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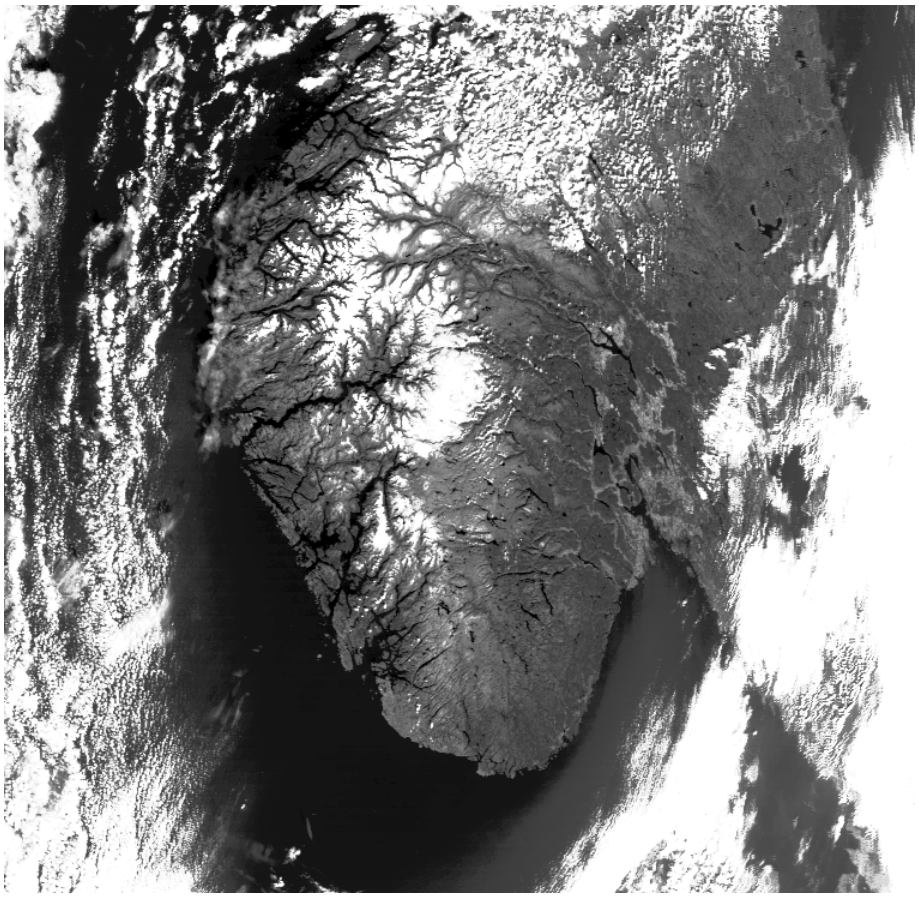
Note

Evaluation of MODIS images from KSAT



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Abstract

Kongsberg Satellite Services (SAT) is downloading MODIS images from the Terra satellite. A program made by Norwegian Computing Center (NR) is used to produce snow cover area (SCA) maps from these images. NR has for many years produced snow maps from MODIS images delivered by NASA. Tests have shown that there are some differences in the SCA results from the two image sources. A study has been made to quantify the differences between the images and the SCA products made from them.

Keywords	MODIS images, snow products
Target group	KSAT, NORUT
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Contents

1 Introduction

Norwegian Computing Center (NR) has for many years produced daily maps showing snow cover area of Norway in the snowmelt season from March/April until July. The basis for these maps is images taken by the MODIS sensor on the Terra satellite. The images have been downloaded from the NASA website. Downloading includes some manual procedures, and the snow map will at the best be ready the day after the satellite passage.

Kongsberg Satellite Services (KSAT) has for some time downloaded MODIS images from Terra. With the optical snow cover retrieval algorithm from NR installed at KSAT, snow cover maps can be produced a short time after the passage of the satellite. In a test period some differences in the snow cover area (SCA) maps made from images from KSAT and NASA have been found. Therefore a study has been carried out to compare the images delivered by KSAT and NASA. The images used by the SCA algorithm are of the type MODIS L1B. In this study we have compared the L1B images and the SCA results to see if there are significant differences in the products.

2 Evaluation

2.1 Images

We have compared MODIS images delivered by KSAT with corresponding images delivered by NASA. Images from 29 May 2007 and images from three dates in September 2007 have been compared.

The most thorough comparison has been made between the MODIS image from 29 May 2007, timed 0924 UTC, delivered by KSAT and the image timed 0930 UTC from NASA.

The KSAT image stretches from south of Norway at the bottom to past the North Pole at the top. The fact that the image reaches so far to the north and even beyond the North Pole, is disturbing the geo correction routine in the snow cover area (SCA) production program. The corrected image and the calculated SCA map have stripes caused by incorrect positioning of data. When the image is being cut just north of Norway before geo correction, these stripes disappear.

The NASA image starts not far north of Norway. At NR we have a routine which automatically cuts the input-image just north of Norway. This routine may be included in the next version of the SCA program for KSAT, if the KSAT MODIS processor cannot manage to cut the image at a proper position in the north. Figure 1 shows band 1 of the NASA image with 250 m resolution, cut just north of Norway. One can see Norway near the left edge of the image. This is not a favourable position because the pixels near the border are larger than in the middle of the image. The pixels will also be overlapping. This will be corrected by the geo correction routine, but it is recommended that one uses images which are taken from passages where the target area (Norway) is situated in the middle of the image.

We have cut the KSAT image to cover the same area as the NASA image and compared the two input images (band 1 and 2, 250 m resolution). The SCA results have been compared for two of the September images.

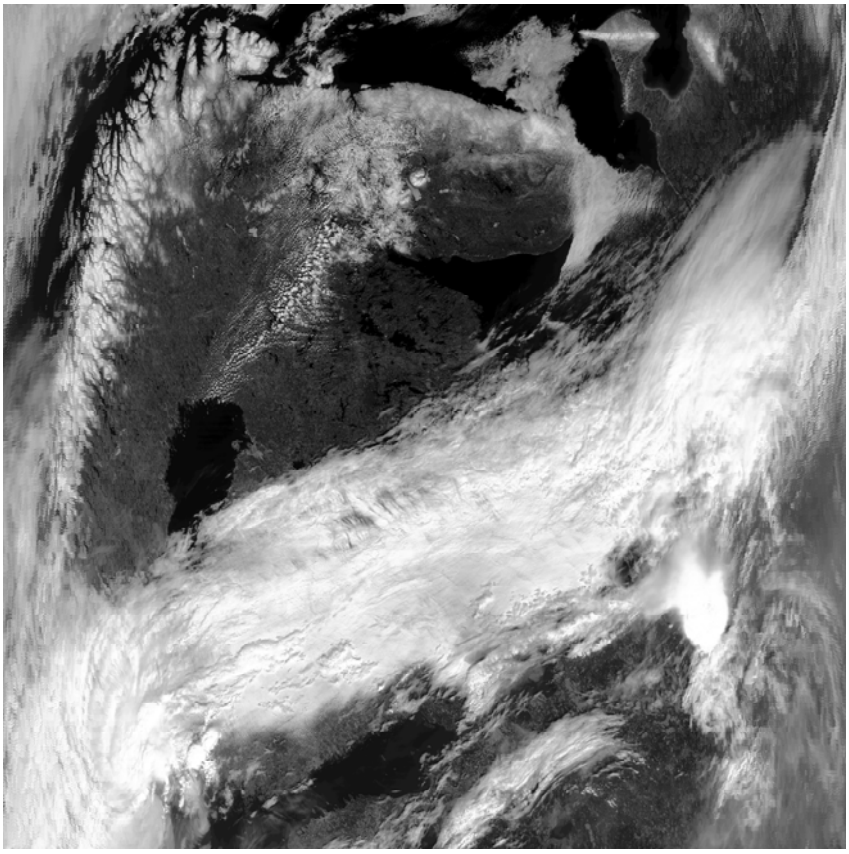

Figure 1 NASA image from 29 May 2007 at 0930 UTC, band 1, 250 m resolution

2.2 Input data

Looking at the raw input values, we find no significant difference in the values used, as shown in
Table **1**.

Band	**Min**	**Max**	**Mean**	**Stdev**
KSAT band 1	304	23692	4333.1	3962.1
NASA band 1	304	23663	4336.1	3964.1
KSAT band 2	162	65533	8802.1	6502.4
NASA band 2	163	65533	8796.8	6498.8

Table 1 Raw input values for band 1 and 2

Seen in an ENVI viewer the two 250 m swath images look quite similar. But if you make a difference image you will see that there are systematic differences. There is a repeating pattern for each 40 lines (one scan), and along each line there are repeating patterns for each 4 samples (see Figure 2 and Figure 3).

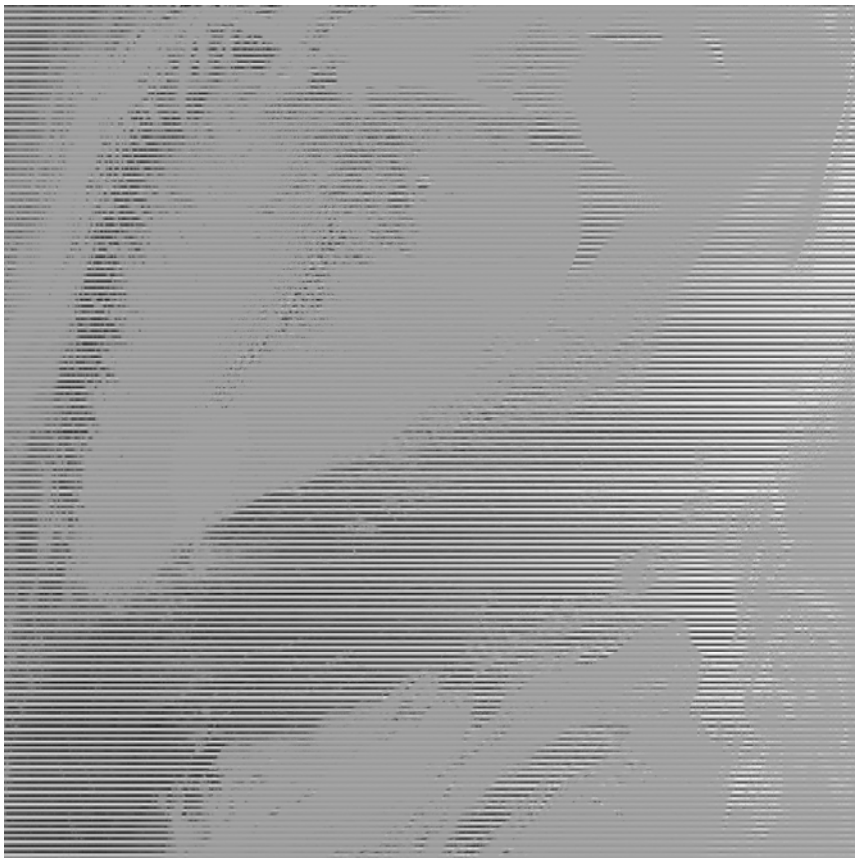

Figure 2 Difference (KSAT minus NASA) of raw input images of band 1 from 29 May 2007 at 0930 UTC.

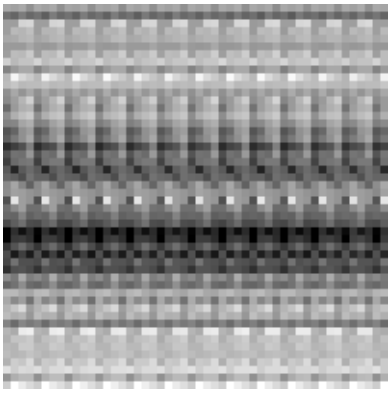

Figure 3 Close up of difference image between KSAT and NASA images from 29 May 2007.

Figure 4 shows the histogram of the difference image in Figure 2. Most of the pixels have values close to each other. The difference of KSAT minus NASA is both positive and negative, centred about the value +1. 9.7 % of the pixels have difference zero. 55.4 % of the pixels have difference less than 0.1 % of the mean value. 97.7 % have difference less than 1% of the mean.

In each of the two images there are similar patterns (see Figure 5), so it is difficult to say which image is the most "correct" one. In areas with low values (sea, bare land), the

differences are small. In areas with high values (snow, clouds), the differences are larger.

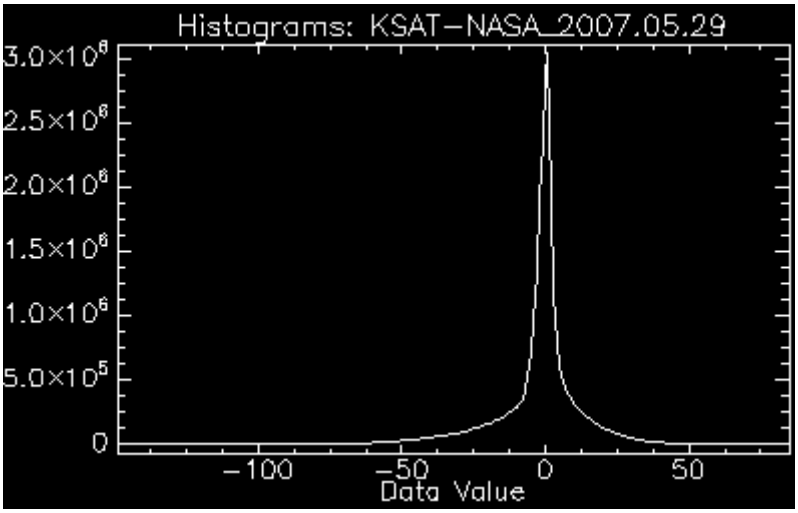

Figure 4 Histogram showing the difference values (KSAT minus NASA) of raw images of band 1 from 29 May 2007 at 0930 UTC. The histogram starts at – 149 and ends at + 85 with maximum at +1.

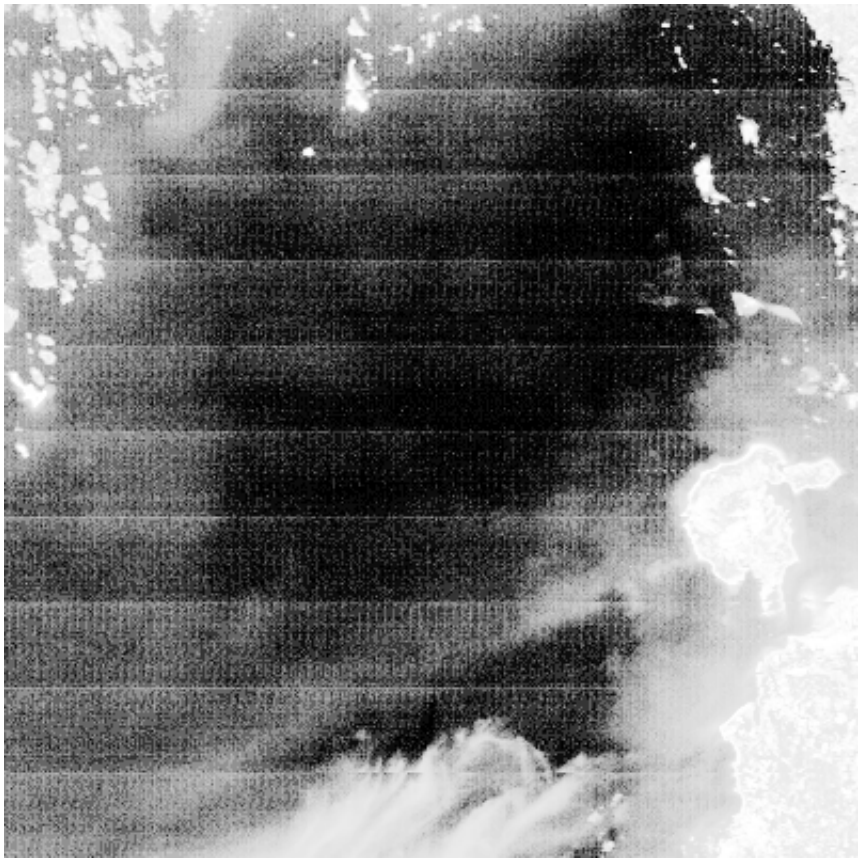

Figure 5 Part of NASA image from 29 May 2007, 0930 UTC. The gray scale has been adjusted to show the repeating patterns in the input values.

In the SCA algorithm the reflectance values of band 1 are being used. The calibration coefficients are different for the two images. But these differences do not make up for

the differences in raw image values. An image showing the difference in reflectance values give the same systematic difference patterns as for the raw image values. Table 2 shows the difference in calibration coefficients for radiance and reflectance for band 1 and 2. The offset used is 0.0 for both radiance and reflectance for both bands.

Band	Radiance	Reflectance
KSAT band 1	0.0262854	5.28131e-05
NASA band 1	0.0262307	5.27032e-05
KSAT band 2	0.0100586	3.27156e-05
NASA band 2	0.0100517	3.26933e-05

Table 2 Calibration coefficients for radiance and reflectance

Table 3 shows statistical values of the difference images made by subtracting the value of each pixel in the NASA image from the corresponding pixel in the KSAT image. This has been done for the raw input images and for the reflectance images. It can be seen that the values of the KSAT image varies from 1% lower to 0.73 % higher than the NASA image, and from 0.79 % lower to 0.94 % higher in reflectance. The mean difference is small.

	Min	Max	Mean	Stdev
Raw input	-149	85	-2.2129959	14.430050
Raw input %	-1.000000	0.731707	-0.048457	0.246294
Reflectance	-0.005695	0.006612	0.000368	0.000827
Reflectance %	-0.793652	0.941670	0.160439	0.246448

Table 3 Difference between raw input and reflectance values of band 1 between KSAT and NASA image, also calculated as % of NASA values.

2.3 Geographic location

Will these differences make noticeable differences in the SCA calculations? Comparing the SCA results, one can see that there is a slight difference in the position of the snow. In the KSAT image the snow is situated somewhat to the west and south of the NASA result. The positions in the geo corrected image are calculated from the lat/lon file included in the HDF file. Here the position of each 4th 250 m pixel is given. This means a grid with grid size 1 km in the centre of image and larger towards the borders.

We have compared the two lat/lon files and have found differences. KSAT minus NASA gives latitude differences varying from negative values in the west through zero to positive values in the east. The longitude differences are all negative, meaning the KSAT image is being situated to the west of the NASA image.

Table 4 shows statistical values of the difference in latitude and longitude values between KSAT and NASA images. The differences are given in degrees and meters. For longitude the differences have been calculated for 60 and 70 degrees north.

Units	Min	Max	Mean	Stdev
Lat deg	-0.001675	0.004623	-0.000227	0.000317
Lat m	-186.1	513.7	-25.2	35.2
Lon deg	-0.069114	-0.000565	-0.002529	0.001098
Lat m at 60 deg	-3839.6	-31.4	-140.5	61.0
Lat m at 70 deg	-2626.3	-21.5	-96.1	41.7

Table 4 Difference in latitude and longitude values between KSAT and NASA images.

We see that the maximum deviation in longitude is probably somewhere between 2626.3 and 3839.6 m. In fact, it is 3629 m at Loen in western Norway. See below.

The differences in meters at the four corners of the images are shown in Table 5.

Corner	Latitude	Longitude
Upper left	-95	-280
Upper right	+150	-244
Lower left	-80	-322
Lower right	+87	-196

Table 5 Difference in meters of image corners (KSAT minus NASA)

In the middle of the image the longitude difference is about 80 meters. In the input image, where the pixel size increases towards the borders, the difference is about 1/4 – 1/3 of a pixel. In a corrected image (all pixels are 250 x 250 m) the difference in position is less than a pixel in most of the image, but close to or more than a pixel at the borders.

These differences are representative for sea and flat landscape. In the northern and western part of Norway there are large height differences within short distances. As there have for both images been used an elevation model for calculating the lat/lon values, you can see a relief of Norway in the western part of the difference images. See Figure 6.

Because of increasing pixel size towards the borders and large differences in elevation on land, there may be inaccuracies in pixel locations both for KSAT and NASA images. Therefore, there also may be large differences in longitude (and latitude) values near the image borders.

A small difference in initial position calculation can give large differences when the elevation model is included, especially in the longitude values. The largest difference is found at Loen in western Norway where the difference in longitude is as large as

3629 m. The neighbouring pixel to the west has a difference of 113 m. In terrain like this there may be large errors in the positions and the image of snow distribution could be misleading.

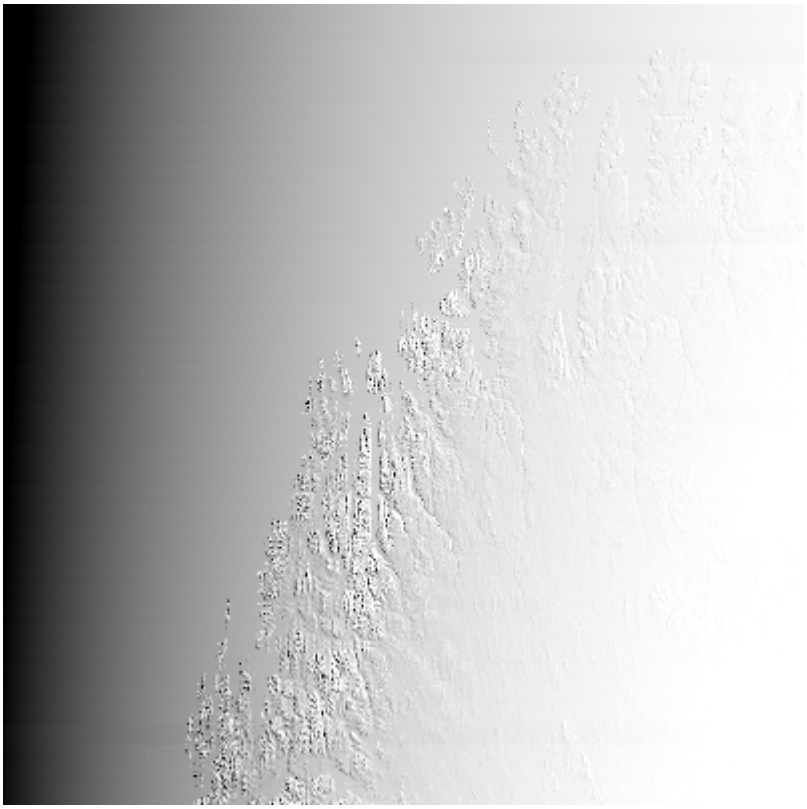

Figure 6 Subset of longitude difference between KSAT and NASA image. Notice the relief map of Northern Norway.

Looking at the geo corrected images it seems as if the NASA image is most correct. Compared to the land/water mask that we use, the snow in the KSAT SCA image is situated in the sea at some places. This implies that the positions given in the KSAT image are too far to the west. An exact evaluation of positions, have not been done.

Because of the differences in position, we have not made a comparison of the SCA result for these two images. We also had some images from September 2007 and have studied these image pairs. We have checked the differences in lat/lon values for these images to see if it they can be used for SCA comparison.

From 17 September 2007 KSAT has delivered an image timed 1158 UTC. This image also stretches very far north. Automatically cut to a reasonable size it has been compared to a mosaic of two NASA images, timed 1200 and 1205 UTC. In this image Norway is situated close to the eastern border of the image. In the western part of the image we have Greenland. The differences in latitude and longitude values can be found in Table 6.

The great differences in longitude are due to Greenland and Norway being situated at the western and eastern borders of the image. The mean differences are small.

Units	Min	Max	Mean	Stdev
Lat deg	-0.004917	0.000557	-0.000048	0.000055
Lat m	-546.3	61.9	-5.3	6.1
Lon deg	-0.091461	0.003284	-0.000271	0.000274
Lon m 60 deg	-5081.2	199.1	-15.1	15.2
Norway lon deg	-0.017462	0.000460	-0.000315	0.000294
Norway lon m 60 deg	-970.1	25.6	-17.5	16.3

Table 6 Differences in latitude and longitude between KSAT and NASA images from 17 September 2007 at 1200 UTC.

The second image pair is from 22 September 2007. KSAT at 1040 and NASA at 1045. The differences of latitude and longitude are shown in Table 7

Units	Min	Max	Mean	Stdev
Lat deg	-0.001549	0.001240	0.000041	0.000073
Lat m	-172.1	137.8	4.6	8.1
Lon deg	-0.003038	0.000092	-0.000292	0.000221
Lon m 60 deg	-168.8	5.1	-16.2	12.3

Table 7 Differences in latitude and longitude between KSAT and NASA images from 22 September 2007 at 1045 UTC.

The third image pair is from 2007.09.27. KSAT at 1059 and NASA 1100 and 1105. The differences in latitude and longitude are shown in Table 8.

Units	Min	Max	Mean	Stdev
Lat deg	-0.000088	0.000256	0.000060	0.000044
Lat m	-9.8	28	6.7	4.9
Lon deg	-0.004822	0.000515	-0.000152	0.000218
Lon m 60 deg	-276.9	28.6	-8.4	12.1

Table 8 Differences in latitude and longitude between KSAT and NASA images from 27 September 2007 at 1100 UTC.

In these two last pairs, Norway is situated in the middle of the image. This seems to reduce the lat/lon differences. The difference of -276.9 is from Iceland which is found at the western edge of the image. For the area of Norway and Sweden, the values are below 0.0005 deg, which is 28 m, mostly below 0.0003 deg, that is 17 m. Even if the maximum difference is large, the mean difference is so small that it does not influence the geo corrected images visually.

However, the same type of differences of data input values can be found for these images as was demonstrated for the image from 29 May. For the swath images, there are exactly the same difference patterns in lines and samples.

2.4 SCA estimation

For 22 and 27 September, where Scandinavia is located in the middle of the images, we have compared the results of SCA estimation.

There are no visible differences in the result images, except for small differences in estimated cloud cover. For the detection of clouds, several bands of the images with 1 km resolution are being used. We have not studied the 1 km images in detail, but suppose that the same type of differences in data and location values appear in these images.

Making a difference image, we find that 99.42 % of the pixels have the same value in the results for 22 September, and 99.28 % for 27. This seems fine, but about 45 % of the image is ocean, and here the pixel values are always the same for both images. The size of the image in pixels is shown below.

Total image	29760000
Sea	13391842
Land	16368158

Table 9 is showing the number of pixels with equal value over land, and in percent of the land area. Many of these pixels are cloud pixels.

Date	No. of pixels with equal value	Pixels with equal value in %
2007.09.22	16194145	98.94
2007.09.27	16154183	98.69

Table 9 Number of pixels with equal values over land areas in images from KSAT and NASA.

Although there are pixels with large difference in values, most of the pixels have difference values of 2 or less, that is 99.76 and 99.79 % of the pixels over land area for the two image pairs.

The differences in estimated cloud cover and snow cover are shown in Table 10.

The SCA product shows the percent of snow in each pixel outside areas covered with clouds. We see that the KSAT images give higher values for the area of clouds and pixels with 100 % snow cover. For pixels with 0 % snow, the differences are both positive and negative. The differences are between 0.08 and 0.22 % of NASA values. The difference in total SCA is 22.75 and 89.5 km². This could seem much, but it is well below 1 % of the area calculated from the NASA images.

Date	Image	Clouds	0 % snow	100 % snow	Total SCA
2007.09.22	KSAT	11174588	4636007	102127	16038.54
	NASA	11165884	4642122	101968	16061.29
	KSAT/NASA	100.08	100.22	100.16	99.86
2007.09.27	KSAT	8779114	6492195	28074	13934.84
	NASA	8759496	6499686	28026	14024.34
	KSAT/NASA	100.22	99.88	100.17	99.36

Table 10 Comparison of estimation of clouds and snow cover between images from KSAT and NASA. The estimated values are given in pixels. The total SCA is given in km², and the KSAT/NASA relation in %.

3 Conclusions

KSAT and NASA MODIS L1B images with 250 m resolution are delivered with small differences in input values and calibration coefficients. The differences in input values seem to follow a certain pattern within each scan (40 lines).

These differences are so small that they do not influence the calculation of SCA essentially. For each pixel there may be larger differences, but these occur only for very few pixels. The differences of the total amount of snow are less than 1 % of the amount calculated for the NASA images. This is far below the uncertainty of the result from the algorithm applied. We have not tested the differences of the images with 1 km resolution in detail, but there are some small differences in the calculated cloud cover. For the two tested images we find that the KSAT images give a larger cloud cover and NASA a larger total snow cover. To see if this is a systematic deviation, we have to investigate more images.

We have no exact knowledge of which of the two images are most correct. As the differences of the results are so small, both KSAT and NASA images can be used for the calculation of snow cover area.

When land areas with large differences in altitude are close to the image edge in west and east, there may be large differences in the calculation of pixel positions, and the estimated SCA map could be misleading. In the image from 29 May 2007, where we found severe differences in the positions, we found the NASA image to give the most correct location. However, for both KSAT and NASA images, the calculations should only be performed with the actual area far from the image borders. For the calculation of SCA for Scandinavia, one should use images acquired between 0945 and 1145 UTC to get the best results.