SAF for Land Surface Analysis (LSA SAF)

VALIDATION REPORT SNOW COVER

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Prepared by:	Land SAF Project Team – FMI Niilo Siljamo and Otto Hyvärinen		
Approved by:	Land SAF Project Manager (IM)		

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1.

Introduction

The daily Snow Cover (SC) product classifies each pixel as snow free, partially snow covered or totally snow covered based on MSG/SEVIRI data. Pixels which are cloud covered or cloud contaminated or too dark all day are not classified.

The SC product is available from 1st of February 2005. Version 1 developed by SMHI was based on NWCSAF Cloud mask product. Version 2 uses pre-processed satellite data directly.

In this report we compare LSASAF SC (LSA SC) version 1.12 (old version), LSASAF SC version 2.05 (new version) and NOAA/NESDIS (IMS) snow cover products for Europe. Our analysis shows that the new version of the LSA SC is much more reliable than the old version, especially during for the winter season. The widely used IMS product also shows very good results for the winter period. During the summer most of the analysis area is snow free and it is quite difficult to compare the quality of snow analysis.

In this work IMS snow cover is used as baseline product to which LSA SC products are compared. In a few cases we also use MODIS images for analysis. Because IMS snow cover analysis is based on satellite data, it suffers of the same limitations as other satellite based snow cover products. Unfortunately good quality in situ measurements of snow cover and especially snow free conditions has been very difficult to obtain. This is because most weather stations do not measure or report snow cover data and in most cases the stations do not report the lack of snow.

2. Examples of the SC products

To show the limitations and strengths of the SC products some examples are shown. First date chosen is January 26th, 2007 (Figure 1). The day was cloudy in many areas, but there were large snow areas in cloud free parts of Central and Southern Europe.

There are some interesting features worth noting in this image and snow cover maps in the Figure 2. For example the northern part of the Jutland Peninsula (Denmark) is snow free as can be confirmed by MODIS images. Both LSA SC products agree, but NOAA/NESDIS classifies this area snow covered. Also the snow line in the central Europe is interesting, because it is different in all three SC products.

It seems that old LSA SC is the least realistic, because there are large snow free areas, which should be either snow covered or unclassified. The new LSA SC and IMS are quite similar, but there are some differences apart from the obvious lack of the unclassified pixels in the IMS. When these two products are compared to satellite images (SEVIRI and MODIS), it seems that the new LSA SC is slightly better.

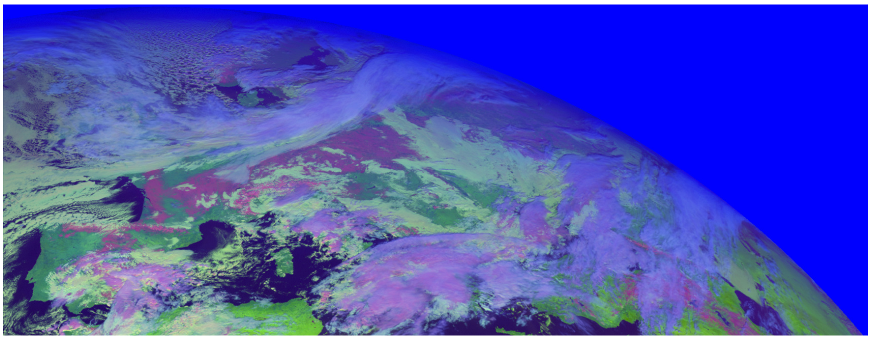

Figure 1 *RGB-composite image of the 26th January, 2007, 1200 UTC, channels 1,3,10i. It can be seen, that there are large snow covered areas (dark magenta). Snow free is green and different clouds are purple or pink.*

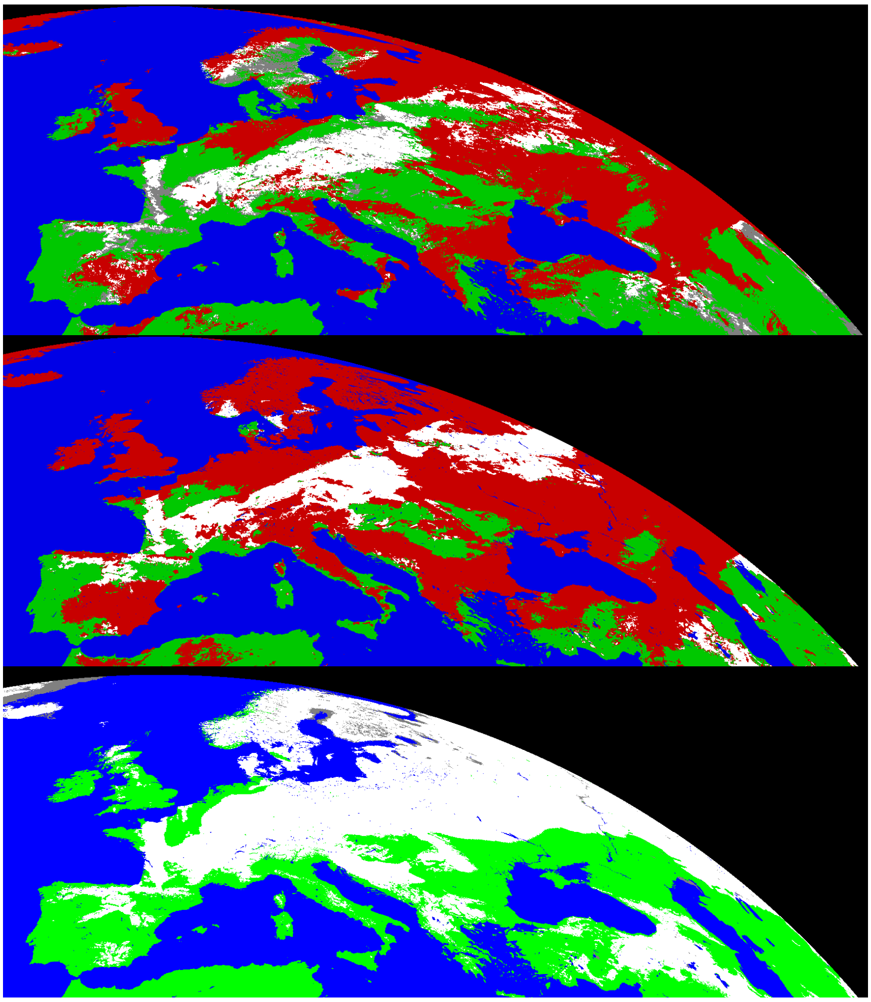

Figure 2 *Three different views about the snow cover in January 26th, 2007. White is snow covered, grey is partially snow covered, green is snow free and red is unclassified. The products are from top: old LSA SC, new LSA SC and NOAA/NESDIS IMS.*

The second date chosen is March 28th, 2007 (Figure 3 and Figure 4). This day is very clear in the northern parts of the Europe. The land cover classification used shows that there are large forests covered by melting snow stretching from Scandinavia to Russia. In this case there is a significant difference between the two LSA SC products.

The old LSA SC has the most problems. It does detect the snow, but it is classified only as partial snow cover. Most of the area is totally snow covered although the trees are snow free. This misclassification might be related to tree and shadows of trees on the ground, which make the detection of snow cover under the trees more difficult.

The new LSA SC and NOAA/NESDIS products show the same features. Both products detect a larger snow covered are than the old LSA SC, but there are also some differences between these two products. It seems that the NOAA/NESDIS product detects more snow, mostly because the snow line is a little bit farther south when compared to the LSA SC product. MODIS images show that LSA SC snow line is probably more realistic. For example in Finland the snow free areas near the coasts are much larger than in the NOAA/NESDIS product.

The third date chosen is October 12th, 2007 (Figure 5 and Figure 6). The old LSA SC product is not available for this day. The most significant feature is the lack of snow in Scandinavia in the NOAA/NESDIS product. The LSA SC product shows that there is a very clear snow belt across Norway and Sweden and in some extent also in Finland as can be seen in the MODIS image in Figure 7.

Unfortunately the LSA SC product does not detect the snow in the Alps in this case. This is probably related to the way land surface temperatures are used in the LSA SC algorithm in barren or sparsely vegetated areas such as mountains. There is a possible solution for this problem but it is not ready for implementation in the version 2.05. It should be noted the LSA SC product has been designed for flat areas, although mountain ranges are not excluded from the product.

There is also an area causing repeating problems on the eastern coast of the Caspian Sea. The Garabogazköl is either a bay of the Caspian Sea or a large lake, which is not classified as water in the land-water mask. This area is sometimes classified as snow covered, because the LSA SC algorithm is not intended for use in water bodies.

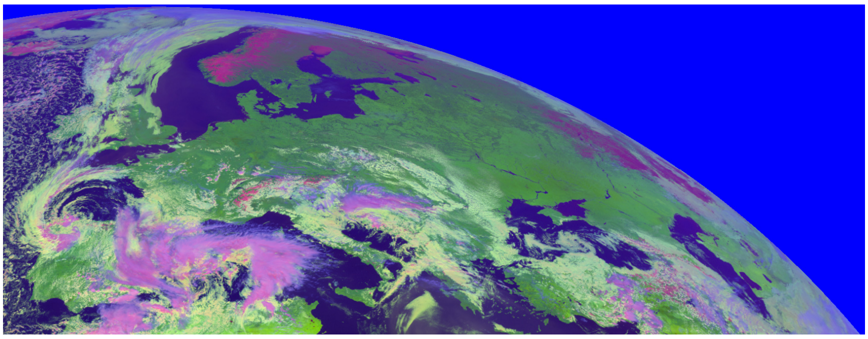

Figure 3 *RGB-composite image of the 28th March, 2007, 1200 UTC, channels 1,3,10i. Snow covered areas (dark magenta) are mainly in the Northern Europe. Snow free is green and different clouds are purple or pink.*

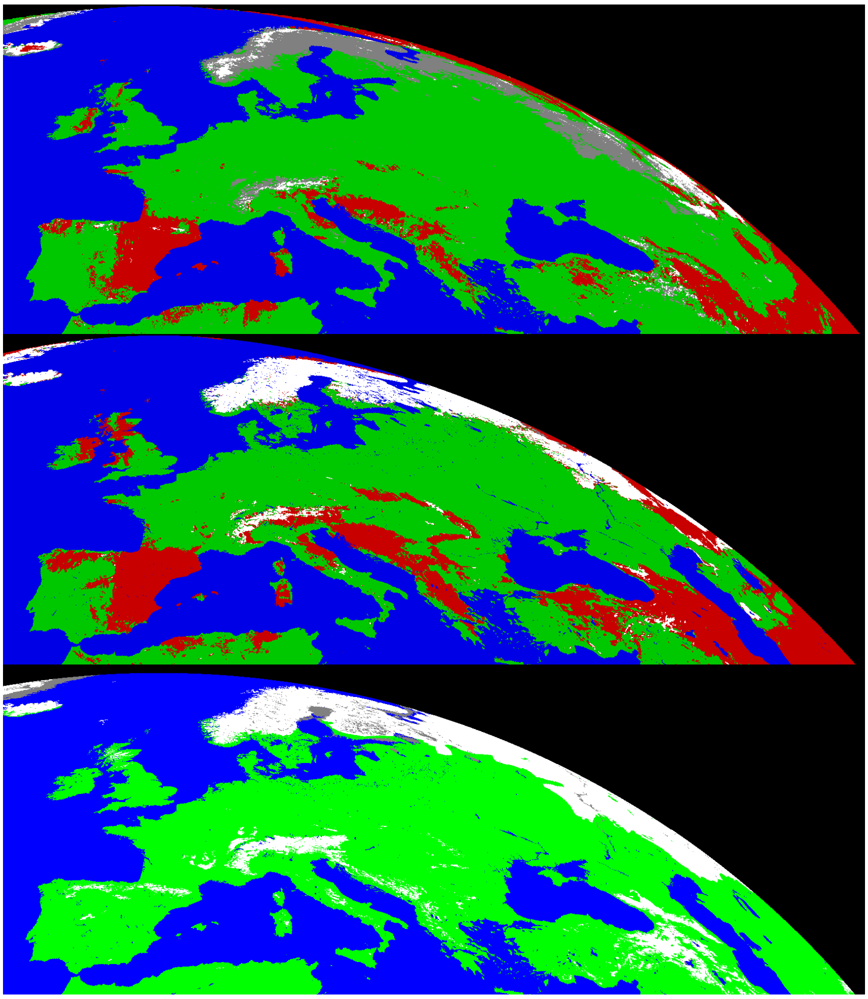

Figure 4 *Three different views about the snow cover in March 28th, 2007. White is snow covered, grey is partially snow covered, green is snow free and red is unclassified. The products are from top old LSA SC, new LSA SC and NOAA/NESDIS IMS.*

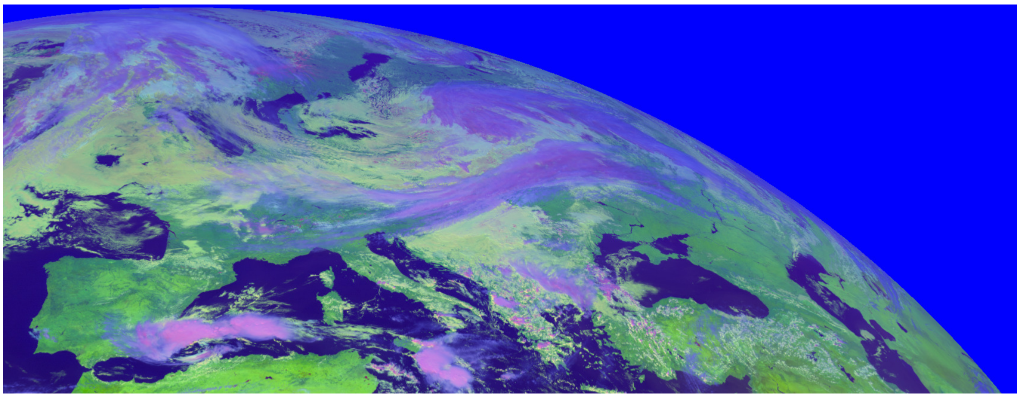

Figure 5 *RGB-composite image of the 12th October, 2007, 1200 UTC, channels 1,3,10i. Snow covered areas (dark magenta) are mainly in the Northern Europe. Snow free is green and different clouds are purple or pink.*

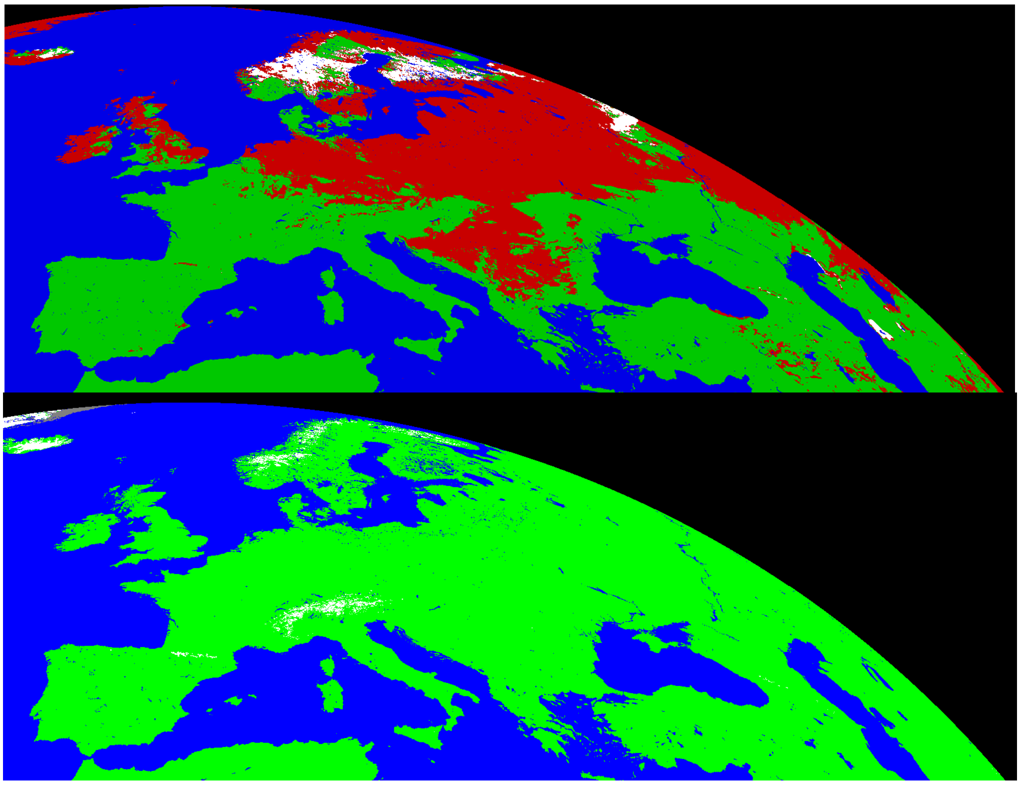

Figure 6 *Two different views of the snow cover in October 12th, 2007. White is snow covered, grey is partially snow covered, green is snow free and red is unclassified. The products are from top are new LSA SC and NOAA/NESDIS IMS.*

Figure 7 *MODIS image October 12th, 2007. Red is snow covered, green snow free. Image courtesy of MODIS Rapid Response Project at NASA/GSFC.*

3. Snow Cover Validation: Year 2007

The examples above show that the new LSA SC system produces realistic snow fields. However, these three selected days are not a proof that the LSA SC product is reliable snow cover product in different snow cover conditions during the year. For this we need to compare the time development of several quality measures, such as probability of detection, false alarm rate and some skill scores.

The first measure of a product based on data on visible and near-infrared channels is the amount of classified pixels in an image. On the other hand, NOAA/NESDIS IMS product uses several other data sources which include also microwave instruments. These can be used to detect the snow under the clouds or in bad lighting conditions. The best option for satellite product validation would be in situ measurements. Unfortunately such data is almost impossible to collect in large scale. For this reason we have used NOAA/NESDIS IMS product as baseline to which both LSA SC products are compared although it is known that IMS is not perfect and it has some more or less serious limitations.

Figure 8 shows a time series of the amount of classified pixels from January to October 2007. The IMS product (red line) shows that there are about 100000 surface pixels which can be classified.

Both old and new LSA SC products can classify 20–75% of the surface. The main reasons for this are clouds, inadequate lighting and algorithm limitations in areas which are difficult to classify. The new LSA SC seems to be more conservative in the classification than the old version. The main reason for this is that the new version tries to avoid classification of surface in conditions where misclassifications are possible.

Figure 8 also shows the amount of snow-covered pixels in the area. It is obvious that the IMS detects more snow than both LSA SC versions which can not classify every pixel in image.

Figure 9 shows the percentage of snow of all classified pixels. During the winter the new LSA SC product seems to detect slightly more snow than the old LSA SC and both show a similar time development as IMS, although the number of detected snow covered pixels is smaller.

Much more useful measures of the product quality are Probability of Detection (POD, Figure 10) and False Alarm Ratio (FAR, Figure 11), bias, Proportion Correct and Heidke Skill Score, which are defined for example in Jolliffe and Stephenson, 2003. The POD describes how many of the IMS snow pixels were also snow covered in LSA SC products. The FAR describes how large proportion of the LSA SC snow pixels were not snow covered in IMS product. The POD shows that during the winter the old LSA SC has serious problems in the detection of snow. However the new LSA SC shows significant improvement during the winter and similar accuracy as the old version during the summer, when the amount of snow covered pixels is so small that usability of POD and FAR as quality indices is limited.

It should be noted that there are still some differences between the new LSA SC and IMS during the winter, but it is difficult to analyse which of the two products is better, because we don’t have enough in situ data for adequate comparison.

The bias shown in the Figure 12 confirms the conclusions we made based on the POD and the FAR. The new LSA SC is significantly better than the old version during the winter and at least as good as the old version during the summer.

The last two measures used are the Proportion Correct (PC, Figure 13) and Heidke Skill Score (HSS, Figure 14). The PC is very simple measure of the product accuracy and can be misleading. There is again clear improvement in the new LSA SC when compared to old LSA SC. Unfortunately there are so many snow free pixels in each image that these dominate the result. A better measure is the HSS, which shows again that during the winter the new LSA SC is not very far from IMS snow cover. During the summer HSS is quite low, because there are relatively more errors in the small amount of snow covered pixels still detected during the summer.

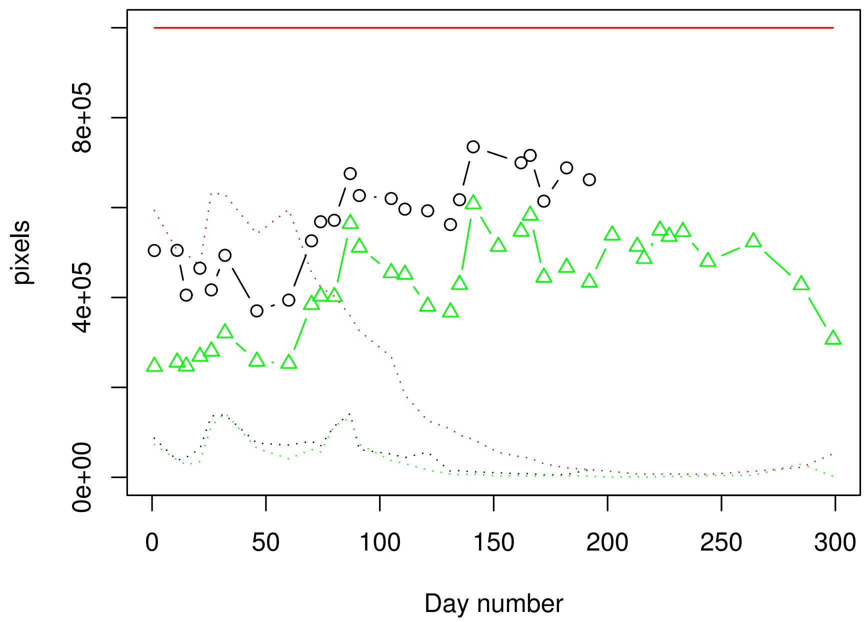

Figure 8 *Time series of amount of snow-covered pixels from the beginning of 2007. Solid lines show the amount of clear pixels in the products, NOAA/NESDIS IMS (solid red line) is always clear, old LSA SC (black line with circles) and new LSA SC (green line with triangles) has unclassified pixels. Dotted lines show detected amount of snow-covered pixels (same colours as above).*

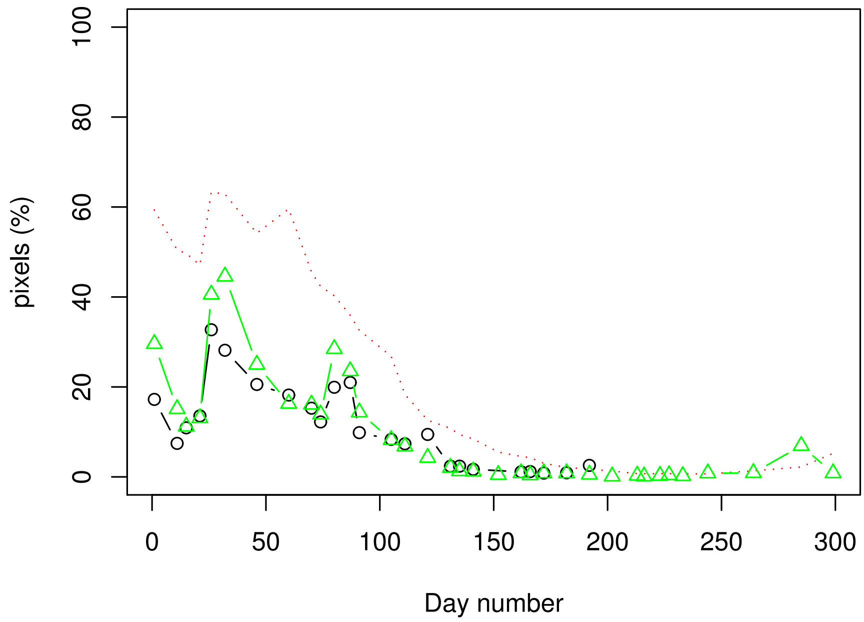

Figure 9 *Snow covered area as percentages of clear pixels, NOAA/NESDIS IMS (red dots), old LSA SC (black line) and new LSA SC (green line).*

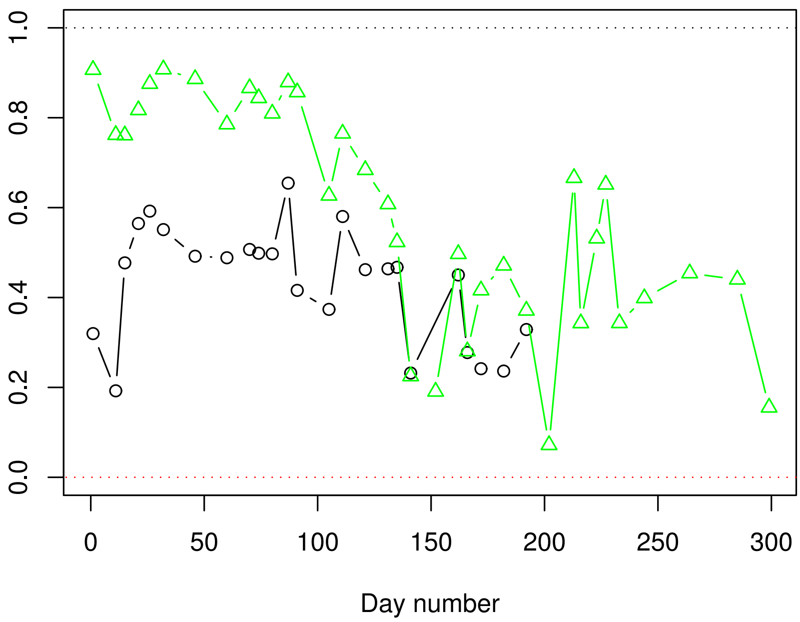

Figure 10 *Probability of detection (POD) of snow against NOAA/NESDIS IMS (black dots). Old LSA SC (black line) does not detect as much snow as the new LSA SC (green line) during the winter. During the summer there is so little snow that this ratio is almost meaningless.*

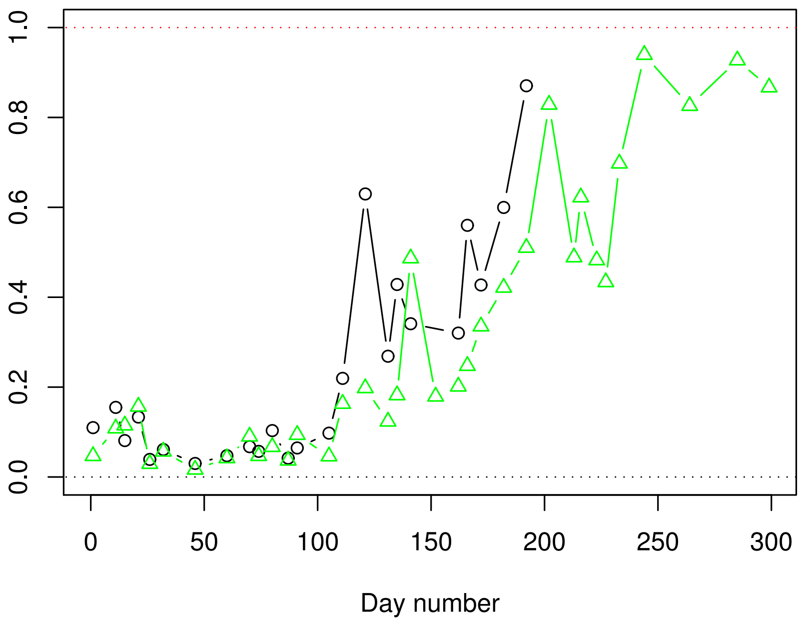

Figure 11 *False alarm ratio (FAR) of snow against NOAA/NESDIS IMS (black dots). Both the old LSA SC (black line) and the new LSA SC (green line) have a low FAR during the winter, but when the snow melts the FAR rises.*

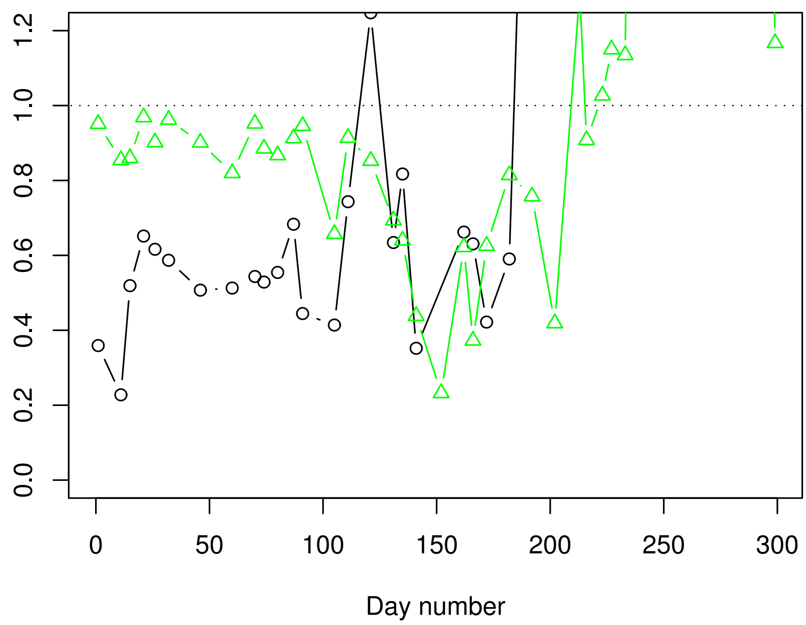

Figure 12 *The bias of old LSA SC (black) and new LSA SC (green) against NOAA/NESDIS IMS.*

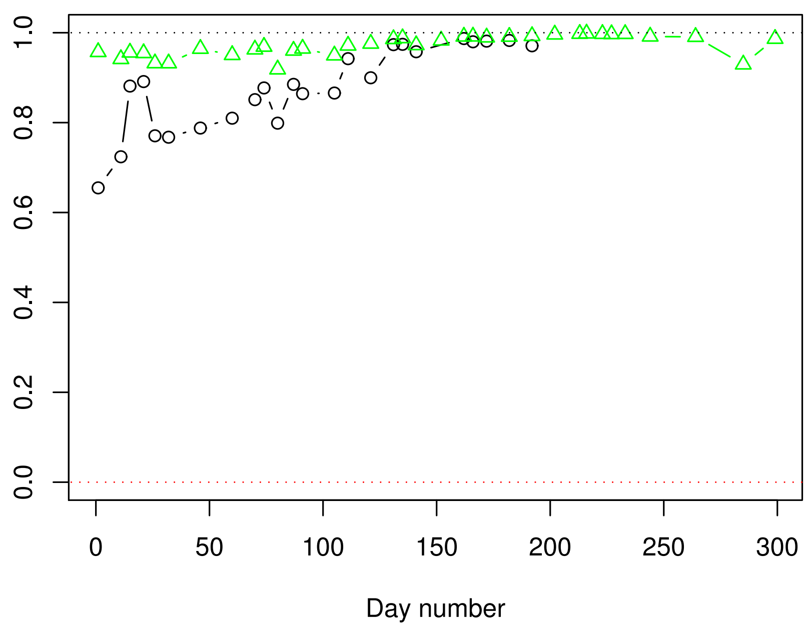

Figure 13 *Proportion Correct (PC) shows that the new LSA SC (green) is better than the old LSA SC (black) during the winter and both are very good during the summer when there is very little snow in Europe.*

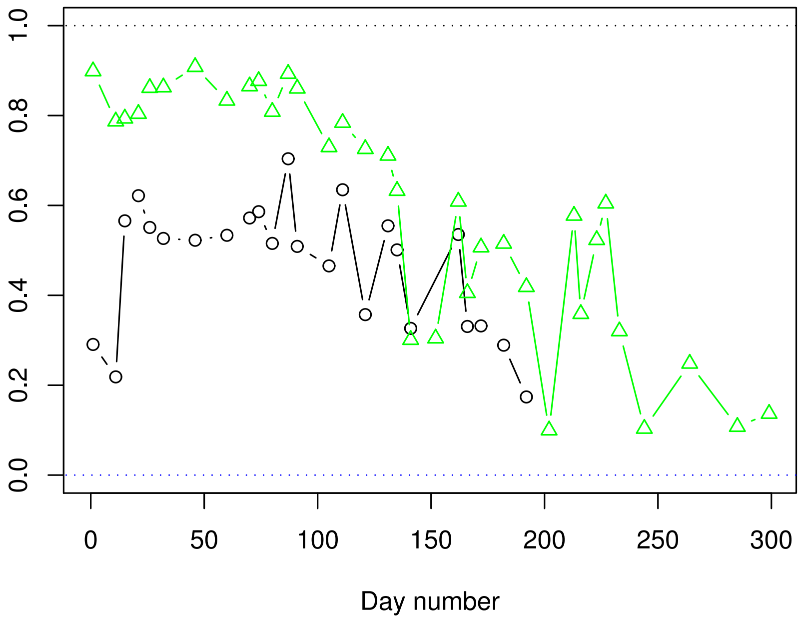

Figure 14 *Heidke Skill Score of the old LSA SC (black) and new LSA SC (green).*

The figures above show the results of the comparison as time series. A more general view about the accuracy of the algorithms has been calculated to tables Table 1 to Table 4. Table 5 shows a summary of different quality scores.

During the winter season there is a significant improvement in the accuracy of the LSASAF snow cover. The number of classified pixels is reduced, but these pixels are mostly those which were misclassified in the old algorithm, The new algorithm is much more conservative and it does not try to classify pixels in possibly cloudy and poorly lighted areas, where misclassifications are much more probable.

Table 1 *Comparison of the old LSASAF snow and the IMS snow during the winter season.*

LSASAF old winter	IMS snow	IMS no snow
LSASAF Snow	464196 (10.9%)	57688 (1.4%)
LSASAF No snow	527925 (12.4%)	3204122 (75.3%)
Not classified	885941	918687

Table 2 *Comparison of the new LSASAF snow and the IMS snow during the winter season.*

LSASAF new winter	IMS snow	IMS no snow
LSASAF Snow	401932 (12.9%)	38135 (1.2%)
LSASAF No snow	102327 (3.3%)	2575034 (82.6%)
Not classified	1373803	1567328

During the summer season the proportion of pixels classified as snow covered by either of the algorithms (LSASAF or IMS) is reduced.

Table 3 *Comparison of the old LSASAF snow and the IMS snow during the summer season.*

LSASAF old summer	IMS snow		IMS no snow	
LSASAF Snow	56592	(1.3%)	40474	(0.9%)
LSASAF No snow	95265	(2.2%)	4236026	(95.7%)
Not classified	70252		627864	

Table 4 *Comparison of the new LSASAF snow and the IMS snow during the summer season.*

LSASAF new summer	IMS snow		IMS no snow	
LSASAF Snow	40219	(0.6%)	24559	(0.34%)
LSASAF No snow	55418	(0.76%)	7150246	(98.3%)
Not classified	158604		2823900	

The five different measures in the Table 5 imply that the new LSASAF algorithm is significantly better than the old version.

Table 5 *Algorithm comparison scores*

	LSASAF old winter	LSASAF new winter	LSASAF old summer	LSASAF new summer
PC	0.862336	0.954943	0.9693478	0.9889997
BIAS	0.5260286	0.8727003	0.6391935	0.677332
POD	0.4678824	0.7970745	0.3726664	0.4205381
FAR	0.1105380	0.08665726	0.416974	0.3791256
HSS	0.4501966	0.7824811	0.3632021	0.4171151

4. **Summary**

The current LSASAF snow cover product (version 2.05) has been compared to the NOAA/NESDIS IMS product which is one of the better known snow cover products. The new version was also compared against the old one to see how much the product has advanced from the original cloud mask based version. Our analysis shows that the new version is significantly better than the old version and is currently at comparable level with NOAA/NESDIS IMS product. Both products present a reasonable and realistic snow cover analysis in clear sky conditions, particularly during the winter season. The LSA SAF team expects that new versions of the SC product will further improve the performance of the product during the winter especially in the currently unclassified areas. During the very late spring and summer both the LSASAF SC and IMS show that the Europe is practically snow free. The few remaining differences between the products must be analysed to find the reasons for the differences and which of the two products is more reliable.

5. **References**

Jolliffe, Ian T. and Stephenson David B., 2003, Forecast Verification: A Practitioner's Guide in Atmospheric Science, John Wiley & Sons