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Topics of the Newsletter

Workshop 1 in Innsbruck, 12-13 January 2010

GlobSnow algorithm evaluation work

esa

FINNISH METEOROLOGICAL INSTITUTE

European Space Agency
DUE - GlobSnow (2008–2011)

Development of Global Snow Monitoring Services

GlobSnow User Workshop 1

The first GlobSnow User workshop will be held at Innsbruck, Austria, 12 - 13 January 2010. The first User workshop will present the work carried out during the first year of operations on GlobSnow. The consortium will present the algorithm evaluation results in detail for both the Snow Extent (SE) and the Snow Water Equivalent (SWE) products. We will also provide the first long term datasets on SWE for all the interested Users and a sample dataset of SE data covering a Pan-European region for the years 2003-2006. The Diagnostic Data Set (DDS) that has been utilized by the consortium for algorithm evaluation will be made openly available through the GlobSnow website during November 2009. The focus for the GlobSnow project for its second phase will also be discussed as well as the detailed requirements for the final GlobSnow product sets. The workshop will be held at the Beautiful city of Innsbruck in Austria during January of 2010. Registration information for the Workshop will be posted on the GlobSnow website during September 2009.

Overview of the GlobSnow algorithm evaluation efforts

The work on the ESA DUE GlobSnow project during the last months has focused on the evaluation of the most prominent methods for snow cover mapping. The intention of the GlobSnow project is to create Essential Climate Variables concerning Terrestrial snow cover. Two distinct snow products will be created within the project: one describing the Snow Extent (SE) and the other describing the Snow Water Equivalent (SWE). The Snow Extent product will cover both Northern and Southern Hemispheres for all the locations with seasonal snow cover, excluding glaciers, Greenland, Antarctica and snow on ice (lakes/seas/oceans). The Snow Water Equivalent product will be generated for Northern Hemisphere, excluding the mountainous areas, Greenland, the glaciers and snow on ice (lakes/seas/oceans). The main focus on the past efforts on GlobSnow has been the evaluation of the possible methodologies for both the SE and the SWE products.

The algorithms for generating the SE product were evaluated on three main test sites: The Alps, Norway and Finland. The Alps and Norway consist mainly of mountainous landscape and Finland is a non-mountainous region dominated by northern boreal forest. The snow extent evaluations were carried out between the years 2003 and 2006. The evaluations were carried out for several different algorithms and some currently available existing products were included in the analyses.

The evaluations for the Snow Water Equivalent algorithms were carried out for test sites Canada, Finland and Northern Eurasia. The evaluated data were acquired from AMSR-E and SSM/I sensors between the years 1995 and 1997 and between 2005 and 2008. The results from the extensive analyses allowed the consortium to move forward with the selection of the final SWE algorithm for the GlobSnow products.

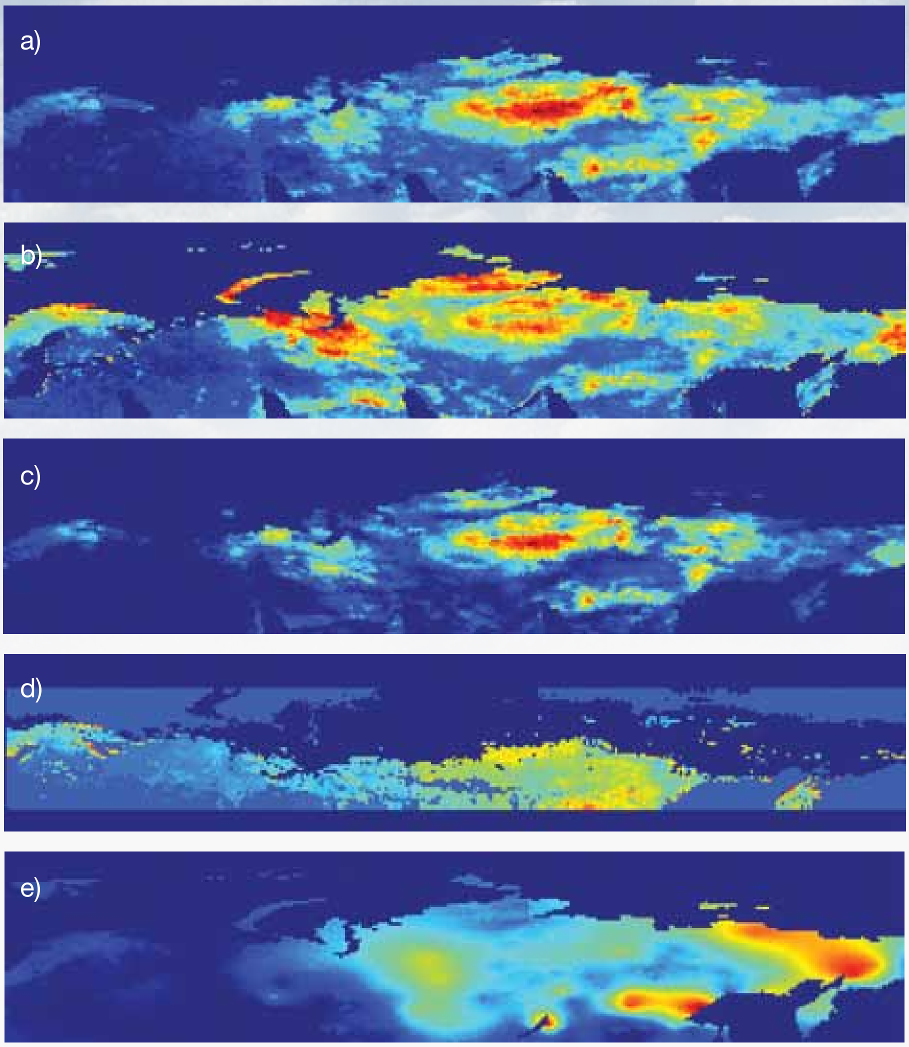

Figure 1: Eurasian SWE maps produced from algorithms by (a) Chang et al. 1987; (b) Aschbacher et al. 1989; (c) Armstrong and Brodzik 2001; (d) Environment Canada suite; (e) Finnish Meteorological Institute suite. All maps represent the SWE conditions for 10 January 1996.

GlobSnow SWE algorithm evaluation

The evaluated SWE algorithms included three main candidates and for the largest geographical region, the Northern Eurasia, a total of five algorithms were evaluated (see Figure 1). The three main algorithms were:

1) *NSICD utilized, currently operational, algorithm suite*
2) *Environment Canada developed SWE estimation suite*
3) *FMI developed data assimilation-based SWE estimation algorithm*

The SWE algorithms were evaluated for three test sites for a minimum of three snow accumulation seasons.

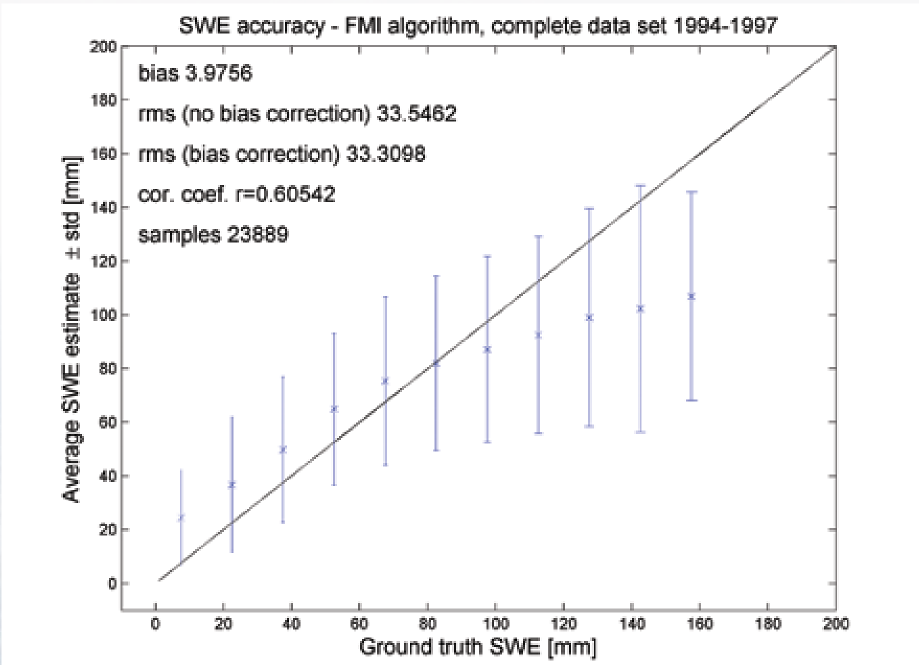

Figure 2: Visualization of FMI algorithm performance over test site Eurasia for SWE conditions of less than 150mm. Notice the extremely large amount of evaluation data, comprising of nearly 24000 data points between the years 1994 and 1997.

	EC	NSICD/Chang et al + derivates	FMI
Finland			
	Good agreement for SWE < 100 mm Low overall bias	Poorest sensitivity to increasing SWE Systematic underestimation Low bias, RMSE only for shallow snow (SWE< 50 mm)	Good performance up to SWE < 150 mm
Eurasia			
	High RMSE values for all seasons; decreased sensitivity to increasing SWE compared to Finnish test area	Good agreement up to SWE < 90 mm. Reversed sensitivity for higher values. Poor overall performance.	Good performance up to SWE < 100 mm. Meets criteria for SWE < 150 mm
Canada			
Tundra	Performed well across lake rich sub-Arctic tundra.	Systematic underestimation.	Low RMSE and bias, but poor correlation with observations.
Northern Boreal	Performed well up to 200 mm SWE.	Poor correlation with observations, even for shallow snow cases.	Significant improvement in performance when SWE <150 mm.
Southern Boreal	Low RMSE and bias, but only moderately strong correlations.	Performed well.	Performed well.
BERMS	Problems with shallow to deep snow transition.	Performed well.	Performed well. Appears to have some problems in determining snow off date.
Prairie	Performed well.	High RMSE and weak correlation.	Performed well.
CMC	Weak correlation and high RMSE, particularly late in the season.	Weak correlation and high RMSE, particularly late in the season.	Relatively low RMSE and high correlation; retains snow cover too long in the spring.
Meets GlobSnow Criteria:			
Yes			
With Conditions			
No			

Table 1: Summary of algorithm performance over Finland, Eurasia and Canada test sites. The colour coding describes whether the algorithm meets the GlobSnow criteria. Green colour denotes that the algorithm meets criteria. Yellow denotes that criteria are met with conditions. Red means that the GlobSnow criteria are not met.

For the Northern Eurasia SSM/I-based SWE data between the years 1994 and 1998 were evaluated. For Canada and Finland AMSR-E data from the years 2004 to 2008 were utilized. The principal reference data consisted of snow depth measurements acquired from snow paths.

All the acquired results from the evaluations of the three test sites were very consistent. The NSIDC algorithm did not perform as well as the algorithm suite from EC and the results from FMI assimilation algorithm (see Figure 2) were in general better than the estimation results from the NSIDC and the EC suites, especially concerning the global application. The evaluations were carried out for all winter seasons between August and May for the different years. Based on the results it was obvious that the typical underestimation of SWE retrievals were more pronounced with the NSIDC and EC algorithms. The assimilation approach of the FMI algorithm is showing especially good results when compared with the different algorithm on higher SWE values. The problem with saturation of the radiometer response on higher SWE values is well mitigated on the FMI algorithm by applying the weather station based auxiliary data. Another benefit of the weather station measured snow data assimilation is seen when using the older SMMR data between 1978 and 1987. The SMMR data does not have a full global cover on a daily basis. However, using the FMI assimilation algorithm, the missing spaceborne radiometer data is complemented with the in-situ point-wise observations from the weather stations; the assimilation approach uses a kriging interpolation approach to parse a full cover snow map using the incomplete satellite data.

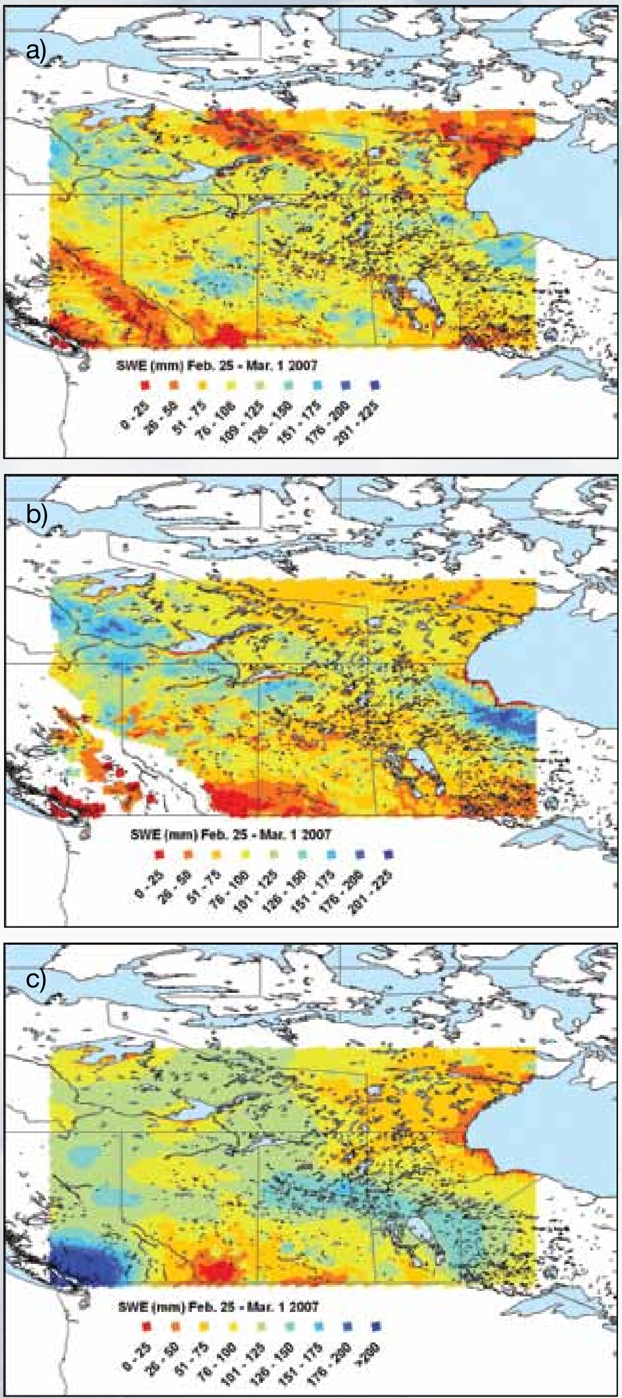

Figure 3: Example SWE retrieval maps for northern Canada acquired with different algorithms: (a) NASA, (b) EC, (c) FMI. All maps represent the SWE conditions for 25 February 2007

In addition to the high accuracy and improved spatial coverage acquired with the FMI assimilation algorithm, another significant advance for the FMI algorithm is its capability to produce accuracy estimates for each retrieved SWE estimate. The calculated error estimates are a significant asset when the SWE products are applied for different end-user applications: whether they are intended for climate monitoring or hydrological forecasting purposes.

The decision (based on the overall summary shown on Table 1) made by the GlobSnow project consortium and the ESA steering authority during the Progress Meeting 1 in Helsinki in June 2009 was to select the FMI algorithm to be used to generate the GlobSnow SWE products.

GlobSnow SE algorithm evaluation

The Snow Extent (SE) team in GlobSnow carried out an extensive evaluation of algorithms for snow cover extent mapping during April-June. The aim was to identify algorithms working well on data from the European Space Agency (ESA) optical sensors ATSR-2 on the ERS-2 satellite and AATSR on Envisat. ATSR-2 data are available globally from 1995 and AATSR from 2002. GlobSnow is aiming for producing a time series of at least 15 years of global snow extents maps.

For evaluation of the SE algorithms and products, three evaluation sites were chosen in order to cover the most important nature types and natural variability in general. The main focus is at the global level, however, the best reference data sets we have access to are from Europe. As extensive natural variability is present in Europe, we chose to focus on this area for this first round of SE tests in GlobSnow.

The three test sites were Jotunheimen mountain area (none-alpine mountain terrain) in South Norway, the Alps (alpine terrain) and Finland (whole country; boreal forest and some open plains). Various versions of NR's 'Norwegian Linear Reflectance' (NLR) fractional snow cover (FSC) algorithm and a spectral unmixing algorithm implemented by ENVEO (based on an algorithm developed at the University of California, Santa Barbara) were evaluated for mountainous terrain. For forested terrain, SYKE's SCAmod algorithm was chosen.

All algorithms were tested using AATSR and MODIS data for days of or close to snow reference data, based on high-resolution earth observation data (like Landsat TM and Terra ASTER) for open areas, and point measurements (weather stations) and transects (snow courses) for the boreal forest. MODIS data gave marginally higher accuracy in most cases for binary snow classification ('snow' and 'no snow'), but the improvement was small or none when using two or four snow classes.

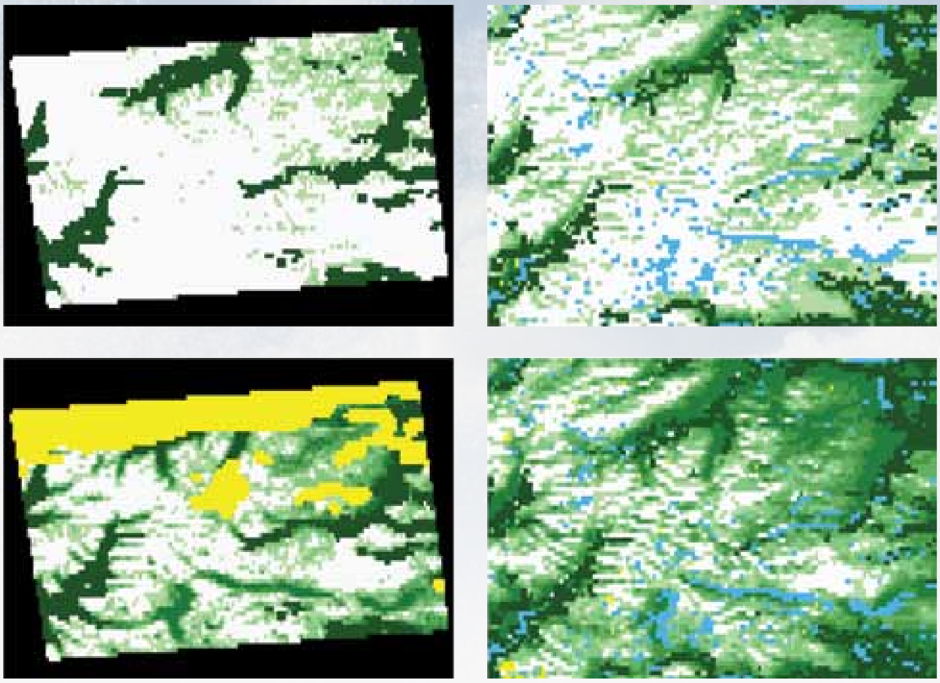

Figure 4: Comparison between snow maps obtained from Landsat TM (left column) with snow maps obtained from AATSR using the NLR algorithm (right column). Note that the spatial resolution of the Landsat-based snow maps has been reduced to the AATSR resolution. The first row compares the results from Landsat on 18 April 2003 (upper left) with the results from AATSR on 16 April (upper right). The second row compares the results from Landsat on 19 October 2003 (lower left) to the results from AATSR on 17 October 2003 (lower right). The yellow colour represents areas classified as clouds, and the blue a water-body mask superimposed onto the snow maps.

Snow maps produced with our algorithms were also compared with the NASA snow product MOD10_L2. NASA's product gave somewhat better results for the 2-class scheme. For the other class schemes, AATSR gave better results in some cases. For FSC, the root-mean-square (RMS) error was just slightly lower for MODIS in most cases. All three algorithms gave adequate results, given the reference data.

For evaluation site Norway (see Figure 4), the single sensor NLR algorithm error rates were 4-5% in the summer period and 13-30% in the winter period for the 2-class scheme. The corresponding error rate intervals for summer and winter periods were 15-32% in and 35-44% for the 3-class scheme and 34-51% and 46-51% for the 4-class scheme. For FSC, the RMS error for the summer months were in the interval 15-16%, while 29-34% in the winter. For the Alps using the spectral unmixing algorithm on AATSR, the total classification error rate was of the order of 8, 14 and 25% for 2-, 3- and 4-class systems, respectively, when compared to Landsat-TM- and Terra-ASTER-based snow maps. For evaluation site Finland (see Figure 5), the snow mapping algorithm for forested areas using AATSR gave 1.1% error rate for the 2-class system and 21% error rate for the 4-class system. The corresponding values when using MODIS data were 1.0 and 15%. The RMS error values for FSC were about 6% for MODIS and 8% for AATSR. (Note that the evaluation data are not similar when comparing the mountain areas and forest areas – spatial and point data, respectively – so the error rates and RMS errors are not directly comparable.)

The SE team were quite pleased with the results obtained as the ATSR-2 and AATSR sensors provide seven spectral channels, while MODIS provides 36. The experiments have shown that sufficient spectral information for snow mapping and cloud screening is present, and they have shown that the algorithms tested are adequate and quite competitive. The work concluded with a recommendation to expand the evaluation experiments to the sub-continental level focussing on pan-European snow maps. A continuous time series of AATSR data will be processed with the three abovementioned algorithms for a three-year period (2003-2005) followed by comprehensive analysis and evaluation of the snow maps. The experiments should be completed by October 1st and lead to a final decision on approach and algorithm selection for the SE product in GlobSnow.

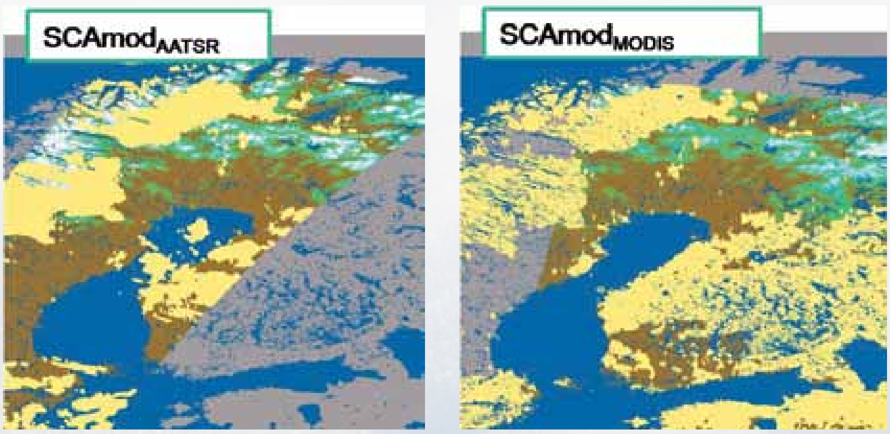

Figure 5: A comparison between a snow map obtained using AATSR (left) with a snow map obtained using MODIS (right) for Finland. The forest snow mapping algorithm SCAmod was used in both cases.

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 database 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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