ESA DUE GLOBSNOW – GLOBAL SNOW DATABASE FOR CLIMATE RESEARCH

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ABSTRACT

This paper presents the efforts of the ESA DUE GlobSnow project for creating two global scale snow dataset covering 15 and 30 years of satellite-based observations, one describing the extent of snow cover (SE) the other describing the snow water equivalent (SWE) characteristics. The main emphasis of the paper is describing the validation work carried out for the SWE product that will cover the non-mountainous regions of Northern Hemisphere on a daily basis starting from 1979. The work has been carried out within the ESA GlobSnow project.

Index Terms— Snow Water Equivalent, Snow Extent, Snow Cover, Essential Climate Variable (ECV)

1. INTRODUCTION

The European Space Agency (ESA) Data User Element (DUE) funded GlobSnow project aims at creating a global database of snow parameters for climate research purposes. The main objective is to create a long term time series for two essential snow parameters. The project will provide information concerning the areal extent of snow (SE) on a global scale and snow water equivalent (SWE) for the Northern Hemisphere. Both products will include the end product derived from the satellite data along with accuracy information for each snow parameter. The temporal span of the SE product will be 15 years and the span for the SWE product will be 30 years. A key improvement of the snow products, when compared with the currently available data sets, will be the inclusion of a statistically derived accuracy estimate accompanying each SE or SWE estimate (on a pixel level).

In addition to the SE and SWE time-series, an operational near-real time (NRT) snow information service will be implemented. The service will provide daily snow maps for hydrological, meteorological, and climate research purposes. The snow products will be based on data acquired from optical and passive microwave-based spaceborne sensors combined with ground-based weather station observations. The work was initiated in November 2008, and is being coordinated by the Finnish Meteorological Institute (FMI). Other project partners involved are NR (Norwegian Computing Centre), ENVEO IT GmbH, GAMMA Remote Sensing AG, Finnish Environment Institute (SYKE), Environment Canada (EC) and Northern Research Institute (Norut).

The GlobSnow products will be based on the state-of-the-art algorithms that are thoroughly validated using an extensive ground truth database gathered from Canada, Scandinavia, Russia and the Alps. The snow products will be generated on a daily, weekly and monthly basis for both SWE and SE. Both the historical data sets and the operational products will be made available through the GlobSnow web-based data dissemination site.

Extensive algorithm evaluation efforts were carried out for the candidate SWE and SE algorithms during 2008 and 2009. The acquired evaluation results, described for the SWE product in the following chapter, have enabled the selection of the algorithms to be utilized for the GlobSnow SE and SWE products. The SWE product is derived using an algorithm developed by FMI and the SE product is a combination of SYKE and NR developed algorithms. Both algorithms showed enhanced estimation characteristics when compared with currently available existing products. Prototype SE and SWE products were released for user evaluation during November 2009 covering the years 1992-2009 for SWE and 2004-2006 for SE. The SWE product covers the Northern Hemisphere and the SE product is provided for Pan-European region. The data are freely available for all interested parties.

2. PRELIMINARY VALIDATION RESULTS FOR THE GLOBSNOW SWE PRODUCT

The selection of the SWE algorithm for GlobSnow project was the result of an extensive evaluation of several different algorithms for three distinct test regions over three winter seasons. The evaluated algorithms included the FMI algorithm [1], Chang algorithm [2], EC algorithms [3, 4], SPD algorithm [5] the NSIDC operational algorithm [6], and the AMSR-E standard SWE product [7]. The test sites were: 1) Northern Eurasia, including data from the years 1995 to 1997 2) Finland containing ground truth data from the years 2005 to 2008 and 3) central Canada including data from the years 2005 to 2008. The complete algorithm evaluation, including an overview of the algorithms, reference datasets, and results is presented in the GlobSnow Design Justification File [8] available via the GlobSnow website (globsnow.fmi.fi).

2.1 Results for the Eurasian test region

Table 1 shows the results acquired for the large test dataset of more than 20 000 samples for Eurasia.

The results indicate that the FMI algorithm was more accurate than that of the other algorithms. The results were acquired using SSM/I based satellite data-derived SWE estimates in comparison with ground truth snow depth measurements conducted from Russian snow courses (INTAS-SCCONE snow path data).

It is evident from Table 1 that the Chang algorithm (and the two derivates investigated) had large RMS errors against the validation data, while the SPD algorithm performed slightly better than the EC algorithm suite in this respect. The relatively weak performance of the EC algorithm suite was expected, as it was developed originally for Canadian land cover and snowpack characteristics, and appears to be hampered by the lack of direct 10 GHz measurements from SSM/I that are utilized to retrieve SWE from AMSR-E measurements under deep snow conditions across the boreal forest [4]. In terms of bias, both the original Chang algorithm and the SPD algorithm perform relatively well when using data from SSM/I descending orbits. The overall bias value is misleading however, as a slight overestimation for shallow snow is compensated by a very large underestimation of areas with high SWE.

The FMI algorithm shows RMSE of 43.2 mm for Eurasia with the complete dataset (26063 samples). Restricting the analysis to SWE values below 150 mm, the FMI algorithm gives an RMSE of 33.5 mm (23889 samples). Other algorithms show RMS errors well beyond this. An illustration of the SWE estimation accuracy for different SWE intervals acquired using the FMI algorithm is shown in Figure 1. The passive microwave SWE retrieval algorithms have a well documented tendency to systematically underestimate SWE under deep snow conditions, as also seen in Figure 1. This is due to a change in the microwave behavior of the snowpack (when SWE exceeds ~150 mm, the snowpack transitions from a scattering medium to a source of emission). The highest RMSE and biases, and lowest correlations for all algorithms were observed for the conditions where SWE exceeds 150 mm threshold.

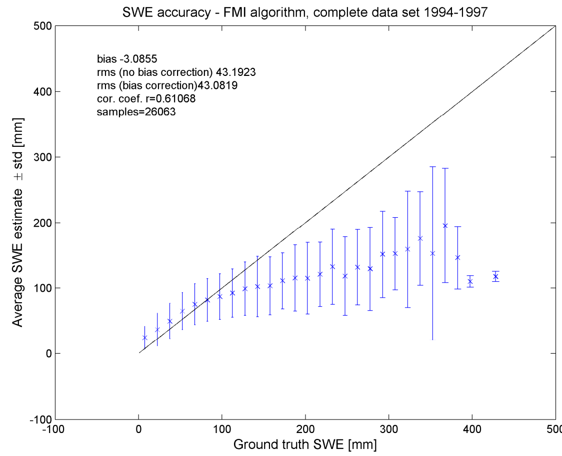

Figure 1. A visualization of the FMI SWE estimation algorithm performance over Eurasia.

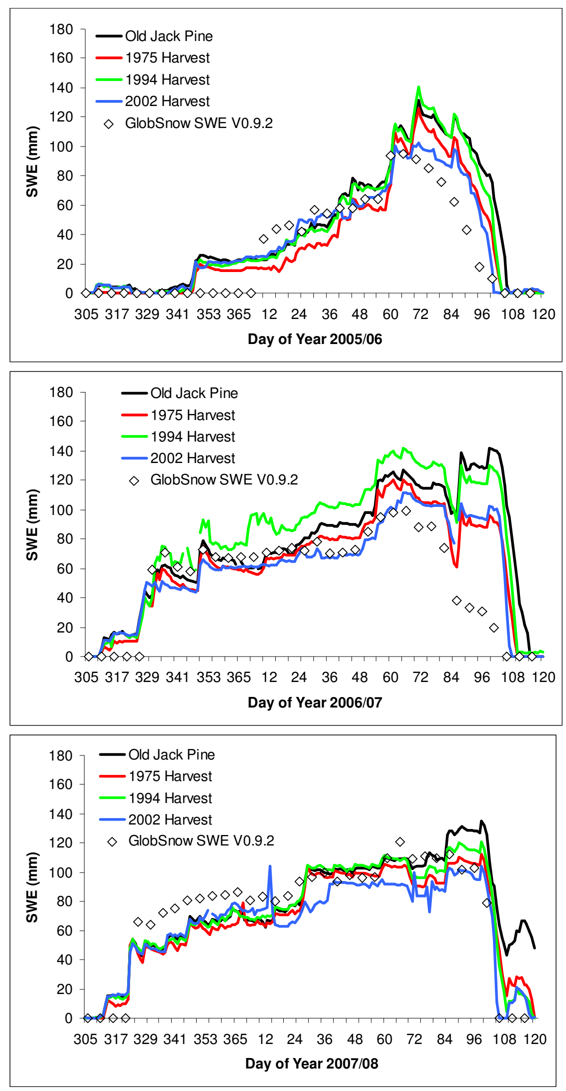

Figure 2. Time series of BERMS measurements compared with GlobSnow retrievals, 2005/06 (top) through 2007/08 (bottom).

The Boreal Ecosystem Research and Monitoring Sites (BERMS) operated by Environment Canada in the southern boreal forest of Saskatchewan represent a valuable reference dataset for GlobSnow SWE retrievals. Hourly snow depth measurements are made a network of sites in various classes of forest cover including jack pine, black spruce, aspen, and a chronosequence of sites that were harvested between 1975 and 2002. In most cases, there are multiple BERMS sites within a single 25 km GlobSnow SWE grid cell. Figure 2 illustrates the time series of BERMS measurements plotted with pentad (5-day) averaged GlobSnow retrievals. The BERMS measurements illustrate the range in SWE that is typical within a coarse footprint SWE retrieval due to snow interactions with the mixed forest vegetation. In spite of this heterogeneity, the GlobSnow SWE retrievals agree well with the BERMS measurements through each season. There is a tendency for early season shallow snow to be missed in the GlobSnow product, and for the retrievals to ablate the snow cover too rapidly in the spring. The analyses provided similar results giving a clear indication for the GlobSnow consortium to move forward with the FMI algorithm for the generation of the full long term data sets. The purpose of the team is to produce and release the 30 years daily SWE data set by October 2010; an example of a final daily SWE product is shown in Figure 3. The long term data along with the comprehensively documented evaluation results will be made openly available for all interested parties. Additional information on the evaluations and the project can be found on the GlobSnow-website: http://globsnow.fmi.fi. Access to the data sets, the documentation and the evaluation results can be acquired by contacting the first author.

Table 1. Summary of tested SWE algorithms over Eurasia, dataset of Jan. 1995- Dec. 1997.

Algorithm	***RMSE***	*Bias*	*Correlation coefficient*	*Unbiased RMSE*	*Samples*
FMI algorithm	43.2 mm	-3.1 mm	0.611	43.1 mm	26063
EC algorithm	67.6 mm	-28.2 mm	0.210	61.5 mm	18109
Chang et al. 1987 (asc node) Chang et al. 1987 (desc node)	71.6 mm 70.7 mm	-8.4 mm 1.6 mm	0.011 0.029	71.1 mm 70.8 mm	26726 27521
SPD algorithm (asc node) SPD algorithm (desc node)	67.1 mm 63.9 mm	-12.7 mm -3.1 mm	0.052 0.121	65.9 mm 63.9 mm	29559 29451
Armstrong et al. 2001 (asc node) Armstrong et al. 2001 (desc node)	72.3 mm 73.7 mm	-44.1 mm -42.9 mm	0.044 0.029	57.3 mm 59.9 mm	21796 24791

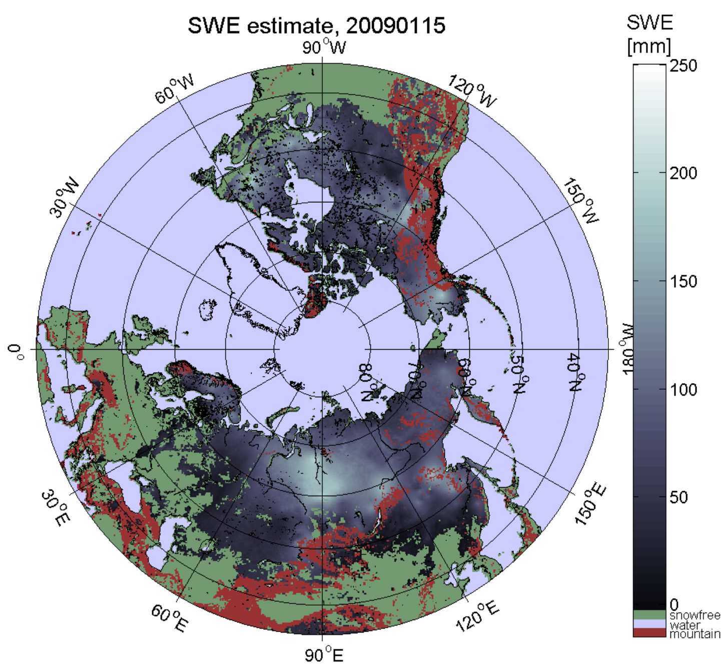

Figure 3. An example of SWE product for Northern Hemisphere for 15 January 2009.

3. SNOW EXTENT PRODUCT

In addition to the SWE data, the GlobSnow project will produce snow extent (SE) products for the whole seasonally snow covered Earth for the years 1995–2010. The global SE product set spanning 15 years is expected to be produced in the autumn of 2010 and will be made freely available.

The 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. The snow cover information is retrieved by two algorithms, one for forested and open areas (SCAmod) and another developed for high-mountain areas of steep topography above the tree line (NLR). The retrieval results from the two algorithms are merged into one product. Clouds are detected by a cloud-cover retrieval algorithm and masked out. Large water bodies (ocean and lakes) are also masked out. The resulting product is provided in a latitude-longitude grid with a 0.01 degree spatial resolution (approximately 1 km).

4. CONCLUSIONS

The performance of the GlobSnow SWE algorithm was evaluated using an extensive multi-year data set consisting of ground based measurements from the land areas of the former Soviet Union and Russia. Based on the evaluations, the FMI algorithm was identified as the strongest candidate for a hemispherical scale algorithm (as required for the GlobSnow SWE purposes). The GlobSnow research baseline states a target accuracy of 25 – 40 mm for SWE on global scale (SWE < 150mm). The FMI algorithm shows RMSE of 43.2 mm for Eurasia with the complete dataset (26063 samples). Restricting the analysis to SWE values below 150 mm, the FMI algorithm gives an RMSE of 33.5 mm (23889 samples). The other evaluated algorithms show RMS errors well beyond the ones observed for the FMI algorithm. The final GlobSnow SWE data set covering the years 1979 – 2009 will be released by October 2010.

5. REFERENCES

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