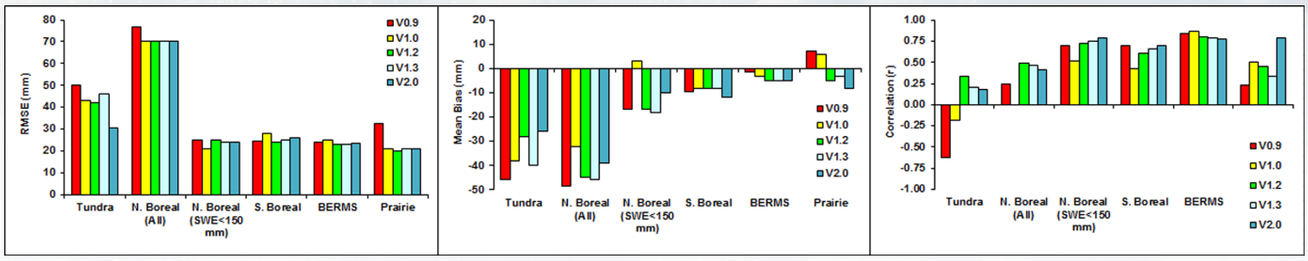


Figure 1: The evaluation of various GlobSnow SWE datasets with Canadian reference data. The left panel shows the Root-Mean-Squared-Error for different datasets, center panel shows the mean bias and right panel shows the correlation coefficients between SWE datasets and the reference data."

Preliminary validation results for the v2.0 SWE product

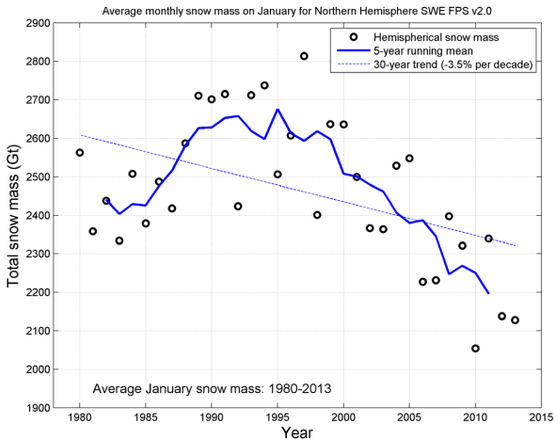
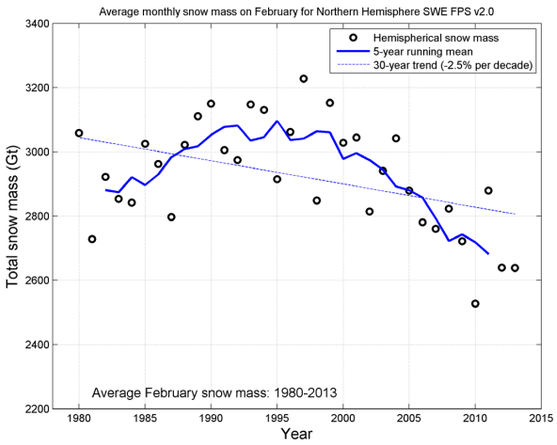


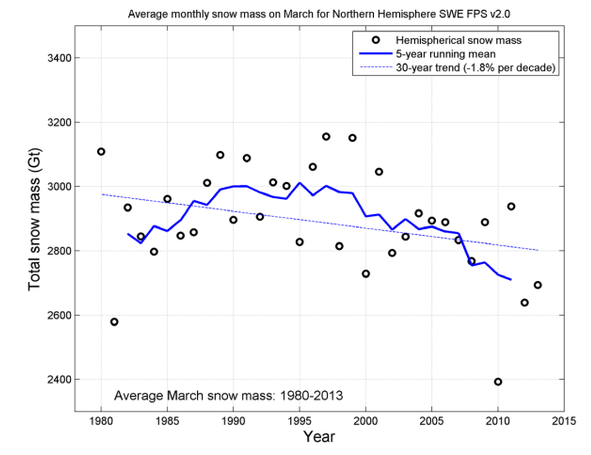
Figure 2: The long term trends, based on GlobSnow SWE v2.0 monthly data, for Northern Hemisphere for 1980 - 2013."



Mountains in Jotunheimen
Photo: Rune Solberg

The GlobSnow v2.0 SWE dataset was evaluated against several independent ground-based datasets collected from the Former Soviet Union, Russia, Canada and Finland. The retrieval accuracy is improved for some regions and is about equal for some regions when compared with the previous v1.0 and v1.3 SWE datasets. The full dataset evaluation is still on-going, but as an example, Figure 1 shows the retrieval characteristics of different GlobSnow SWE datasets when compared with Canadian reference data. It is evident that for Tundra and Northern Boreal forest zone the retrieval accuracy has improved, while for other regions it has stayed the same.

The long term trends, based on the GlobSnow v2.0 SWE dataset, are similar to the trends from previous GlobSnow datasets and hemispheric snow data from other sources. The hemispheric snow mass has been declining for the spring months since a peak in the late 1990's, as shown in Figure 2.



GlobSnow SE v2.0 data

As in earlier v1.2, The Daily Fractional Snow Cover (DFSC) product provides fractional snow cover (FSC) in percentage (%) per grid cell for all satellite overpasses of a given day. The product represents the best estimate of daily 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 with the best solar illumination (highest solar elevation) are selected.

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:

- $0\% \leq FSC \leq 10\%$
- $10\% < FSC \leq 50\%$
- $50\% < FSC \leq 90\%$
- $90\% < FSC \leq 100\%$

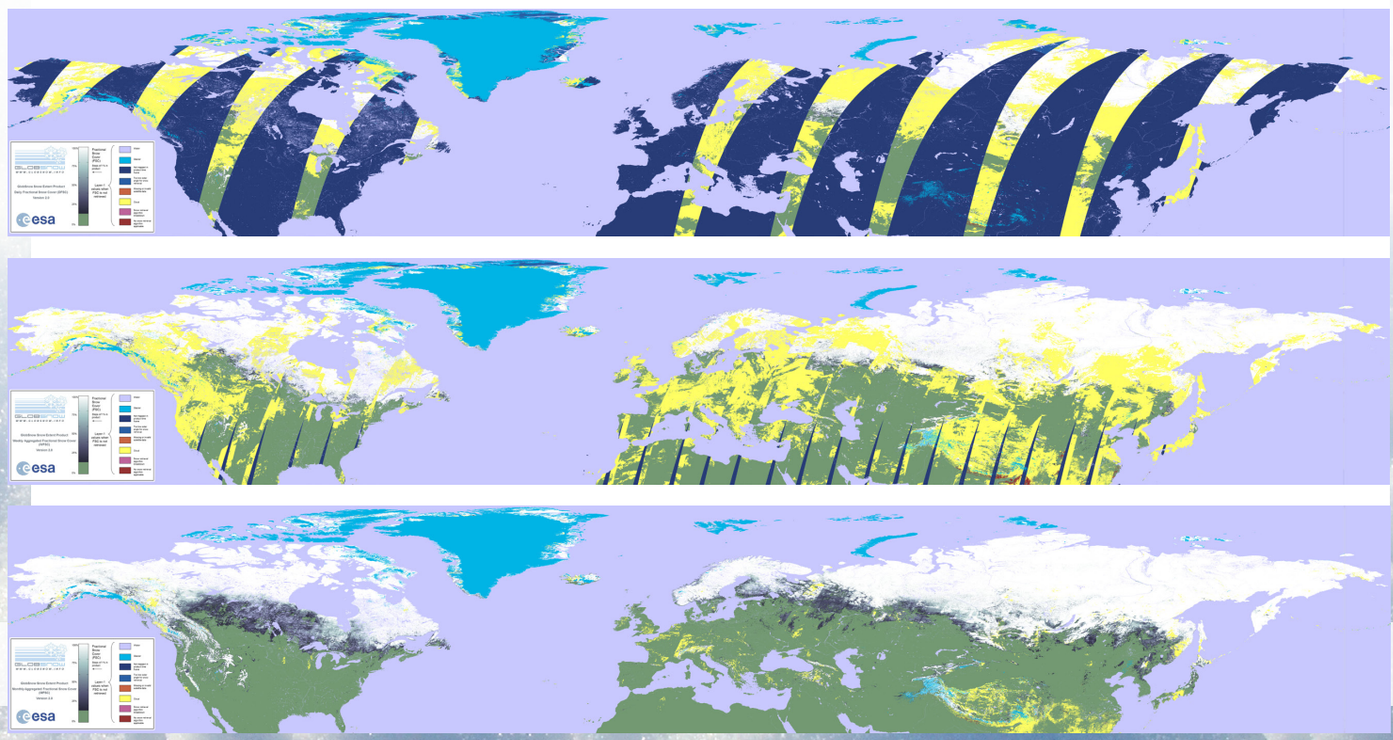
The Weekly Aggregated Fractional Snow Cover (WFSC) product is based on all satellite overpasses within a seven-day period. For each pixel, the product provides the last available estimate within past seven days.

The Monthly Aggregated Fractional Snow Cover (MFSC) product is based on all satellite overpasses within a calendar month period. Fractional Snow Cover is provided as an average of all available estimates within the period. It is based on DFSC products for the given calendar month.

Version 2.0 SE is provided with a single method applied to all cloud-free pixels, instead of using an alternative method for mountain areas as in v1.2. The SCAmod-method for FSC-retrieval uses a semi-empirical radiative transfer-based reflectance model where apparent forest canopy transmissivity plays a key role to account for the effect of forest canopy. The reflectances for wet snow, snow-free ground and (opaque) forest canopy serve as model parameters. The significant difference between v1.2 and v2.0 SE products results from the improvement in the hemispheric forest transmissivity map so that it better identifies the dense forests.

Another significant change is related to use of varying snow-free ground reflectance data. Earlier GlobSnow v1.2 SE used a fixed value (10.0%-units) for snow-free ground reflectance at around 0.55µm (corresponding to band 5 and 1 of ATSR-2 and AATSR, respectively). In practice, the spatial variability of snow-free ground reflectance causes an error contribution to the FSC estimation. Thus, it was necessary to investigate the magnitude and variations of the true snow-free ground reflectance for different land covers and apply this information in SCAmod as auxiliary data. In regions of seasonal snow cover, an analysis of MODIS time-series was

Figure 3: A sample set of GlobSnow v2.0 SE products for April 2006. Top: daily product 13 April, Middle: weekly product 15 April, Bottom: monthly product.



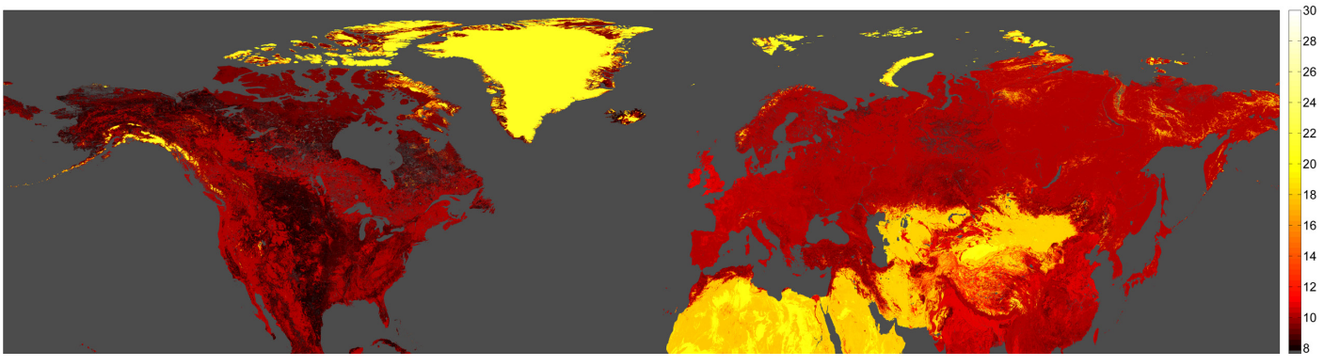


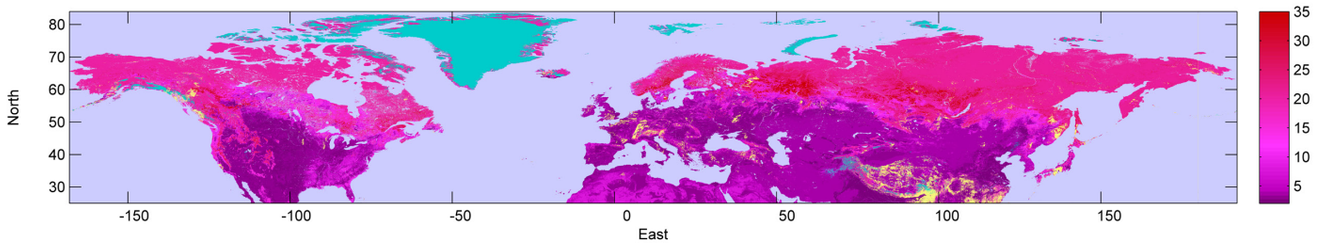
Figure 4:Snow-free ground reflectance map for Eurasia and North America (in %-units).

carried out in order to extract a representative sample set of postwinter reflectance In non-forested areas. This was accomplished for the study area covering Central, Eastern and Northern Europe and for various land cover categories by applying ESA GlobCover data as reference. The time-series analysis was then extended to encompass also North America. However, the pixel-wise time-series approach used so far in Europe and North America is laborious (and not feasible for obtaining global statistics). Therefore, to obtain the class-stratified snow-free ground reflectance field in other regions, sampling from MOD09 surface reflectance products was conducted. Finally, the GlobSnow post-winter (mean and variance) reflectance map was derived by using the class-stratified snow-free ground statistics together with GlobCover data. The v2.0 map is presented in Fig. 4.

Version 2.0 also includes a specific uncertainty layer. The calculation procedure of the statistical error of the FSC estimate at the pixel level was implemented and integrated with the product processing line. This error is a measure of uncertainty propagated from the observed variances of SCAmod model parameters and therefore depends on the FSC and the local transmissivity as well. The consideration of total error in SE product could additionally include the contribution of systematic error. This would require the determination of total residual errors (at pixel level) from validation experiments. In case of FSC estimation, only the statistical error part is implemented, since the available reference data does not allow the detailed determination of the systematic error. Further work to improve the consideration of statistical error requires, above all, the refinement of variances of different constituents of SCAmod which are the uncertainties of two-way forest canopy transmissivity, wet snow reflectance, snow-free ground reflectance and forest canopy reflectance (opaque canopy).

The uncertainty layer for monthly product Apr, 2004, corresponding to monthly product in Fig 3, is presented in Fig. 5).

Figure 5: Standard deviation of FSC estimate for SE monthly product April 2004. Statistical error for each FSC estimate is provided in FSC %-units.



Reference for GlobSnow legacy SE method
Metsämäki, S., Mattila, O.-P., Pulliainen, J., Niemi, K., Luojus, K., Böttcher, K. “An optical reflectance model-based method for fractional snow cover mapping applicable to continental scale”, Remote Sensing of Environment, Vol. 123, August 2012, pp. 508-521, doi: 10.1016/j.rse.2012.04.010.

Salminen, M., Pulliainen, J., Metsämäki, S., Böttcher, K. and Heinilä, K. (2013). MODIS-derived snow-free ground reflectance statistics of selected Eurasian non-forested land cover types for the application of estimating fractional snow cover. Remote Sensing of Environment, 138, 51-64.

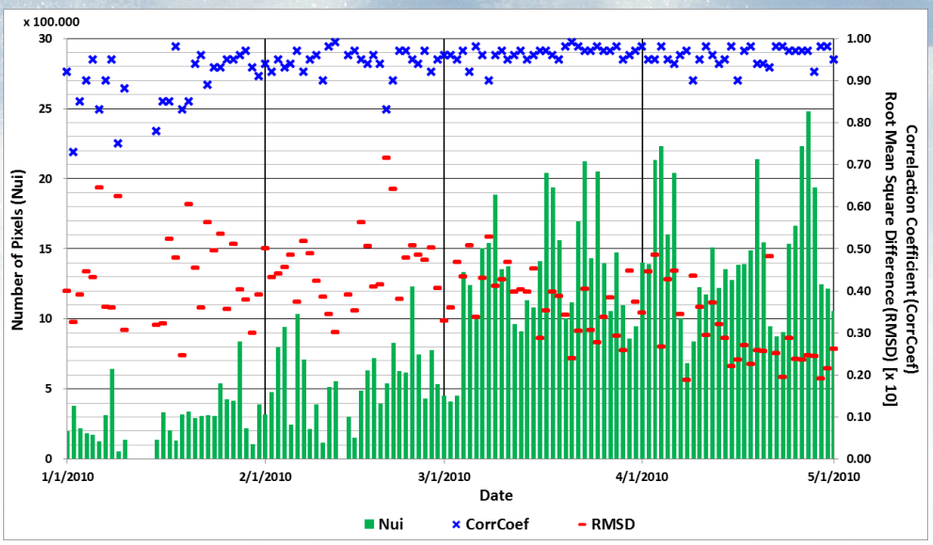


Figure 6: Statistical parameters Number of pixels (green bars), Root Mean Square Difference (red dots) and Correlation Coefficient (blue crosses) resulting from the daily intercomparison of the GlobSnow-2 version 2.0 SE product with the fractional snow cover product of the EU FP7 project CryoLand covering the area 72N/11W to 35N/50E with about 500 m grid size for the period 1st of January 2010 to 1st of May 2010.

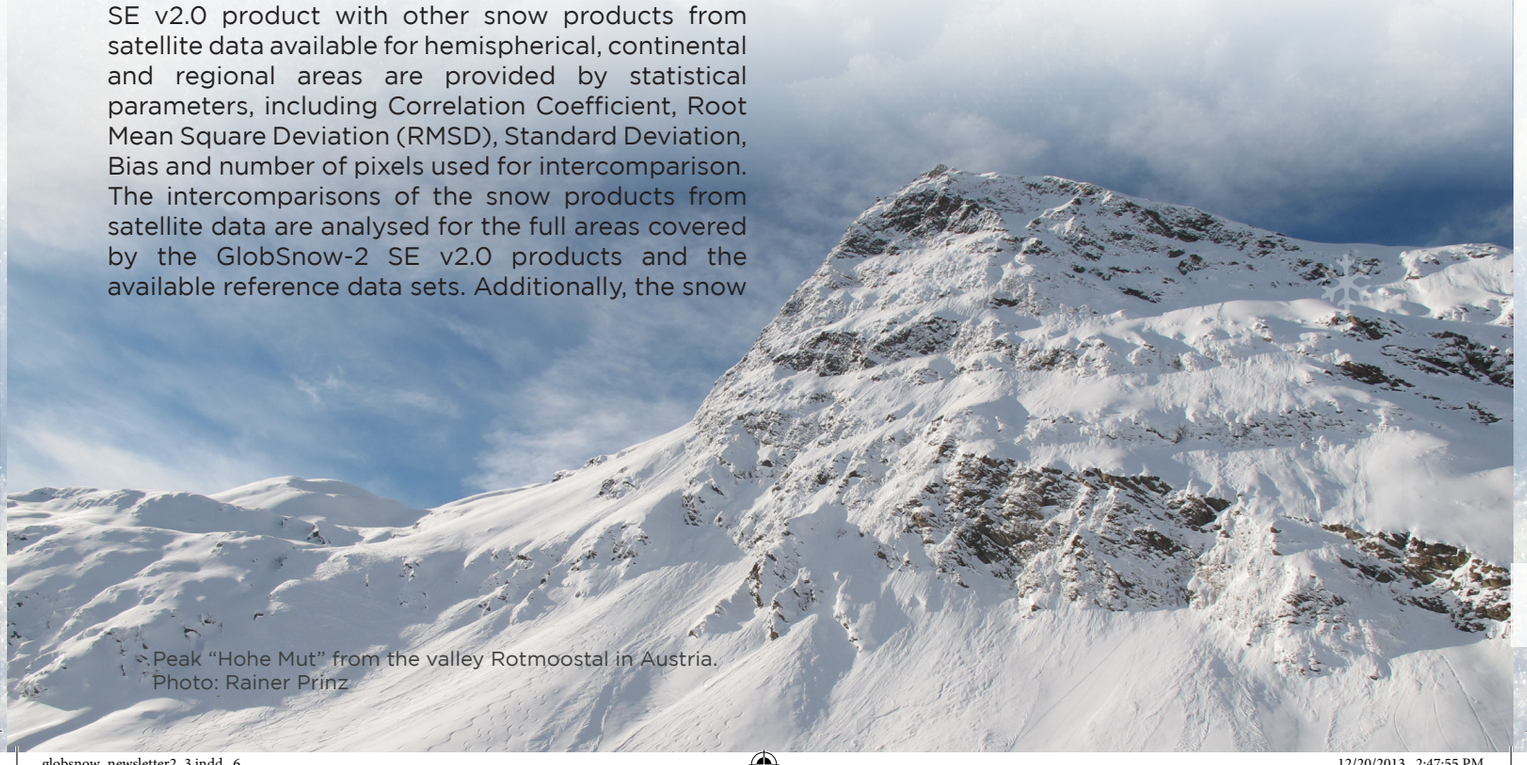
SE intercomparison activities

Assessing the quality of the recently released version 2.0 of the GlobSnow-2 Snow Extent (SE v2.0) products is crucial for the usability of the products. In the Work Package 5.2, led by ENVEO, the focus is on the intercomparison and evaluation of the GlobSnow-2 SE v2.0 products with selected reference data. Based on the experiences of the preliminary validation activities performed in Phase 1, a validation concept has been elaborated considering different spatial and temporal scales for product intercomparisons. Intercomparisons are planned to be performed with snow products from satellite data on hemispherical, continental and regional scale for selected test sites in Europe, Russia, Asia and North America covering different surface types, and on a local scale using in-situ snow measurements available in Austria, Switzerland and Finland.

The results of the intercomparisons of the GlobSnow-2 SE v2.0 product with other snow products from satellite data available for hemispherical, continental and regional areas are provided by statistical parameters, including Correlation Coefficient, Root Mean Square Deviation (RMSD), Standard Deviation, Bias and number of pixels used for intercomparison. The intercomparisons of the snow products from satellite data are analysed for the full areas covered by the GlobSnow-2 SE v2.0 products and the available reference data sets. Additionally, the snow cover is analysed with respect to different surface classes, such as forested and non-forested areas, and in complex terrain the impact of the topography on the snow cover is investigated.

Additionally to the snow products from other EO data daily in-situ snow measurements available for Switzerland, Austria and Finland for the period 1999 – 2010 are used for a long-term intercomparison at individual pixels. For Austria and the Carpathian mountains gridded snow depth information derived from a snow model are available and will be used for intercomparison with the daily GlobSnow-2 SE v2.0 product of the years 2003, 2004 and 2006.

As the GlobSnow-2 project aims to prepare a climate data record for global snow extent also the sensor consistency of AATSR and ATSR-2 for retrieving snow cover information using the SCAmod algorithm will be further investigated.



Peak “Hohe Mut” from the valley Rotmoostal in Austria.
Photo: Rainer Prinz

GlobSnow User Consultation Meeting, 3-6 February 2014 @ Bern, Switzerland

The 7th Workshop on Remote Sensing of Land ice and Snow of the European Association of Remote Sensing Laboratories (EARSeL) will take place at the Department of Geography, University of Bern, Switzerland, from 03 - 06 February 2014.

The Workshop aims at giving an overview on the most recent research in the field of remote sensing of snow and ice. This includes presentations on environmental research focussing on snow and ice as indicators of a changing cryosphere, new technologies for retrieving cryospheric parameters from various types of remote sensing data, theoretical considerations for algorithm design, state-of-the-art retrieval algorithms, data assimilation of remote sensing data and in situ observations in process models as well as current and planned sensors for snow and ice.

One day of the workshop is dedicated to the ESA Globsnow-2 project: A special session will consist of presentations given by the project consortium providing the newest results from SE and SWE product developments and from the validation process. Along with this, presentations from the user community will be included in this session. In this context, the ESA-Globsnow User Consultation Meeting (UCM-4) will be integrated into the EARSeL LISSIG Workshop. The objective is to discuss and consolidate the white paper released by the ESA Globsnow-2 consortium as well as to gather future user requirements to monitor and model snow parameters.

Any interested persons are cordially invited to register on http://www.earsel.org/SIG/Snow-Ice/workshop/registration.php. For further details on the workshop please visit the official conference website http://www.earsel.org/SIG/Snow-Ice/workshop/call.php. The preliminary program will be available by end of December 2013.

GlobSnow white paper - User feedback is needed!

Satellite-based snow products are generated within a large diversity of frameworks and initiatives and produced for a broad range of end-users. The GlobSnow-2 community is working on a White Paper with the goal to provide an overview of the state of satellite snow products and services, to examine how well users needs are currently met. The White Paper highlights possible improvements through opportunities with upcoming new satellite infrastructures. The White Paper was initiated at the Workshop on European Satellite Snow Monitoring Perspectives held at EUMETSAT in Darmstadt, Germany, 4-5 December 2012.

A draft of the White Paper will be sent out to the GlobSnow-2 User Community at the end of January 2014. At a co-location meeting following the EARSeL Remote Sensing of Land Ice and Snow Workshop (3-6 February 2014 at the University of Bern, Switzerland) a User Consultation meeting will be organized to collect and synthesize user feedbacks.

The effort for collecting the White Paper is led by the Federal Office of Meteorology and Climatology MeteoSwiss, assisted by FMI and supported by all consortium partners.

Based on the user needs and gaps in satellite-based snow products and services and taking into account new opportunities, user's needs could be better met with upcoming satellite infrastructure and future services. The White Paper will consider the requirements for Research & Development needed to put in place the next generation of operational snow services as well as products for scientific research. Hence, as a user of GlobSnow-2 data you are very welcome to participate at the workshop – give us your feedback!

Project overview

The European Space Agency (ESA) Data User Element (DUE) funded GlobSnow-2 project is a direct continuation to the GlobSnow-1 project that was active from 2008 to 2012. The objective of the GlobSnow-2 project is further enhancement of the retrieval methodologies for SE and SWE products and a re-processing of the long term datasets utilizing the improved retrieval algorithms before the end of the project.

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