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COMPARISON OF RADARSAT AND IKONOS SATELLITE IMAGES – Detection and visibility of man-made objects

BRETAR Frédéric, WEYDAHL Dan Johan

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Vidar S Andersen
Director of Research

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FORSVARETS FORSKNINGSINSTITUTT
Norwegian Defence Research Establishment
P O Box 25, NO-2027 Kjeller, Norway

FORSVARETS FORSKNINGSINSTITUTT (FFI)
Norwegian Defence Research Establishment

P O BOX 25
N0-2027 KJELLER, NORWAY

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8) ABSTRACT

This report compares the visual appearance and detection of different man-made objects in an area close to Bergen city in Norway using IKONOS (1 m resolution) and RADARSAT (9 m resolution) images respectively.

The results show that the RADARSAT images add very limited information to the IKONOS panchromatic image for many mapping applications. One explanation for the seemingly lack of information from the SAR data in this study, is that the IKONOS sensor image the Earth ground with a resolution of 1 m, while the RADARSAT Fine mode only has 9 m resolution.

Despite these matters, this study also shows that RADARSAT may sometimes uniquely detect certain objects: some buildings gave a strong backscatter even if they were partly hidden in the forest, buoys may very well be detected on a low SAR backscatter ocean surface, parked helicopters and airplanes were represented as bright points, electrical wires laid out in a direction favourable to the incidence radar beam. There are also examples that strong RADARSAT backscatter may confirm the presence of bridges as well as building structures/forms already seen in the IKONOS image.

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COMPARISON OF RADARSAT AND IKONOS SATELLITE IMAGES – Detection and visibility of man-made objects

1 INTRODUCTION

The scientific community has shown great interest to both IKONOS and RADARSAT satellite data. These two devices provide two different points of view of the Earth surface from space. Observations from the former are worked out through the optical domain, whereas the latter observes the Earth through the C-band (microwave frequencies). In this respect, one can have access to two different sorts of information.

The very fine resolution of IKONOS (about 1 meter) gives the opportunity to make very accurate analysis. However, optical satellite remote sensing depends on sunlight illuminating the Earth in order to obtain useful imagery. Its performance is restricted by the presence of clouds, fog, smoke or darkness. A radar satellite can operate day or night regardless of weather conditions.

A synthetic aperture radar (SAR) system gives the backscattering properties of vegetated surfaces, but also of structures and metal objects. One can therefore obtain a lot of important elements from a SAR image analysis. In some instances, the presence or absence of a bright point in a SAR image may be all that is needed to come to a conclusive remark or at least a better understanding of the surface classes that are obtained from classification and interpretation of the optical satellite images.

Introducing knowledge from SAR images may also tell us more about the complexity of the objects on the ground that could possibly not have been done using the optical images alone. The aim of this study is therefore to analyse and compare IKONOS and RADARSAT images acquired over the same geographical area, in order to extract the maximum of structural and spectral information over some selected objects and structures.

This report first presents the study area over the vicinity of Bergen. Then, general information as to IKONOS and RADARSAT sensors is exposed. The satellite image data set as well as other background information sources, are then presented. Finally, the analysis methodology is described before the results are presented.

2 BACKGROUND

2.1 The study area

Both RADARSAT and IKONOS acquisitions cover the Bergen airport in Norway with its surroundings. Images from this area were already available at Norwegian Defence Research Establishment (FFI) at the time of this study, and this area is therefore selected as the test site.

This test area is characterised by the airport, air terminals and the runway, industrial and urban areas, harbours, main and small roads, boats, airplanes, cars, and complex shaped buildings.

Figure 2.1 *Map of the vicinity of Bergen where black rectangles depict the footprints of the RADARSAT and IKONOS images used in this study. Copyright map data: Statens Kartverk.*

Natural features like lakes, coastlines, forests, and clearings are also present. The elevation of the area varies from sea level to 150 metres above the sea level. Most of the features analysed in this study are located between 40-60 metres above the sea level, and will therefore not entail a very large shift as far as the co-registration is concerned.

2.2 The cardinal effect in SAR images

The cardinal effect occurs in SAR images for extended features which orientation does not part further than roughly ±20° from the azimuth direction. If the scatterer positions are organised such that their average geometric structure is aligned with the phase front of the illumination, then the radar echo from these scatterers will also add in phase. Now, since the RADARSAT satellite inclination (98.6°) is not very far from the north-south direction, the bright backscatter caused by the cardinal direction effect will more or less be aligned in the north-south and west-east directions. The cardinal effect will be well represented in some parts of the RADARSAT images discussed in this report.

3 THE DATA SET

In this study, we have used three sorts of data from three different remote sensors, namely IKONOS, RADARSAT and airborne aerial photos. A map covering the major part of the selected area has also been used in order to correct misregistrations due to the topographic relief.

3.1 IKONOS

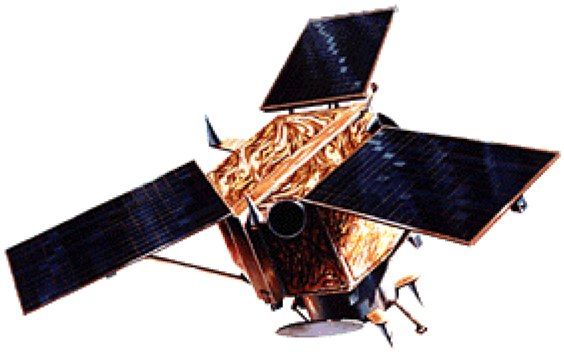

Figure 3.1 IKONOS satellite.

IKONOS is the world's first commercial satellite to collect images with one-metre resolution panchromatic and 4-metres multispectral. It was launched in September 1999 and was designed to collect about 600 images per day. To date, the IKONOS satellite has collected more than 74 million square kilometres of imagery. Table 3.1 gathers some technical information about this satellite.

The IKONOS imagery used in this study was acquired on 2nd of September 2000 at 11:07:00 (UTC) over the vicinity of Bergen, with a viewing angle of 50.8° from the horizontal plan.

Resolution	1-metres panchromatic 4-metre multispectral
Swath Widths	11 km at nadir
Altitude	681 km
Inclination	98.1°
Speed	7 kilometres per second
Revisit frequency	2.9 days at 1-metre resolution (40 degrees latitude), more frequent for higher latitudes,
Viewing angle	off-nadir up-to-60°

Table 3.1 Technical information about IKONOS satellite.

3.2 RADARSAT

RADARSAT-1 was launched in November 1995. This is the first Canadian remote sensing satellite. The orbit for RADARSAT is sun-synchronous and at an altitude of 798 km and an inclination of 98.6°. The orbit period is 100.7 minutes and the repeat cycle is 24 days. However, the system allows one to image an area in 1-day interval over the high Arctic and approximately 3-days interval at mid-latitude. This is partly due to the steering beam capability.

The RADARSAT is a C-band system (5.3 GHz) operating with HH polarisation. The system can be operated in a variety of beam selection modes providing various swaths widths, resolutions, and look angles. Table 3.2 and figure 3.2 will summarise the modes in which the system operates.

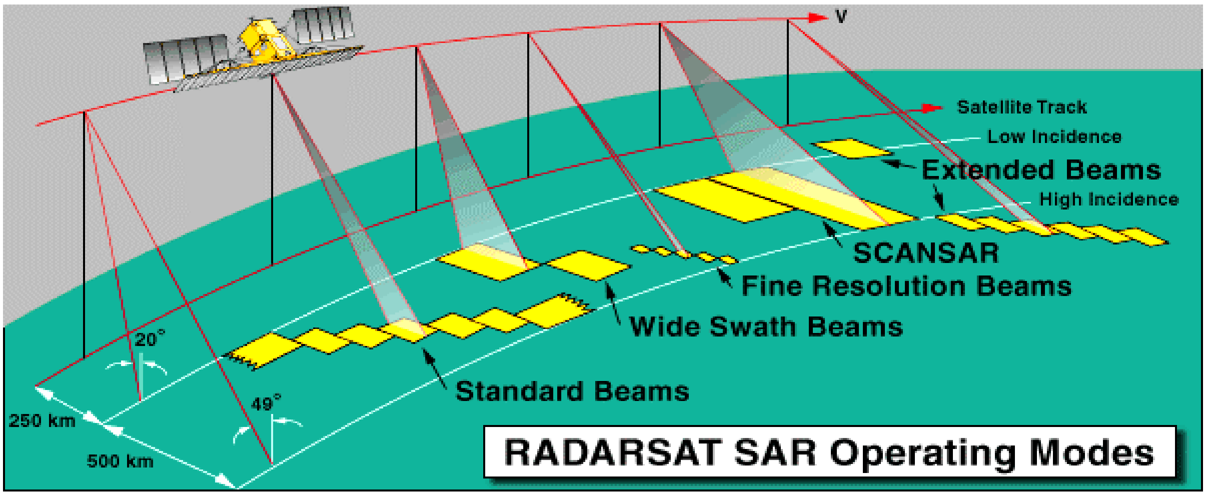

Figure 3.2 RADARSAT operating modes

It is the fine resolution RADARSAT image modes that are used here. More specifically, the Fine 5 beam with an incidence angle of 46.5 at mid-swath. The images were acquired on 7th and 31st of October 1998, at 17:31:33 (UTC) and 17:31:42 (UTC) respectively. Both are ascending images over the Bergen region.

Beam Mode	Swath (km)	Look Angle (degrees)	Nominal Resolution (m) (range * azimuth)
Standard	100	20-49	21 * 28
Wide swath (1)	165	20-31	48-30 * 28
Wide swath (2)	150	31-39	32-25 * 28
Fine Resolution	45	37-48	11-9 * 9
ScanSAR (narrow)	305	20-40	50 * 50
ScanSAR (wide)	510	20-49	100 * 100
Extended (high)	75	50-60	22-19 * 28
Extended (low)	170	10-23	63-28 * 28

Table 3.2 RADARSAT beam selection modes

3.3 Digital aerial photos

In order to make a relevant comparison between IKONOS and RADARSAT images, it was decided to use another sort of support, namely digital aerial photos, which were digitally scanned to a resolution of approximately 30 centimetres. These coloured photos will give us the possibility to have extremely accurate data so that we should distinguish the bulk of elements present in the area in a significant way.

The aerial photos were acquired on 26th of June 1999 in the scale 1:15000, with a transversal (west-east) overlap of 60%. Figure 3.3 is an extracted part of the fly map of the mission over the vicinity of Bergen (including Bergen airport). Black dots represent roughly the centre of each photo, and black rectangles, the ground print of the camera. We have used six aerial photos corresponding to positions C2, C3, C4 and D2, D3, D4 on figure 3.3.

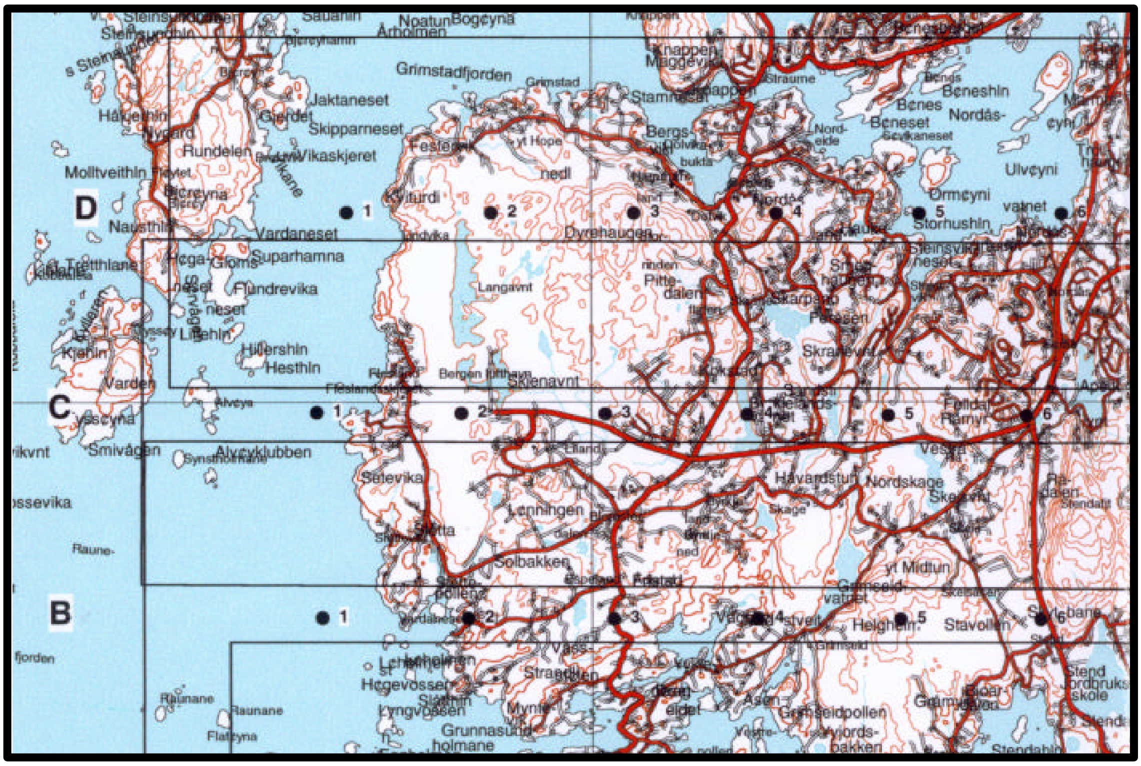

Figure 3.3 Aerial photo coverage map of the vicinity of Bergen, 26th of June 1999.

3.4 Map

A paper map was also used in support of the satellite image analysis. This map is from the commune of Bergen, scale 1:10000, and is provided by Oppmålingsavdelingen. The great advantage of using a map in addition to aerial photos, is that there is no distortion caused by viewing angles. This will help us to find similar features from both satellite images.

4 PRE-PROCESSING

4.1 Methodology

The aim of this study is to present a visual comparison between both IKONOS and RADARSAT images over the area of Bergen. Since the remote sensing data sets are acquired with long time intervals (see figure 4.1), only qualitative assessments will be performed here.

Figure. 4.1 Acquired time between the remote sensing data sets

Since the IKONOS image is oriented almost north-south (355°), it was decided to keep it as a reference. As a result, both the RADARSAT image and the map will be co-registered to the IKONOS image, using common ground control points (GCPs) seen in the images.

Aerial photographs have from far a better resolution than RADARSAT and even IKONOS, knowing that they are digitally scanned to a resolution of approximately 30 centimetres resolution, instead of a 10-metres and a 1-metre resolution respectively. We will therefore be able to classify in a better way the different interesting features, with either a significant SAR backscattering (low or high) or a typical optical signature. However, for displaying reasons, the extracted aerial photos have been resampled from their initial resolution to a 1-metre resolution, corresponding to the IKONOS resolution. One can point out that the aerial photos have not been co-registered to the IKONOS image geometry since they differ only a few degrees rotation from each other.

Many interesting man-made and natural features were selected from the two satellite images (IKONOS and RADARSAT). It was then investigated how these features appeared in the other image.

4.2 Co-registration and resampling

Accurate geocoding would require a digital elevation model (DEM) covering the area. Since none was available at the time, it was decided to do the image co-registration by using the coastline, where we could consider the altitude to be roughly constant. Considering the high orbital stability of both sensors, a first order transformation has been used. This transformation is a linear one, which is able to modify the location, the scale, the skew in X and/or Y, and to rotate the image to be registered. Four ground control points (GCPs) were selected. These points are located far apart in the corresponding image.

The first order transform will work only in the flat parts and not in the hilly areas. But using local altitudes from the map in the scale 1:10000 may compensate for this. The SAR positions obtained from the transforms were therefore adjusted using these local altitudes so that the ground feature geographical location gave a better correspondence with the IKONOS image.

4.3 Speckle filtering

SAR images are generated using coherent processing of the scattered signals, and will therefore have a high degree of speckle. The speckle has the characteristics of a random multiplicative noise in the sense that the noise level increases with the average grey level of a local area.

The presence of speckle reduces the ability of a human observer to resolve fine detail. It may therefore be desirable to reduce the amount of speckle. Applying a simple box-averaging filter can do this. However, a better choice is using an *adaptive* speckle filter that takes the local statistics into account in the filtering process. One such adaptive filter is the Frost filter (1). A modified version of the Frost filter was developed at FFI (2).

This modified version will filter a lot in homogeneous areas, but keep the 1-look RADARSAT Fine mode pixel values unchanged in heterogeneous areas. In areas where the estimated statistics fall in between these two extremes, the filtering will be weighted by a linear function. The parameters of the linear function are set using both theoretical statistics (e.g. s/μ) and visual appearance.

5 DATA ANALYSIS

5.1 Airport buildings

Figure 5.1 depicts the air terminal of the Bergen airport. As one can point it out at the first sight, many different complex items are brought out in the IKONOS imagery. The 1-metre resolution allows distinguishing the aircraft fine structure located at certain terminal extremities, but also the air terminal geometry with a high degree of accuracy. It is sufficient to have a look on the aerial photo over the same area, in order to recognise the entire air terminal structure.

As far as the RADARSAT image in figure 5.1 is concerned, the lower resolution does not allow depicting the same sort of features. However, the bright backscattering at the level of the air terminal extremities bring out interesting structures. We are able to count the number of boarding corridors (11 pieces). It is impossible to detect the presence of aircraft with a fairly part of confidence: bright backscatter can also be trucks or ground equipment.

Figure 5.2 represents a set of airport buildings located north of the main terminal. The IKONOS imagery shows important details on its right part. One can indeed observe interesting features on the ground. The aerial photo helps us to describe these features. Giving more attention to this part of the image, they appear to be helicopters. But we can notice that trucks are presents there as well, parked next to the helicopter area. This remark could be applied to the RADARSAT imagery. In this respect, one can point out a characteristic bright point on the top right of the image. The resolution is too low to describe the feature, but it is most likely to be backscatter from a helicopter, trucks or other airport ground equipment.

RADARSAT backscatter can be very directional sensitive with respect to radar viewing angle. Considering the range-azimuth directions sketched on figure 5.2, one can remark that the very bright band crossing the imagery is related to the building stretched in the azimuth direction. On the contrary, the radar receives limited echo from the building that is layed out in the range direction. This phenomena is characteristic of the well-known cardinal effect (see chapter 2.2).

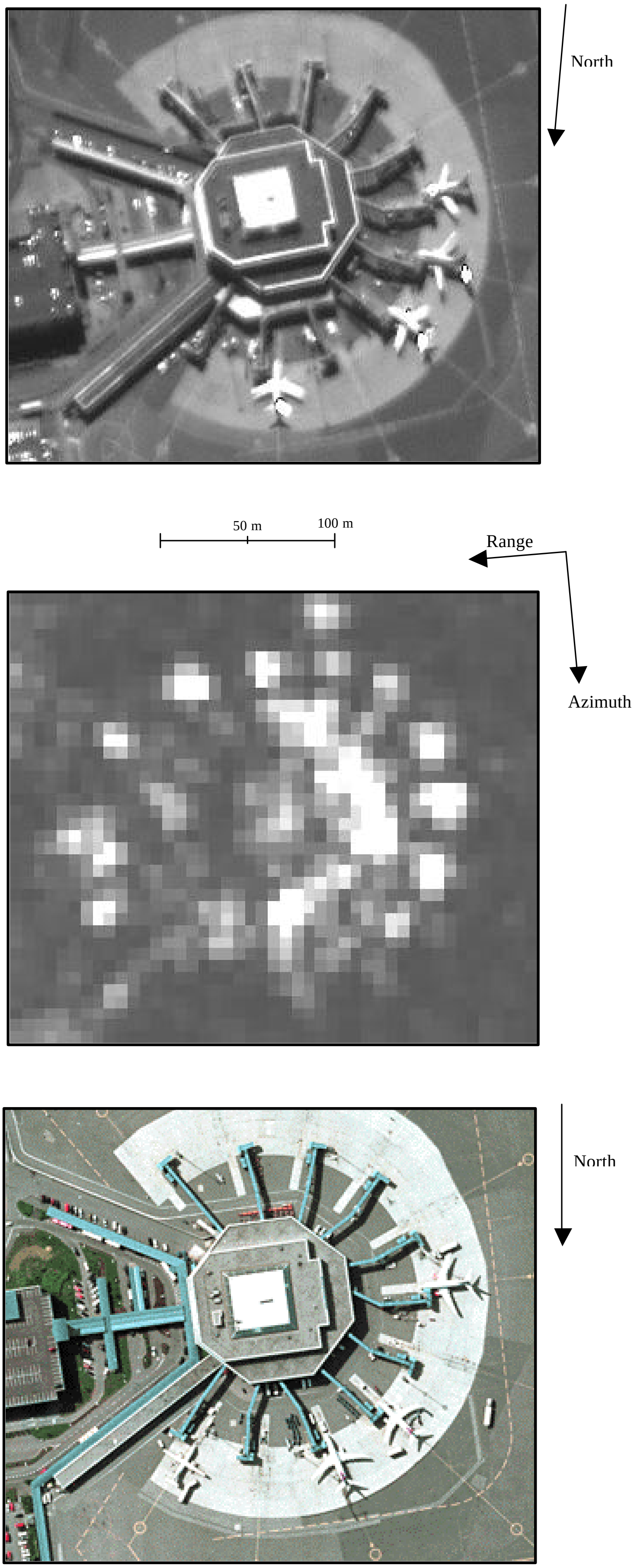

Figure 5.1 Terminal at Bergen airport. IKONOS (top), RADARSAT (middle) from 7th October 1998, and aerial photo (down).

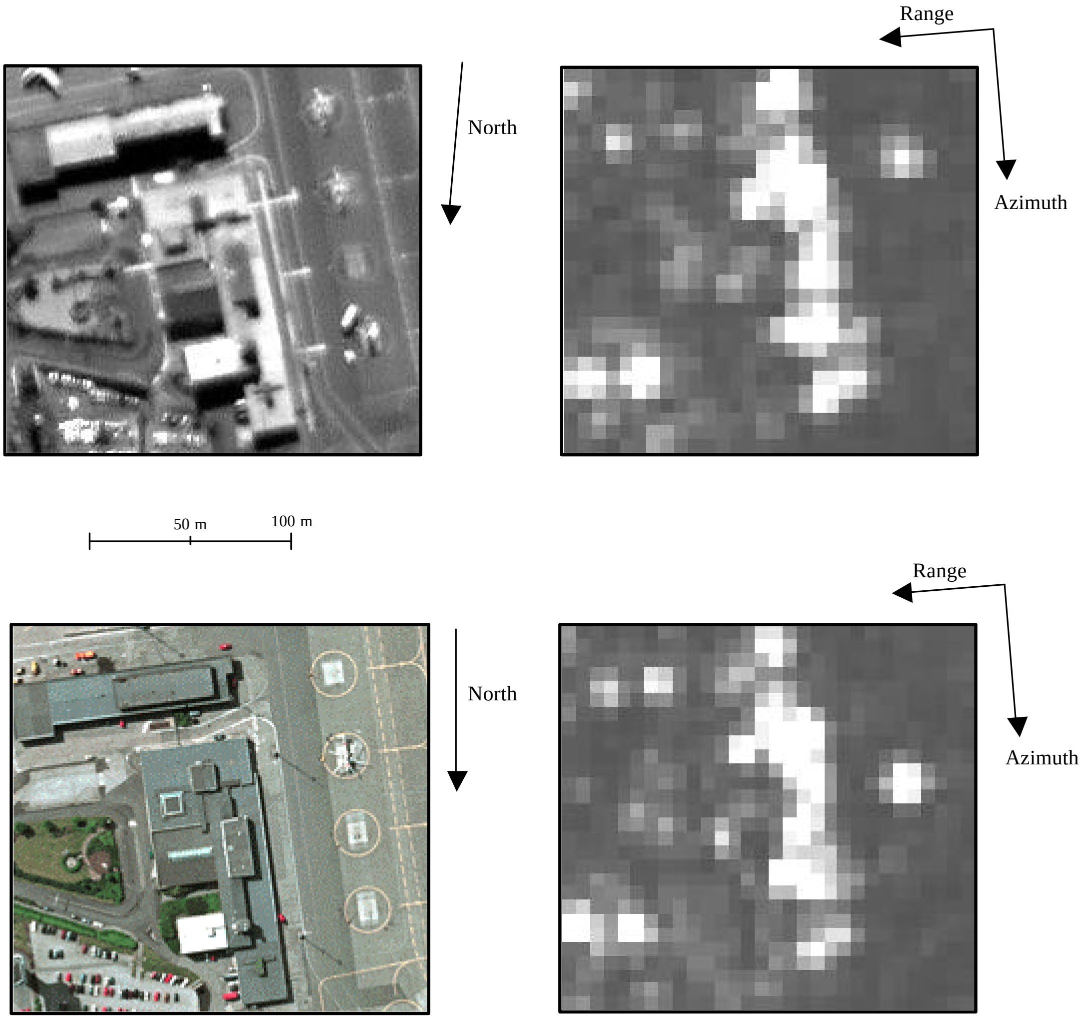

Figure 5.2 Airport buildings and helicopter parking next to runway. IKONOS (up left), RADARSAT from 7th October 1998 (up right), aerial photo (low left), and RADARSAT from 31st October 1998 (low right).

Figure 5.3 depicts three hangars located near the airport. The IKONOS image gives an interesting point of view. However and because of the shadow, a part of the information is hidden. We will come back on this subject. The RADARSAT image, with a very bright feature in the middle brings a supplementary piece of information as to the structure of the main hangar. As we can see on the aerial photo, the south front of the hangar owns an additional small building structure. This projection is not visible on the IKONOS image due to the shadowing effect (IKONOS had a viewing angle of 50.8 degrees).

The shadow in the IKONOS image could nevertheless be relevant in the analysis since the building height may be estimated.

Looking only at the RADARSAT image, and assuming the presence of the cardinal effect, would give the wrong directions of the buildings. Interpreting buildings based on bright backscatter alone is therefore dangerous.

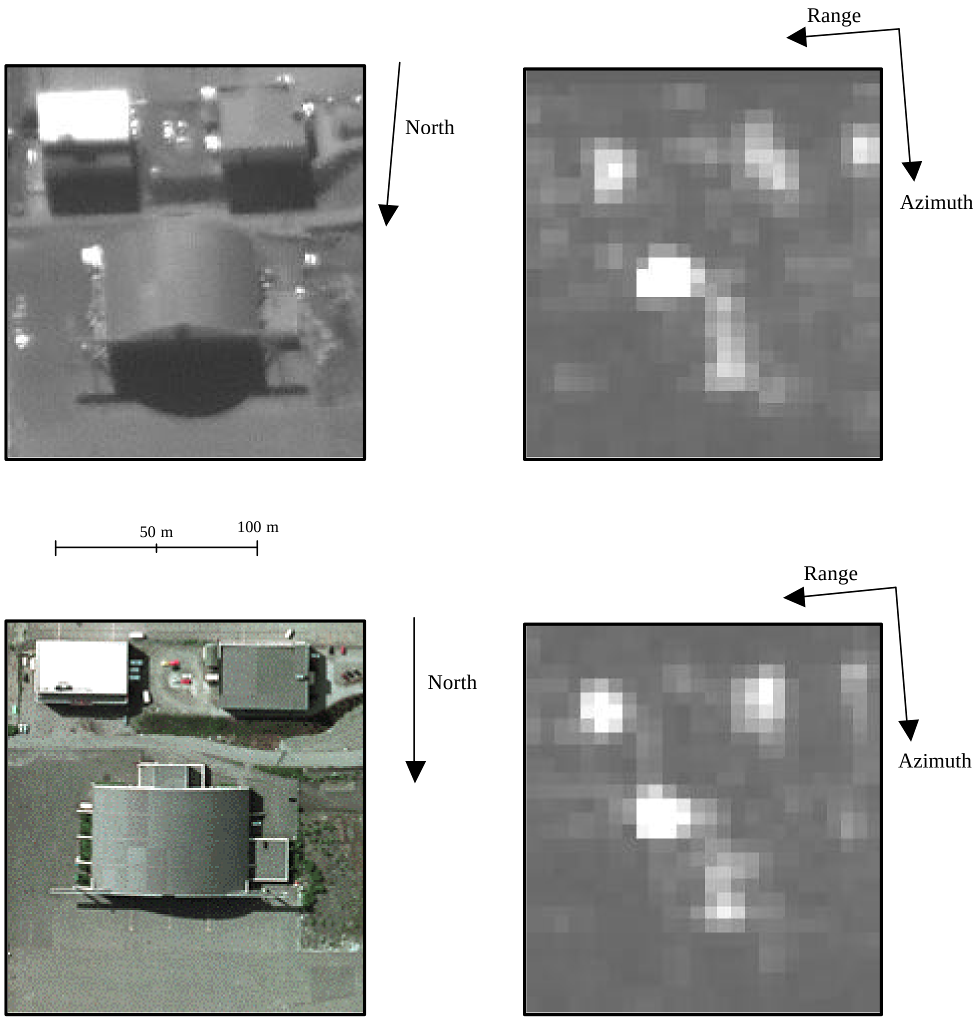

Figure 5.3 Hangars at Bergen airport. IKONOS (up left), RADARSAT from 7th October 1998 (up right), aerial photo (low left), and RADARSAT image from 31st October 1998 (low right).

5.2 Wharf

Other interesting features are located next to the seashore. In the RADARSAT imagery, the difference between the backscattering from water and land surface is so high that the coastline is very well defined. Such is indeed the case with the wharf observed in Kvernavika, see figure 5.4. The coastline is quite visible in the RADARSAT image, but unfortunately, instead of the detailed wharf depicted in the IKONOS image, only a cove is visible. This may however be due to the construction of the wharf, as may be assumed from comparing the air photo and the IKONOS image. This assumption is nevertheless not confirmed by contacting local citizens. We can also notice that the SAR backscatter is so high in this area, so that buildings cannot be discriminated. Speckle filtering did not improve the SAR image quality in a significant way.

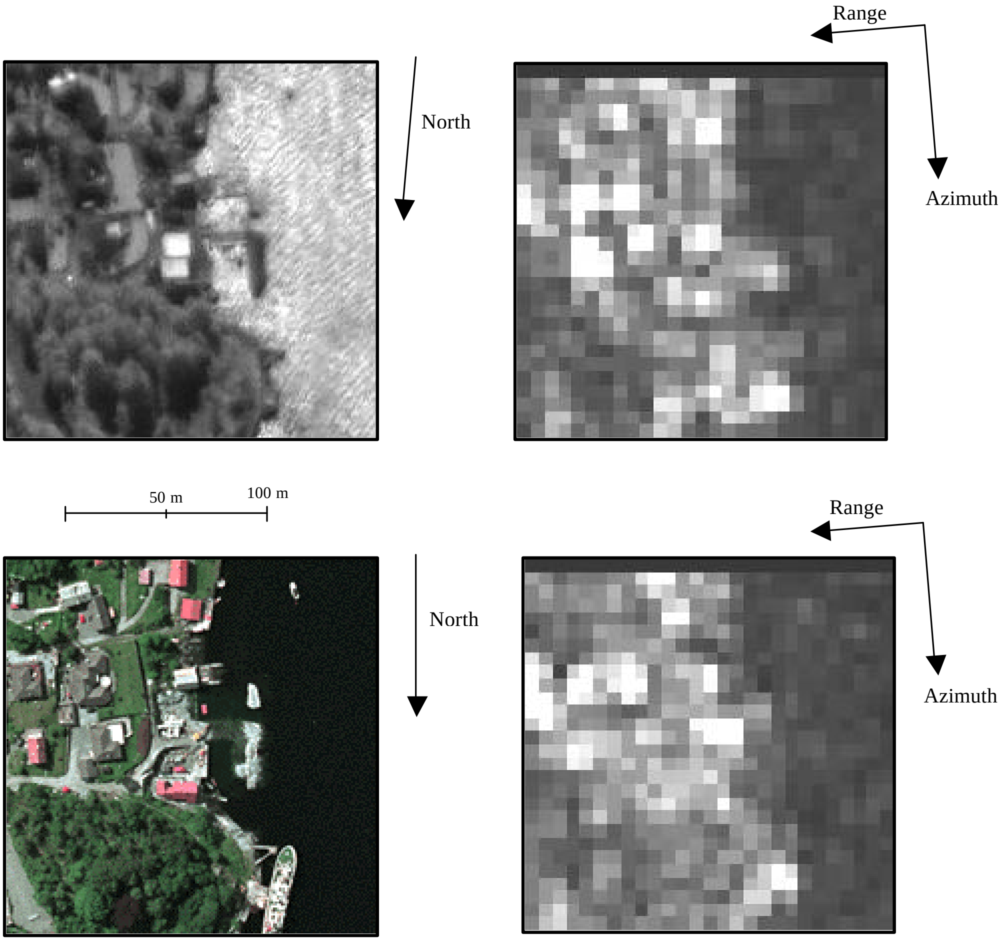

Figure 5.4 *Wharf at Kvernavika, west coast. IKONOS (up left), RADARSAT from 7th October 1998 (up right), aerial photo (low left), and RADARSAT from 31st October 1998 (low right).*

5.3 Car park detection

Figure 5.5 shows a car park located next to the airport. The intrinsic geometry of a set of cars is particularly interesting in the study of the backscattered intensity in the RADARSAT images. Multi-reflections and parking lines are advantageous to a bright radar response. As one can notice it in both scenes from 7th and 31st October 1998, the car parking structure cannot be seen because of the poor resolution of the sensor. We can only detect the backscattering change, which could be an evidence of cars being moved. This is most likely because the 7th October 1998 was on a Wednesday, while 31st October was a Saturday. In the case of the IKONOS image, we are able to discern how the car park is laid out, but also which parts have most cars.

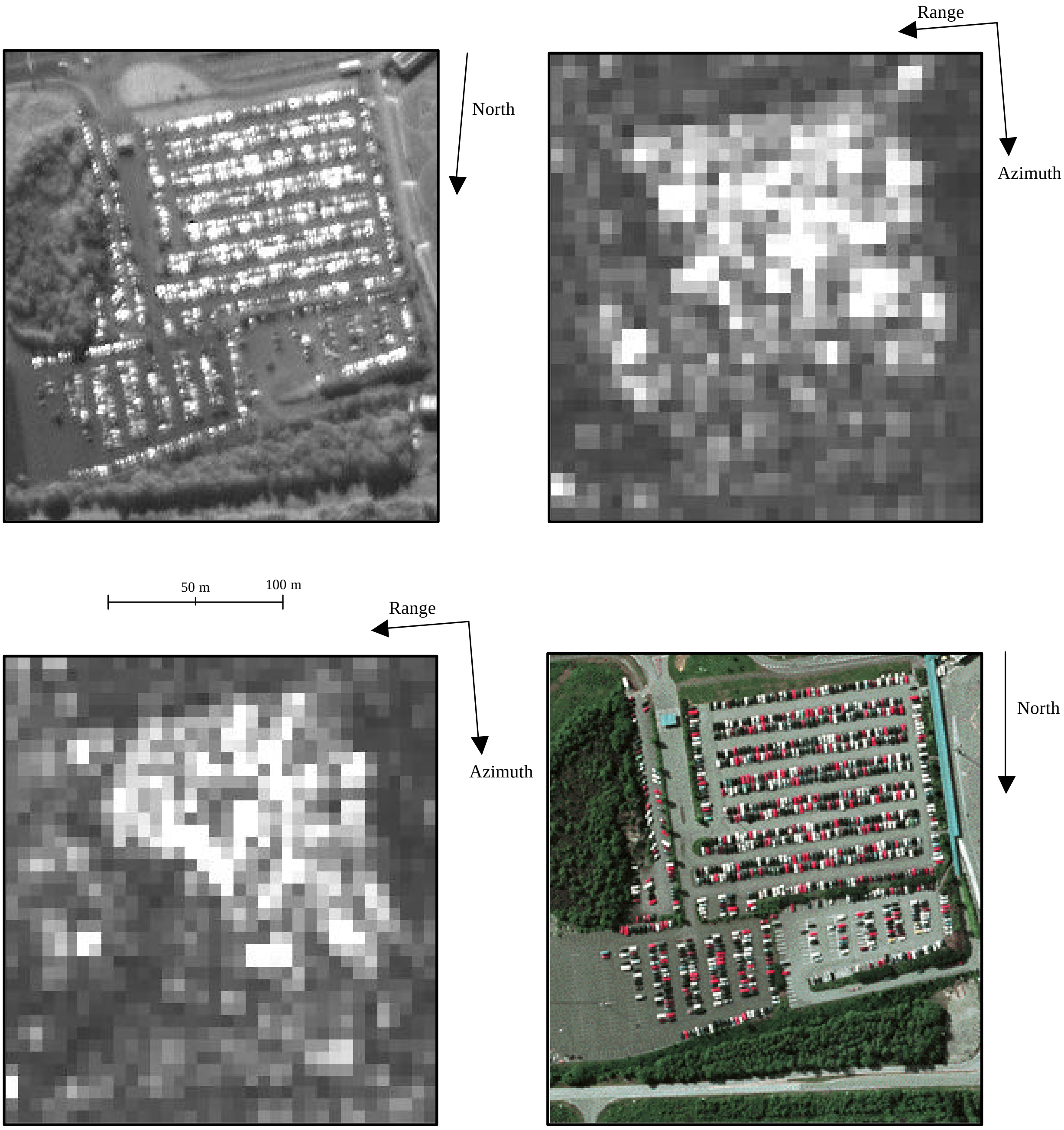

Figure 5.5 *Car park near the airport terminal. IKONOS (up left), RADARSAT from 7th October 1998 (up right),), RADARSAT from 31st October 1998 (low left), and aerial photo (low right).*

5.4 House detection in a forest area

One of the main profitable elements brought by a radar system is its capacity of seeing through certain natural features, like canopy. However, the C-band SAR system can only partially penetrate the canopy.

The test area in Bergen contains many types of natural landscapes, where forest is one of them. Figure 5.6 presents RADARSAT images acquired on 7th and 31st October 1998. A very characteristic bright point on both pictures gives us the certitude that this place is the location of a particular, man-made or natural structure. IKONOS does not bring much more information as far as this feature is concerned. We can also remark that the radar response recorded on 31st October is more important than the one recorded on 7th October. One reason for this can be evolution of the neighbouring canopy between the two dates.

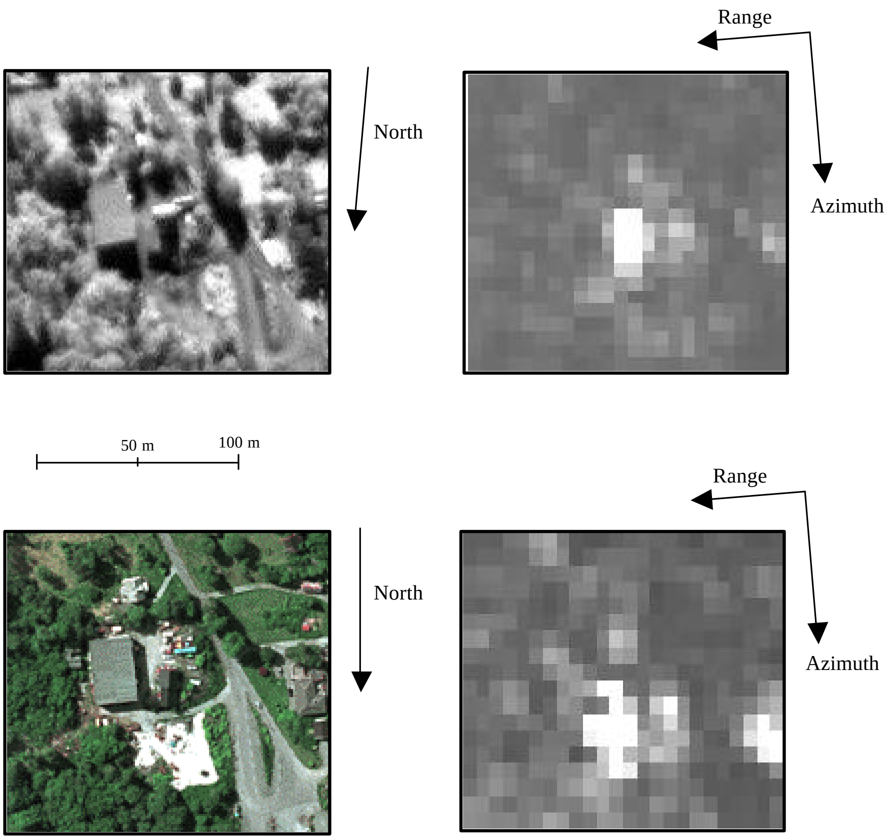

Figure 5.6 *House in the vicinity of Kvernavika, west coast. IKONOS (up left), RADARSAT from 7th October 1998 (up right), aerial photo (low left), and RADARSAT from 31st October 1998 (low right).*

The buildings present in the area shown in figures 5.6, 5.7, and 5.8 are not always easily detected in the IKONOS image. The RADARSAT images gave a well-defined strong backscatter from some places. With the help of the aerial photo and studying in a more accurate way the IKONOS image, we can refer the bright backscattered signatures (radar) to specific houses or structures in the IKONOS image. This shows that RADARSAT is able to give some additional information although not all buildings were detected.

Figure 5.7 and 5.8 are particularly interesting since one cannot suppose the presence of buildings or houses according to visual inspection of the IKONOS image.

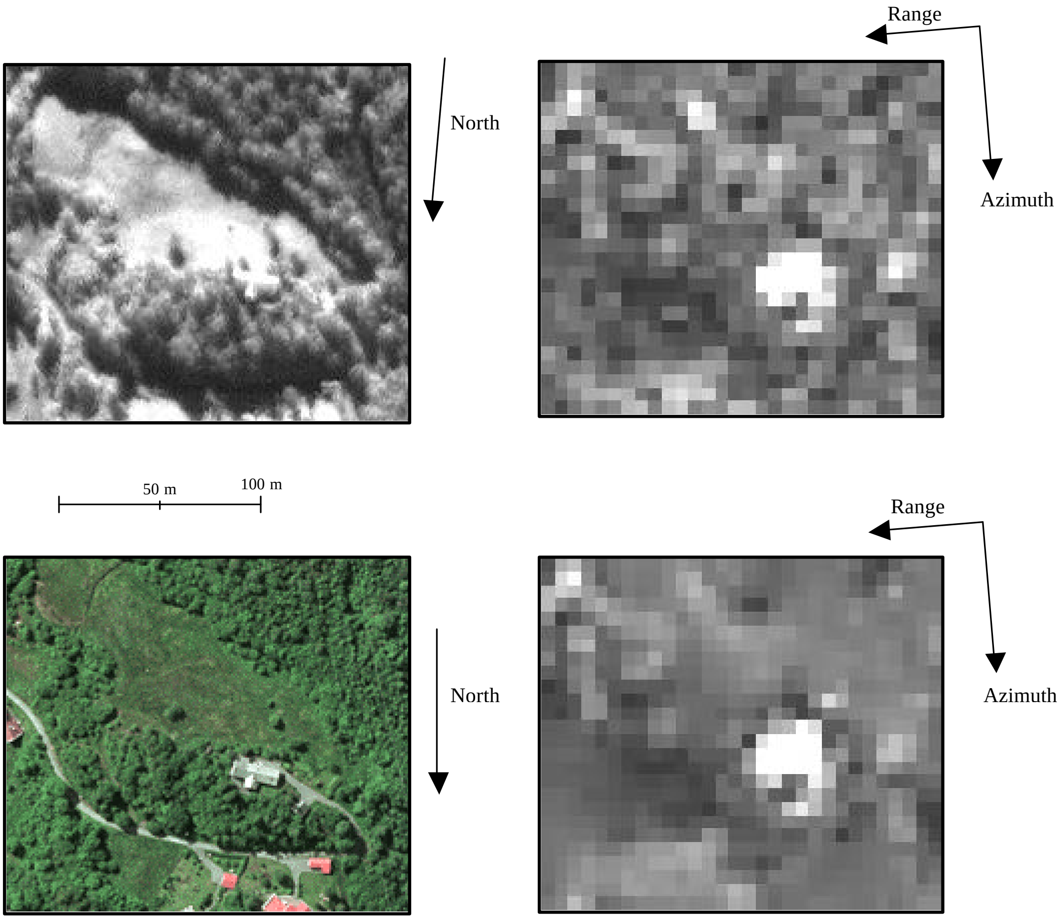

Figure 5.7 *House near Dolvik. IKONOS (up left), RADARSAT from 7th October 1998 (up right), aerial photo (low left), and RADARSAT from 7th October 1998 (low right) smoothed with a speckle filter.*

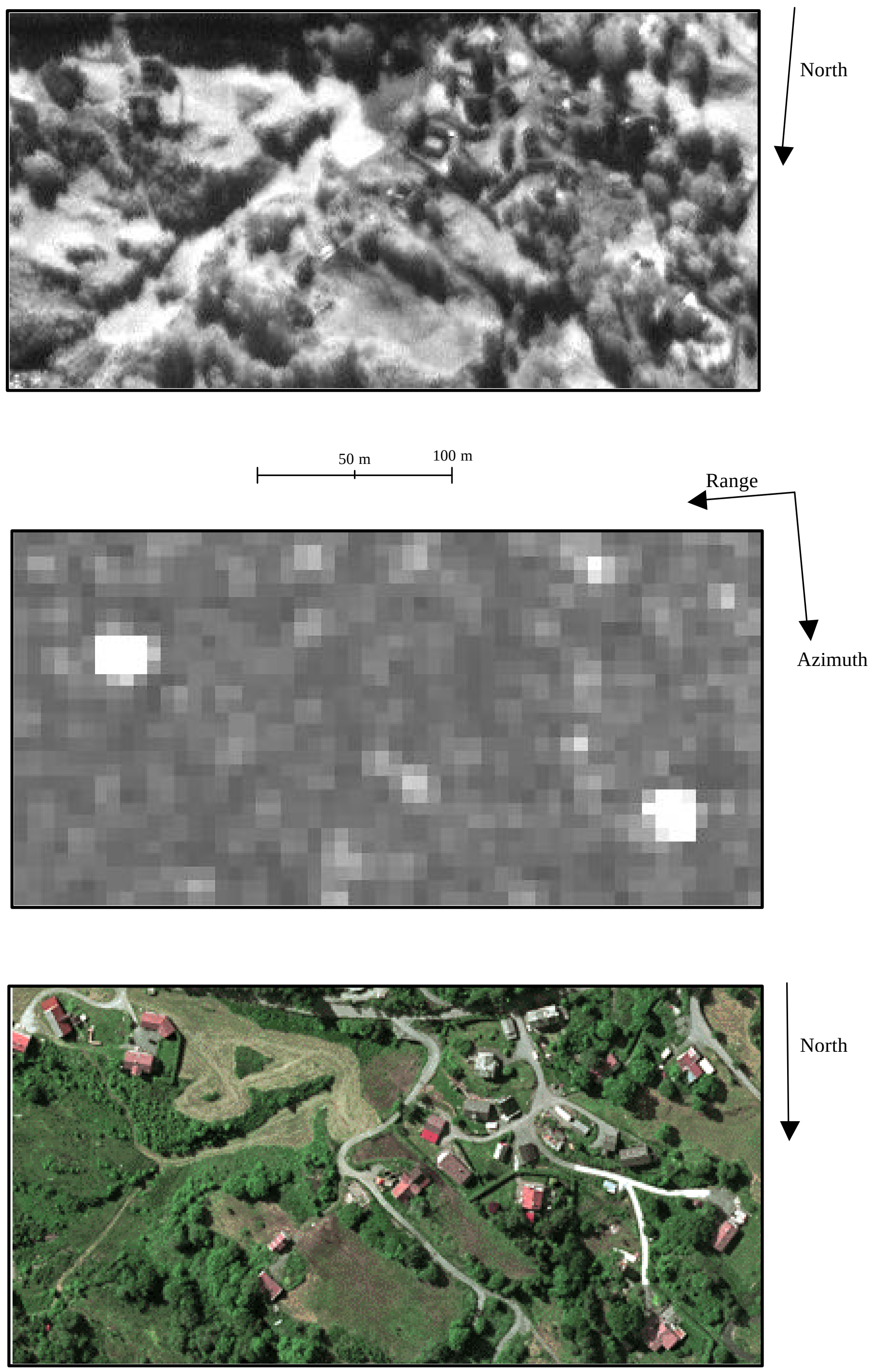

Figure 5.8 *Strong SAR backscatter from two different houses, Grimstad. IKONOS (up), RADARSAT from 7^{th} October (middle), and aerial photo (low).*

5.5 Buildings and urban areas

The IKONOS image presented in figure 5.9 does not allow detecting precise elements. However, the aerial photo clearly shows some buildings or greenhouses.

Observing the RADARSAT image from 31st October 1998, one points out very relevant linear structures, which are in relation with long buildings seen in the aerial photo. Three of them are particularly well represented in the SAR image with a bright backscattering.

The northernmost white building in the aerial photo seems not to give an important radar echo, which is not the case with other buildings oriented in the same direction. Parts of the low backscatter area must be the parking zone.

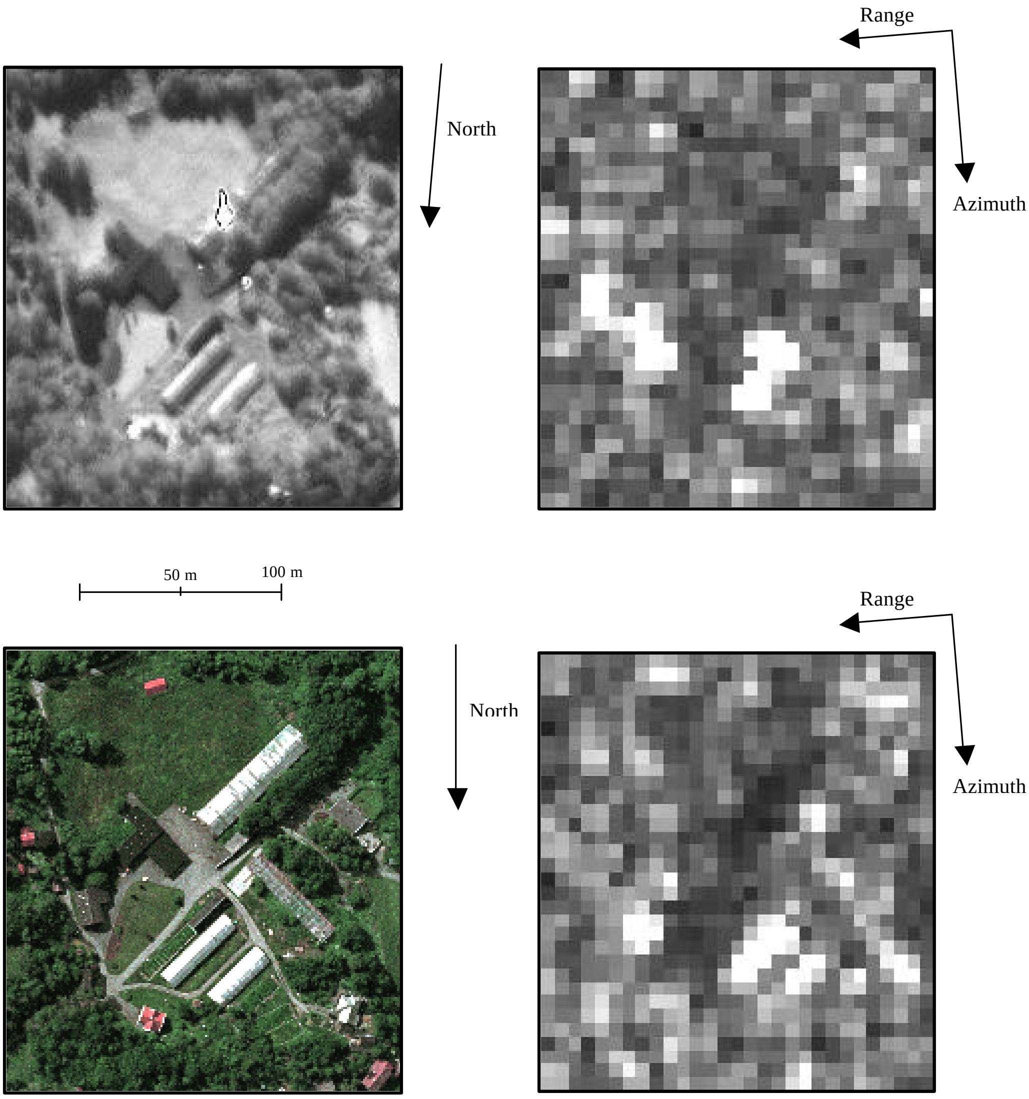

Figure 5.9 Buildings and greenhouses at Storhaugen. IKONOS (up left), RADARSAT from 7th October 1998 (up right), aerial photo (low left), and RADARSAT from 31st October 1998 (low right).

Figure 5.10 has been acquired by IKONOS over an urban area. The most interesting feature over against figure 5.11 is the large centred building. It has a characteristic radar signature, namely a black roof surrounded by a bright rectangle. The latter could be a description of the upper structure of the roof: it may describe the presence of elevated edges all around the roof, but it may also be the response from smaller man-made objects all around the building.

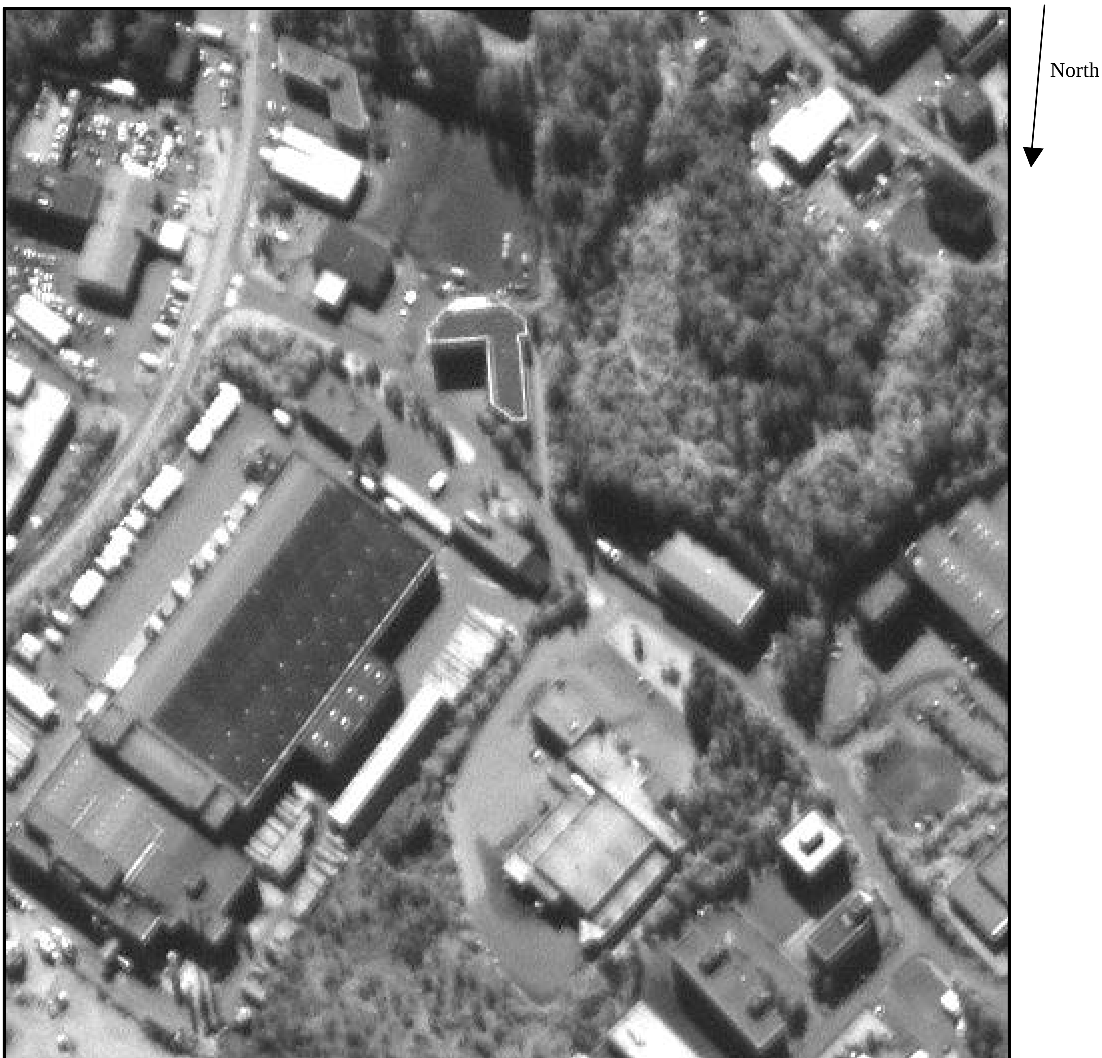

Figure 5.10 Urban area at Bjørnåsen, IKONOS.

Many bright points in the right part of figure 5.11 do not represent the real structure of buildings seen on the IKONOS image or in the aerial photo (figure 5.12). Only parts of the building structure are detected, and this radar echo is not easily connected to a cardinal direction effect when referring to the range-azimuth directions in the image. We will also notice that certain buildings give a low SAR backscatter, as also is seen in figure 5.14.

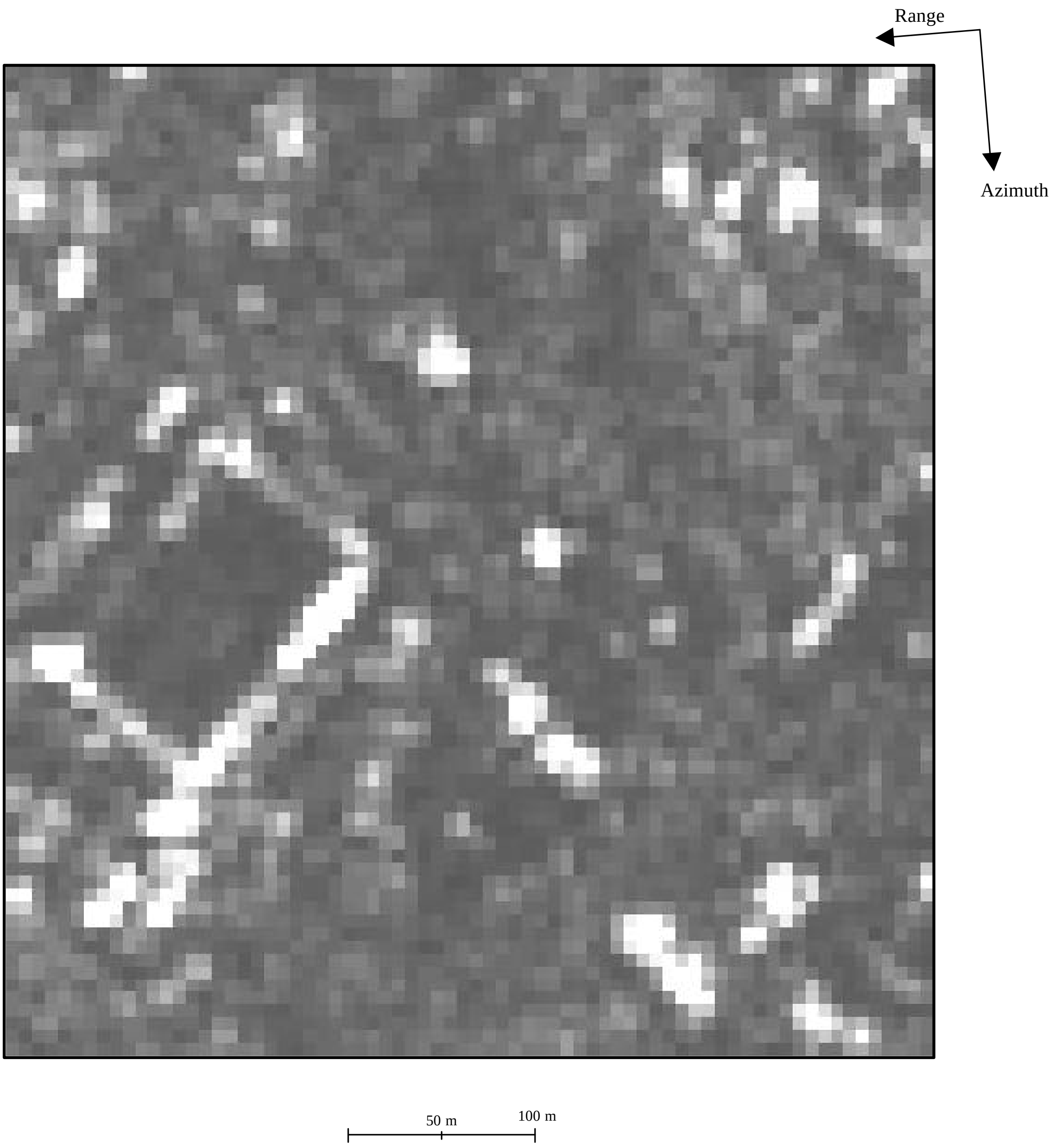

Figure 5.11 Urban area at Bjørnåsen. RADARSAT image from 7th October 1998.

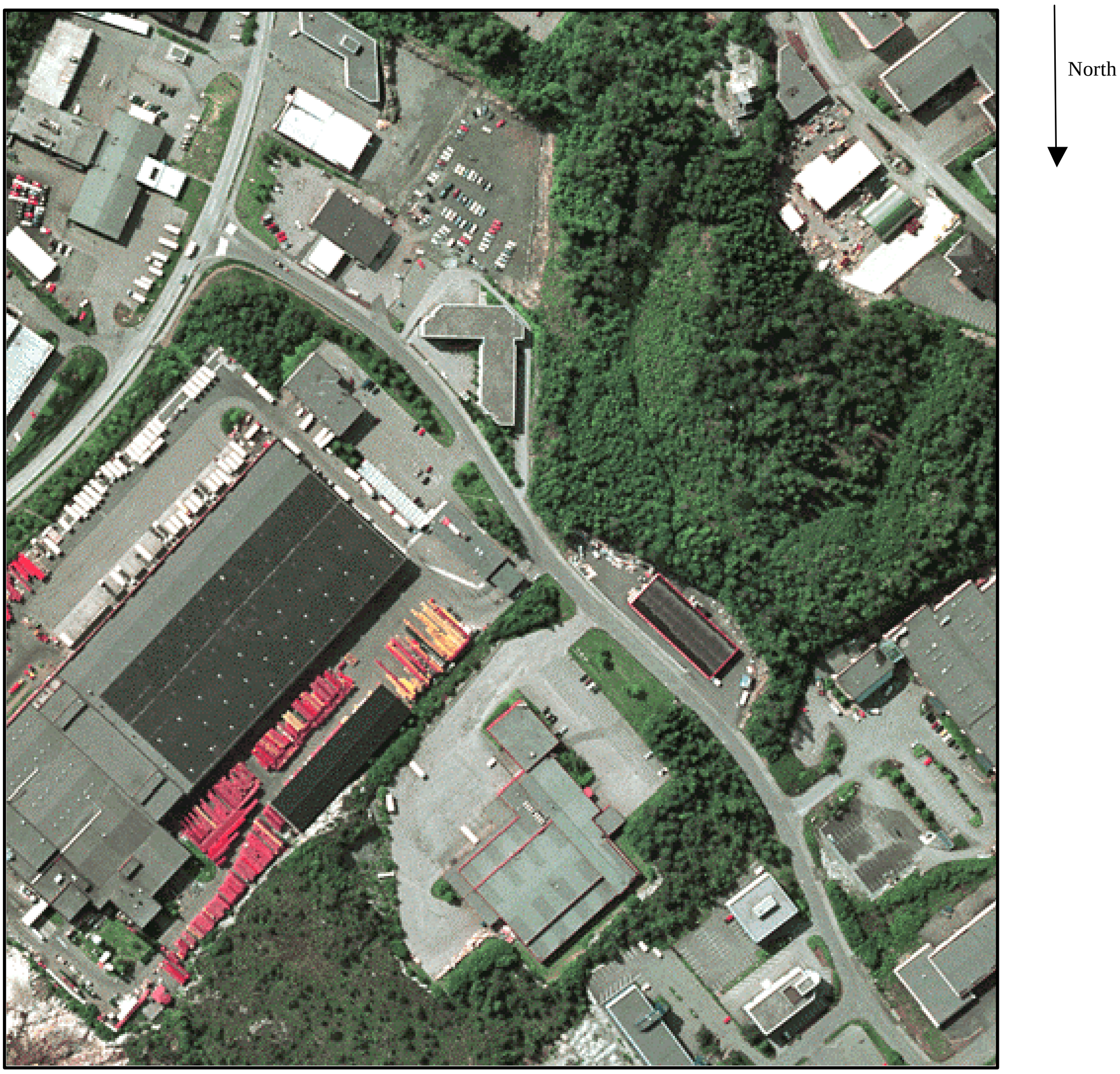

Figure 5.12 Urban area at Bjørnåsen. Aerial photography.

Figure 5.13 is interesting because it shows how it is possible to make a misinterpretation by looking at a RADARSAT image. The ones presented here show a rough L structure with regards to the upper left building. Having a look at the IKONOS and the aerial photo, it happens that it was only one single building, edged by cars, trees, and containers.

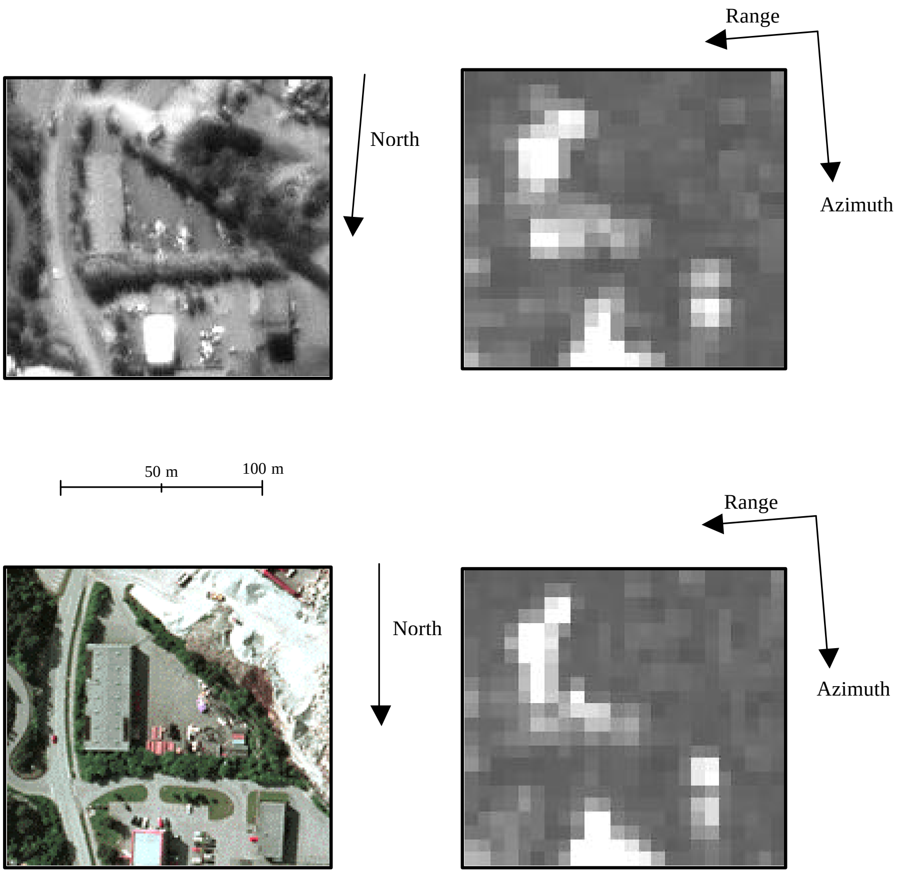

Figure 5.13 Building at Birkelandsskjenet. IKONOS (up left), RADARSAT from 7th October 1998 (up right), aerial photo (low left), and RADARSAT from 31st October 1998 (low right).

Figure 5.14 shows two RADARSAT images acquired 7th and 31st October 1998. The large building seen in the IKONOS image has a very low SAR backscatter. This may indicate a fairly flat roof structure, and/or a roof with few complex metal objects or corners.

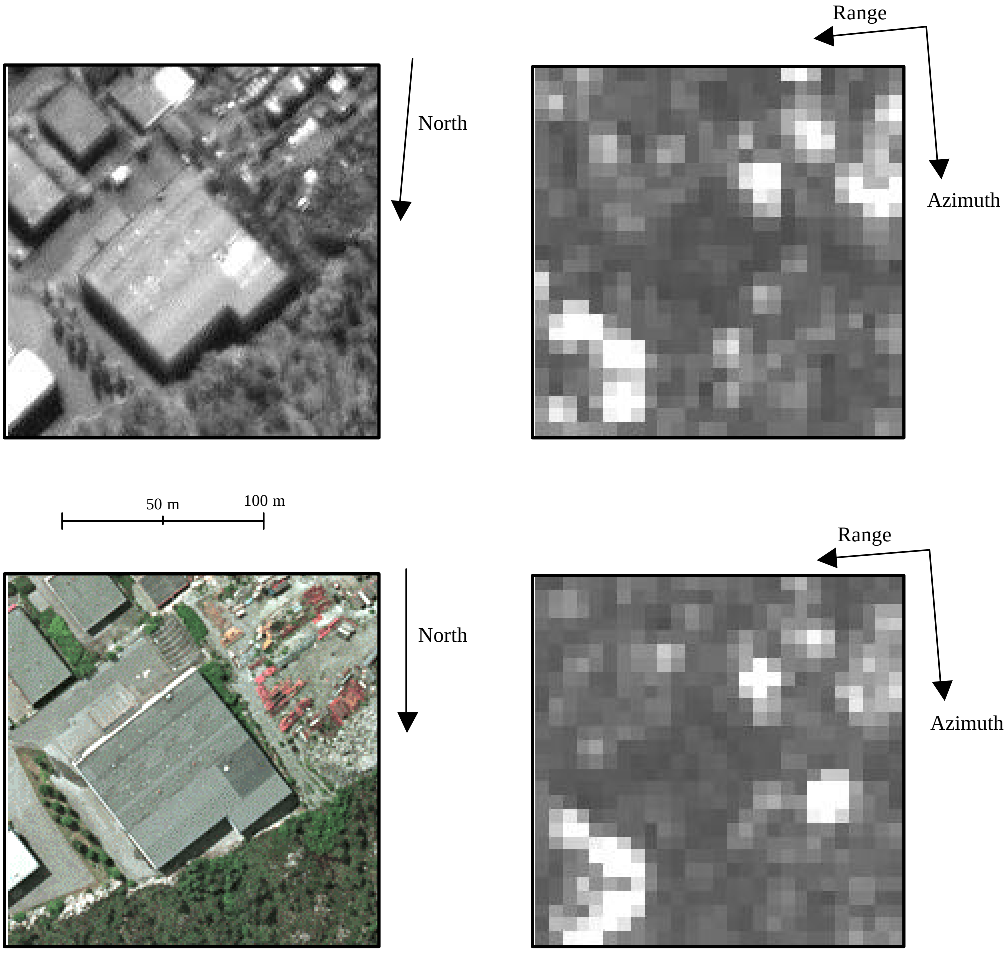

Figure 5.14 Building at Rundehaugen. IKONOS (up left), RADARSAT from 7th October 1998 (up right), aerial photo (low left), and RADARSAT from 31st October 1998 (low right).

5.6 Buoy detection

RADARSAT can also allow detecting small features that do not have a powerful signature in the optical domain, but a bright backscatter in the radar domain. Figure 5.15 illustrates this case with buoy detection near Saltvikneset.

The bright point in the middle of the RADARSAT image recorded twice at two different dates, might be an evidence of the presence of a buoy. There is no evidence of a buoy in the IKONOS image.

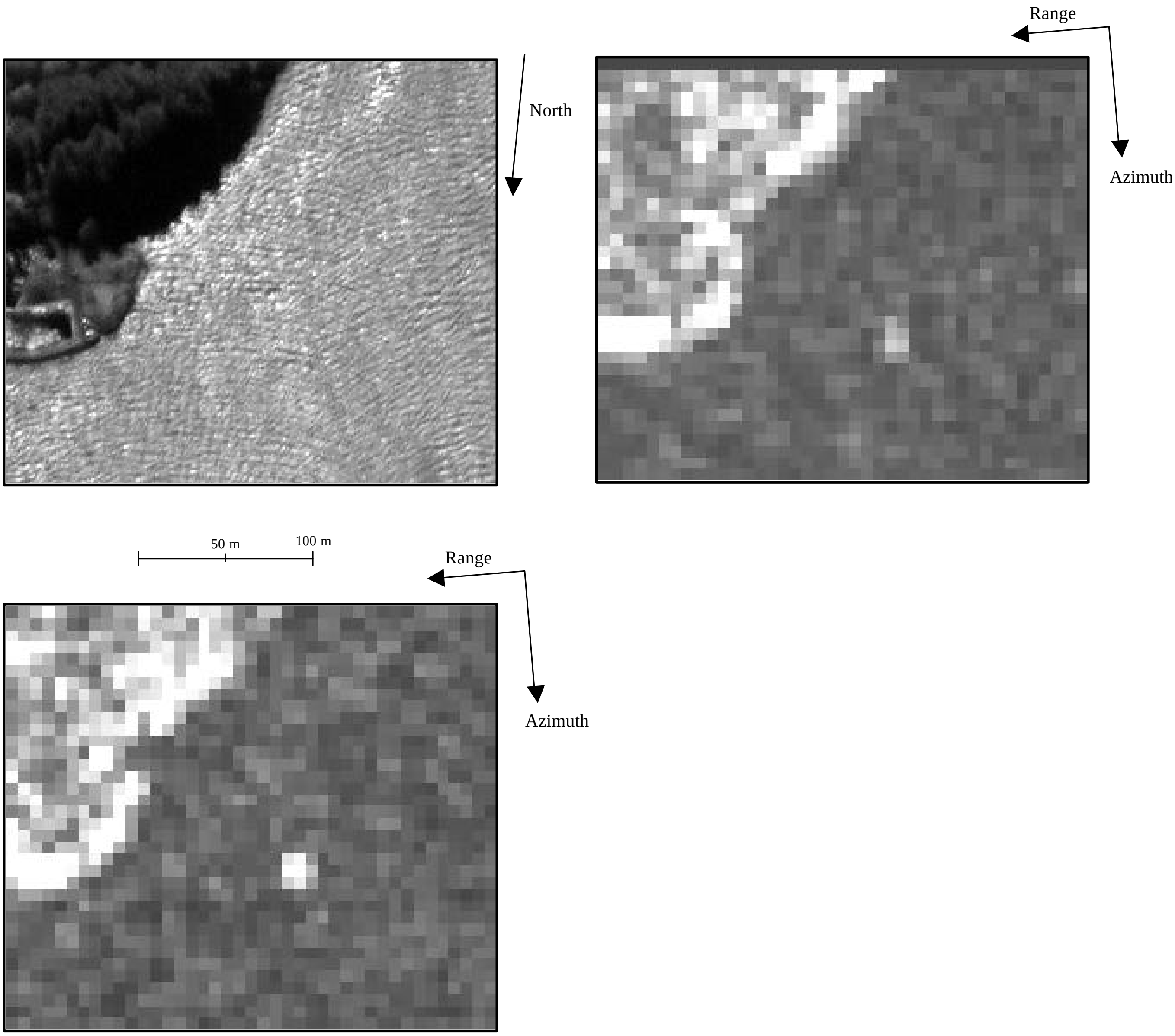

Figure 5.15 Buoy west Saltvikneset. IKONOS (up left), RADARSAT from 7th October 1998 (up right) and RADARSAT from 31st October 1998 (low left).

5.7 Harbours

Figure 5.16 is the IKONOS view over a harbour at Dolvika bay. Many features can be resolved in the high-resolution satellite image. One can, for example, easily distinguish between the floating stages and the boats themselves.

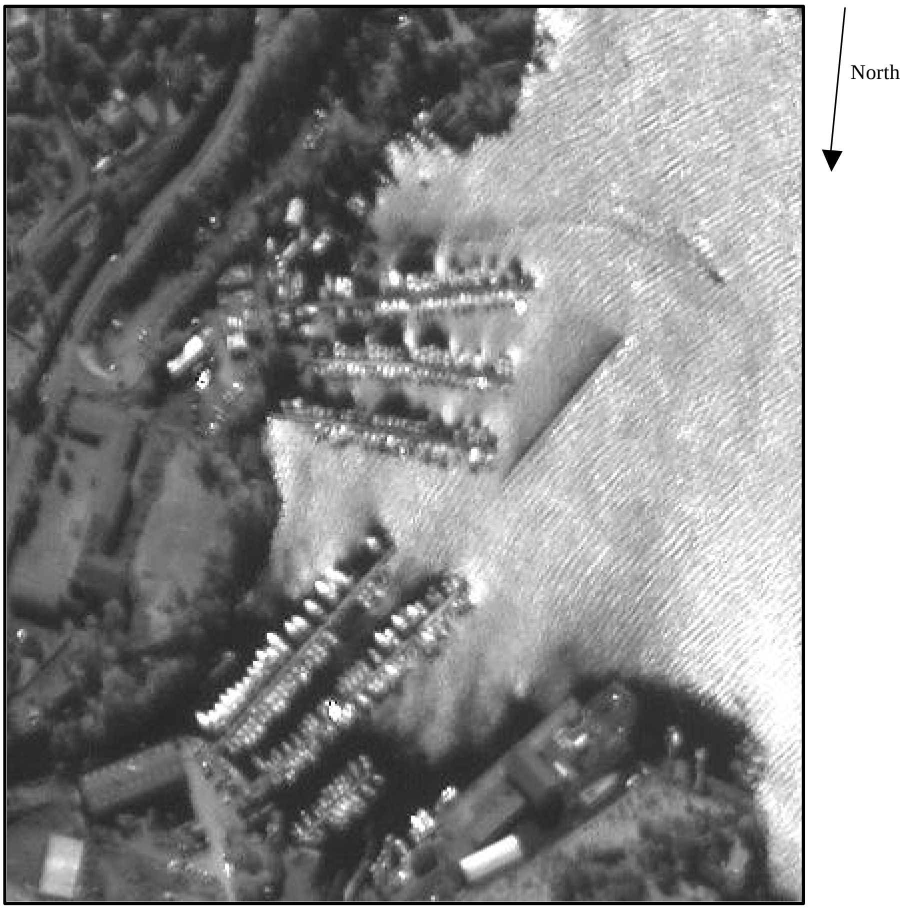

Figure 5.16 Harbour at Dolvika bay. IKONOS.

Figure 5.17 is the same harbour as the above-mentioned. The RADARSAT 9-m resolution image does not allow us to catch the fine structure of the harbour. Without other sources of information, the interpretation will be very limited.

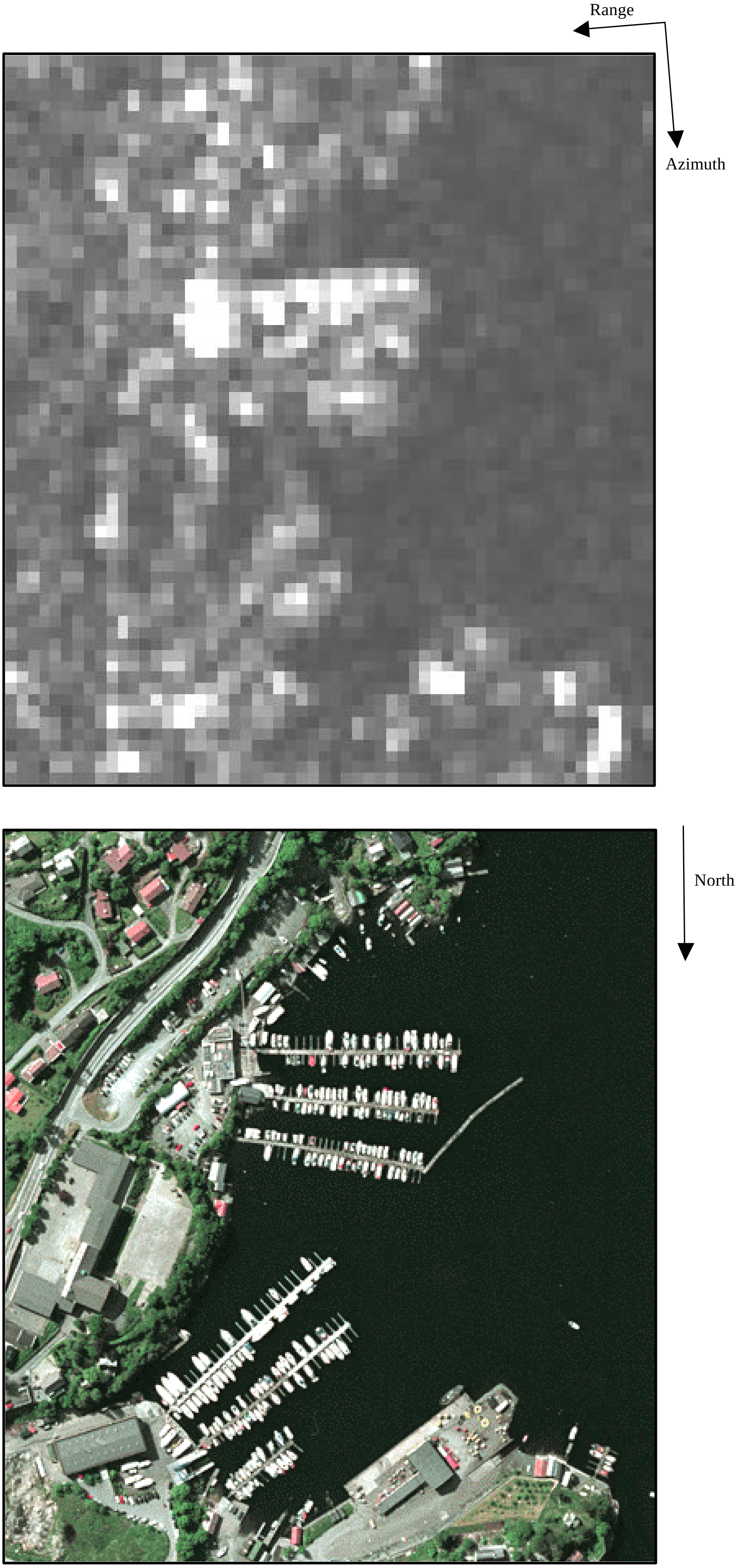

Figure 5.17 Harbour at Dolvika bay. RADARSAT image from 7th October 1998 (top) and aerial photography (low).

Both images presented hereafter in figure 5.18 are another example of harbour detection, but in this case, one is clearly able to distinguish the four floating stages not only on the IKONOS image but also on the RADARSAT image. We can indeed remark that floating stages are more spaced in figure 5.18 than in figure 5.17 for instant.

In many cases, it is possible to distinguish between boats in the IKONOS image, but this is not the case with RADARSAT. However, the large pier structure can be detected by means of the RADARSAT image.

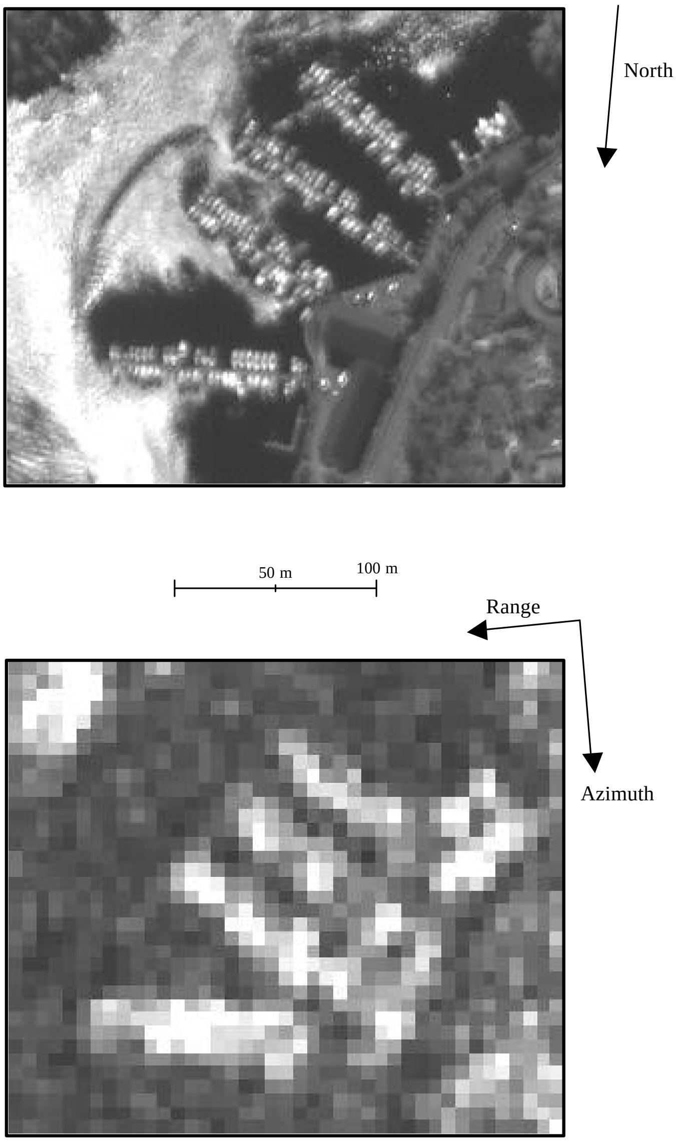

Figure 5.18 Harbour in IKONOS (up) and RADARSAT from 7th October 1998 (low).

5.8 Bridge detection

Figure 5.19 presents a bridge recorded with the IKONOS and RADARSAT sensors. The bright response in the RADARSAT image may be a consequence of multi-reflections onto the sea and bridge, but also due to corner and metal structures on the bridge itself. The strong SAR response is fairly stable over time.

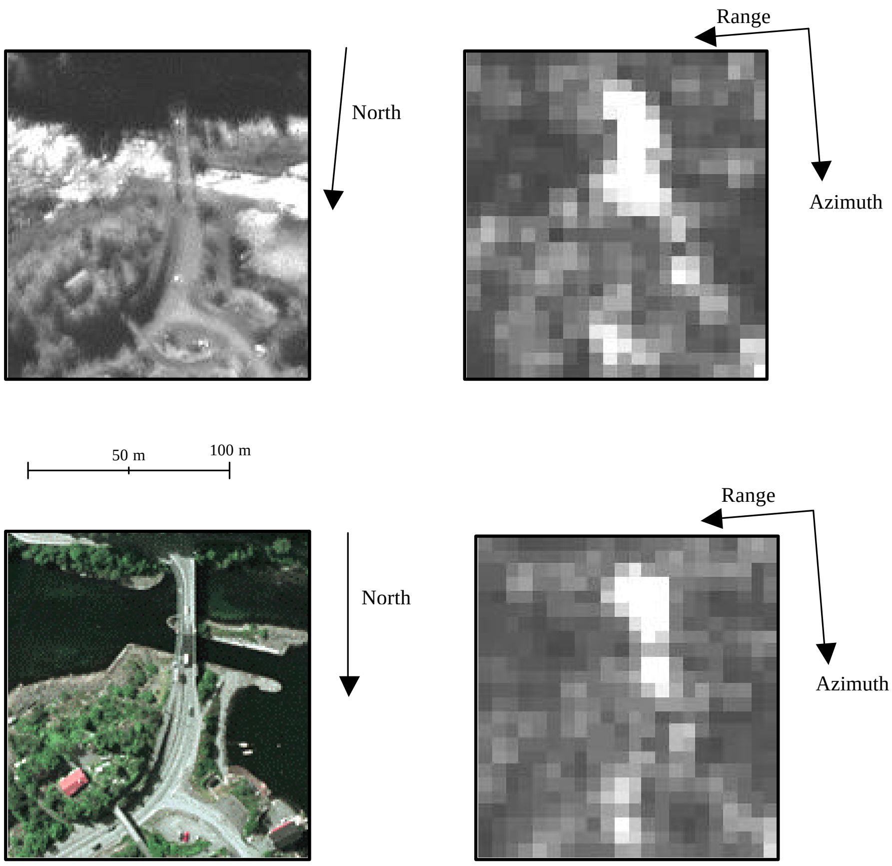

Figure 5.19 Bridge at Ruskeneset. IKONOS (up left), RADARSAT from 7th October 1998 (up right), aerial photo (low left), and RADARSAT from 31st October 1998 (low right).

5.9 Electrical power lines

Figure 5.20 lets us see three straight lines related to electrical power line wires from the evidence of the aerial photography. What is seen here are not directly the electrical wires stretched between their masts (the wire diameter is from far smaller than the IKONOS and the aerial photo resolution, even if several ones are matched together), but the contrast between the bright background in IKONOS, and the dark optical response of the wires.

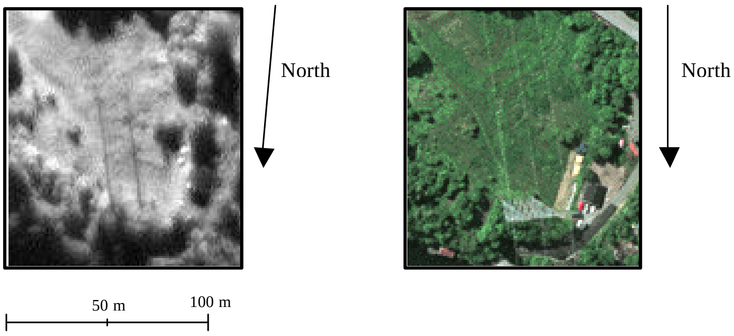

Figure 5.20 Electrical power line near Knappen. IKONOS (left) and aerial photography (right).

Figure 5.21 is the following part of the same electrical power line presented in figure 5.20 located on the opposite side of the fjord, Knappasundet. The same phenomenon is observable.

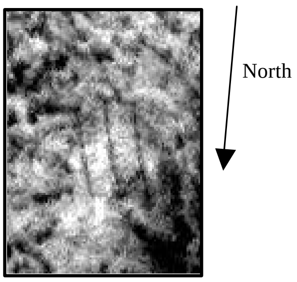

Figure 5.21 Same electrical power line at Hammarsland, IKONOS.

Figure 5.22 is still the same electrical power line over the Knappasundet strait, but one can notice from now on, the particularly impressive radar response seen in the RADARSAT images from 7th and 31st October 1998. This response has nothing to do with the contrast as it is explained previously, since we are no longer in the optical domain. We notice that the wires are located in the "cardinal" direction. Multi-reflections onto an elevated object, which is located above a watered area, can provide a significant response and change the ground geometry by shifting the elevated feature in the radar direction. The reflection may also come from the presence of "balls" slid onto the wires to prevent aircraft collision. The bright longitudinal SAR response in the top right of figure 5.22 makes it less likely to interpret this response as backscatter from a ship. Wind conditions may lead to different SAR response from the wire-ocean interaction.

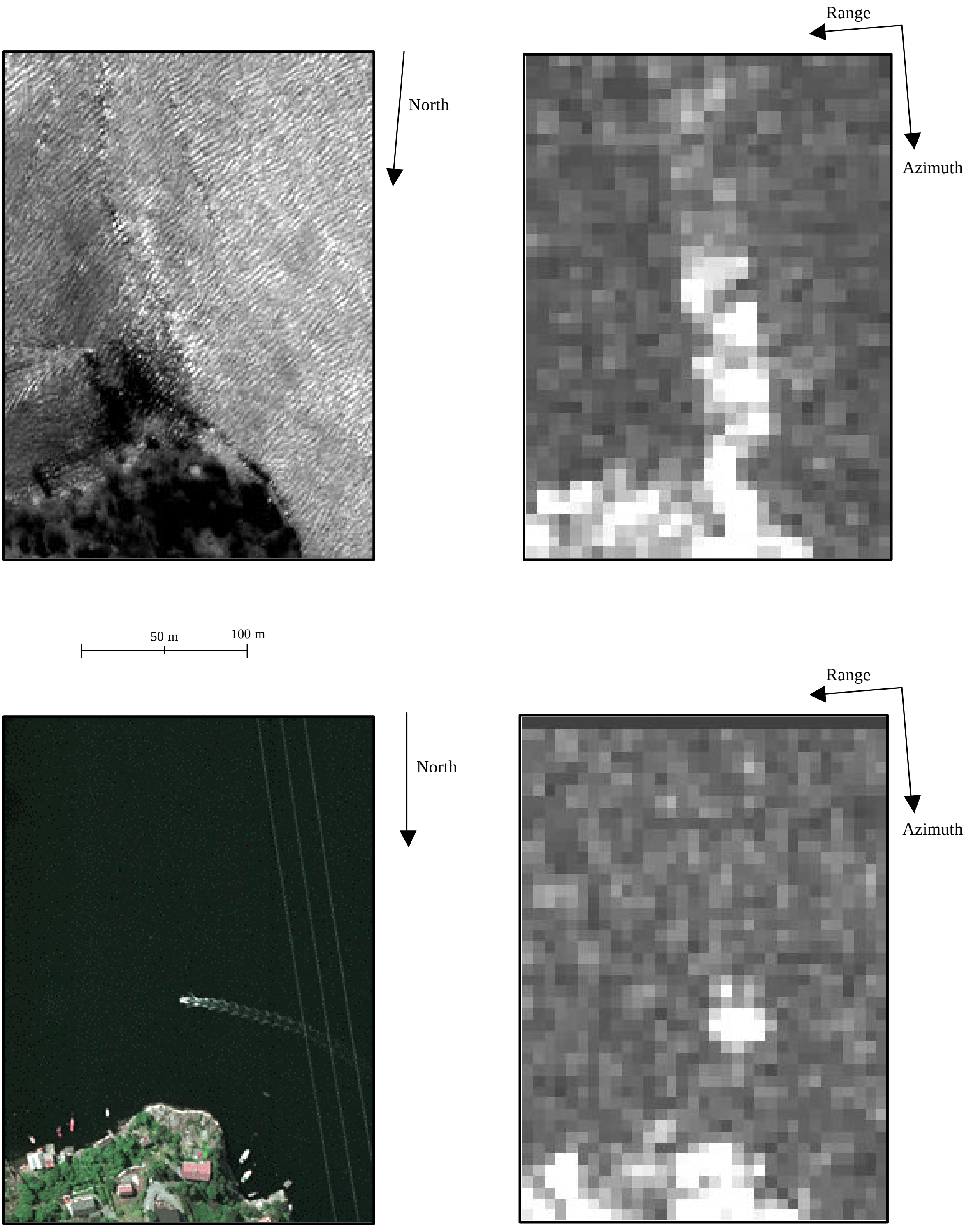

Figure 5.22 Electrical power line near Knappen. IKONOS (up left), RADARSAT from 7th October 1998 (up right), aerial photo (low left), and RADARSAT from 31st October 1998 (low right).

5.10 Oil tanks detection

Figure 5.23 shows that many details from the oil tank area can be detected in the IKONOS image. In the two RADARSAT images shown in figure 5.24, one can notice some bright points that fit with the position of tanks. Tanks or cylinders will often appear as isotropic scattering objects, so oil tanks will very likely give a strong backscatter in SAR images. The very bright response in the up right part of the RADARSAT image could be attributed to the cardinal effect on the building roof

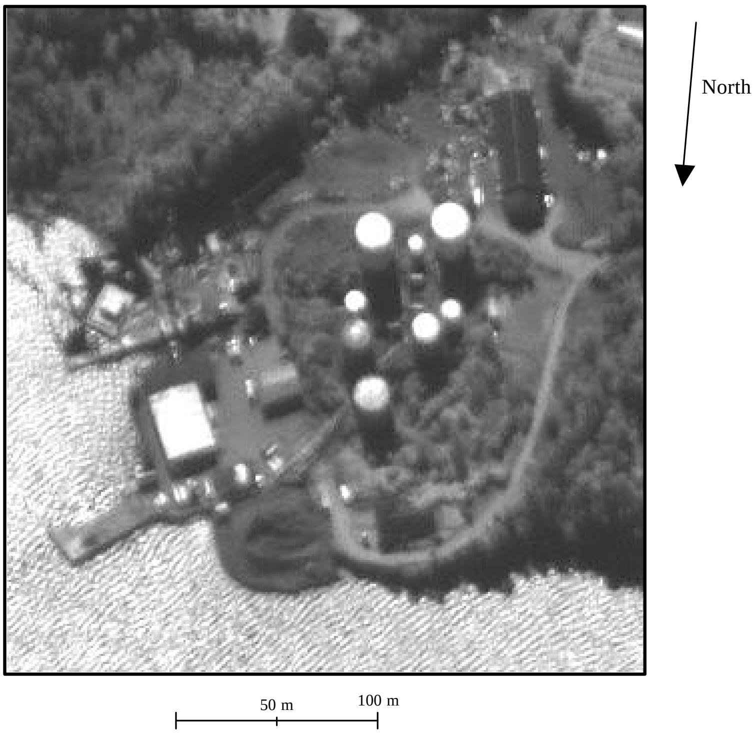

Figure 5.23 IKONOS image of industrial tanks at Stamsneset

The circular geometry of the tanks is totally lost in the RADARSAT images due to the poor 9-m resolution.

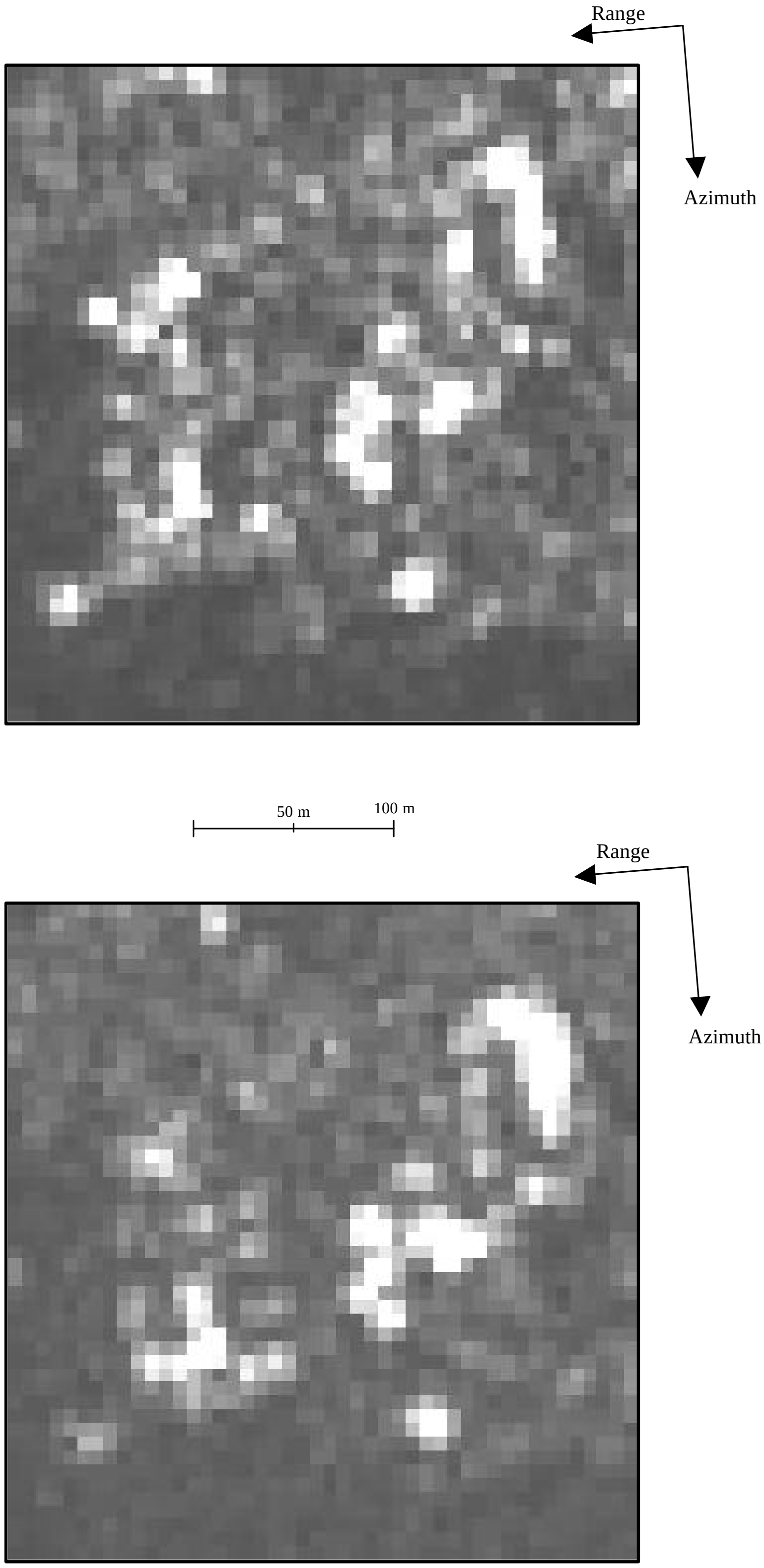

Figure 5.24 Industrial tanks at Stamsneset. RADARSAT from 7th October 1998 (up) and RADARSAT from 31st October 1998 (low).

5.11 Complex shaped buildings

In this part, we will talk about the detection of complex shaped buildings, which is an interesting application of radar imagery.

Figure 5.25 depicts the IKONOS image of an area of complex shaped buildings. Comparing it with figure 5.27, the aerial photography over the same area, one can easily notice that the finest geometry is kept and many details are present. There is a significant difference between the optical signatures of trees and grass: grass gives a strong response in the IKONOS image.

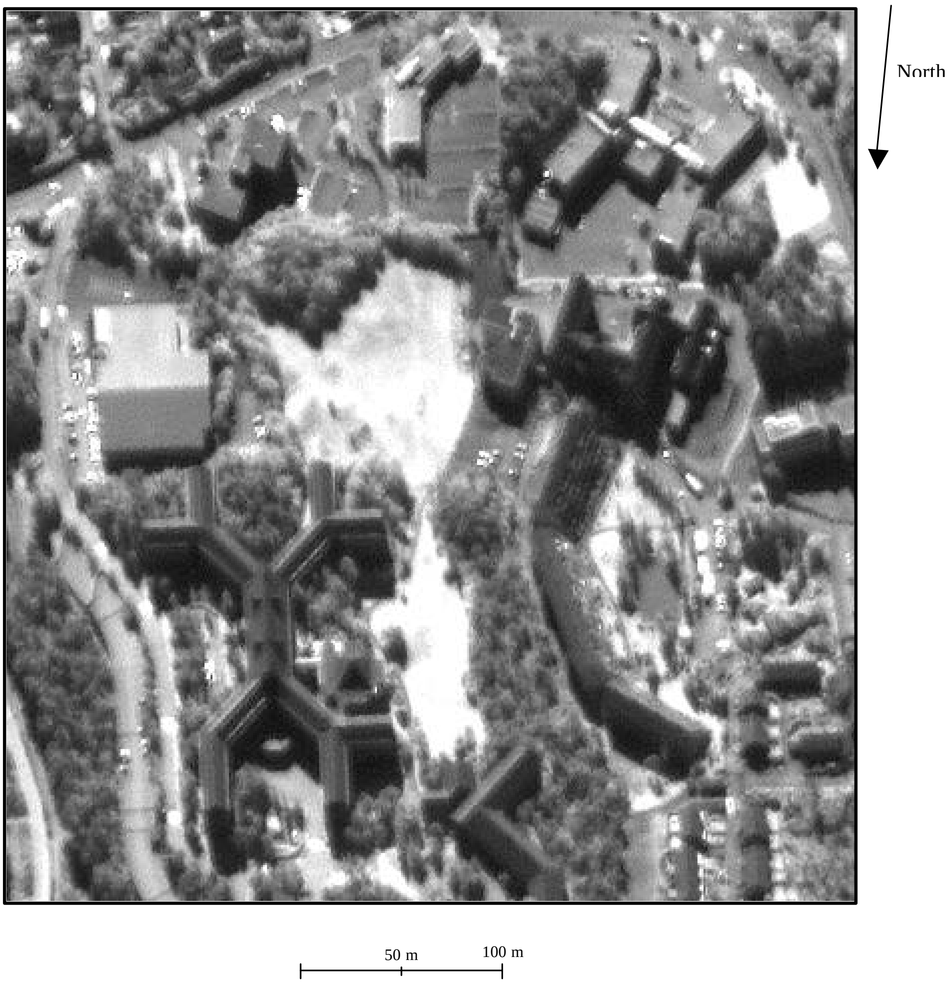

Figure 5.25 Complex shaped buildings at Sandsli Kjelandsnet. IKONOS

Whereas the IKONOS image keeps a very good resolution and a fine level of accuracy, such is not the case with the RADARSAT image in figure 5.26.

The X-shape building in the lower left part of the picture does not provide a significant backscatter. The building structure will therefore not be detected with a fair part of confidence. However, the curved shape building in the right part of figure 5.27 has a bright radar response. Parts of this response could be attributed to the cardinal effect.

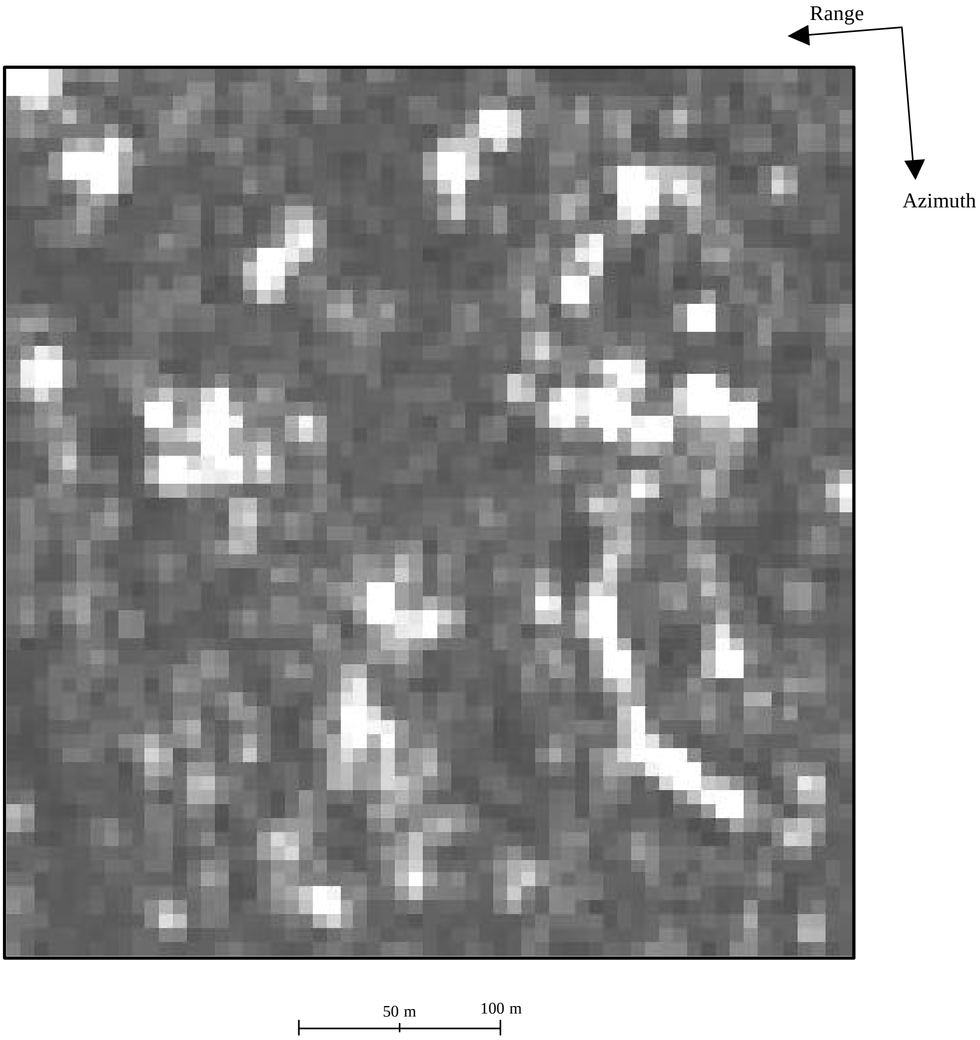

Figure 5.26 Complex shaped buildings at Sandsli Kjelandsnet. RADARSAT from 7th October 1998.

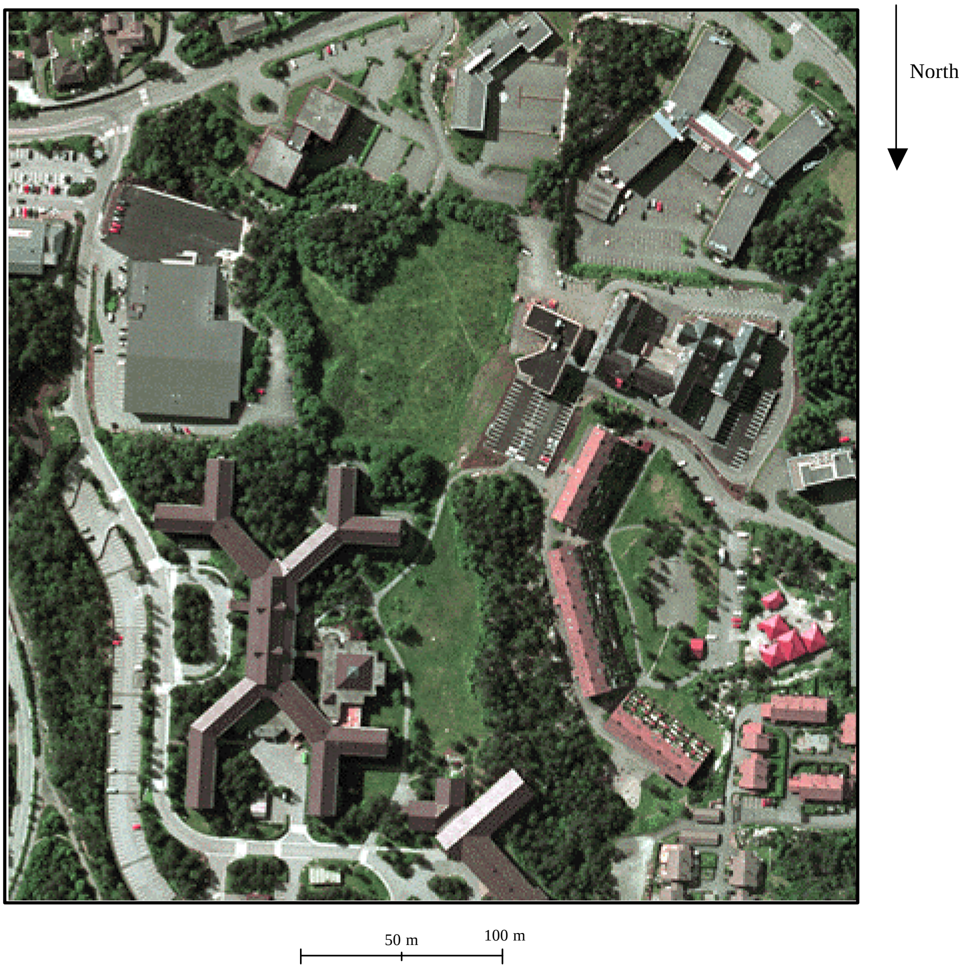

Figure 5.27 Complex shaped buildings at Sandsli Kjelandsnet. Aerial photography.

Figure 5.28 presents another complex shaped building. The RADARSAT image from 7th October provides the real double-U shape of the building, which is not so visible on IKONOS image because of the proximity of grey levels. The smoothing keeps bright information but does not improve the final resolution.

It is evident that the radar sometimes allows detecting objects in an interesting and complementary way, but that it can also become blind towards other buildings and structures.

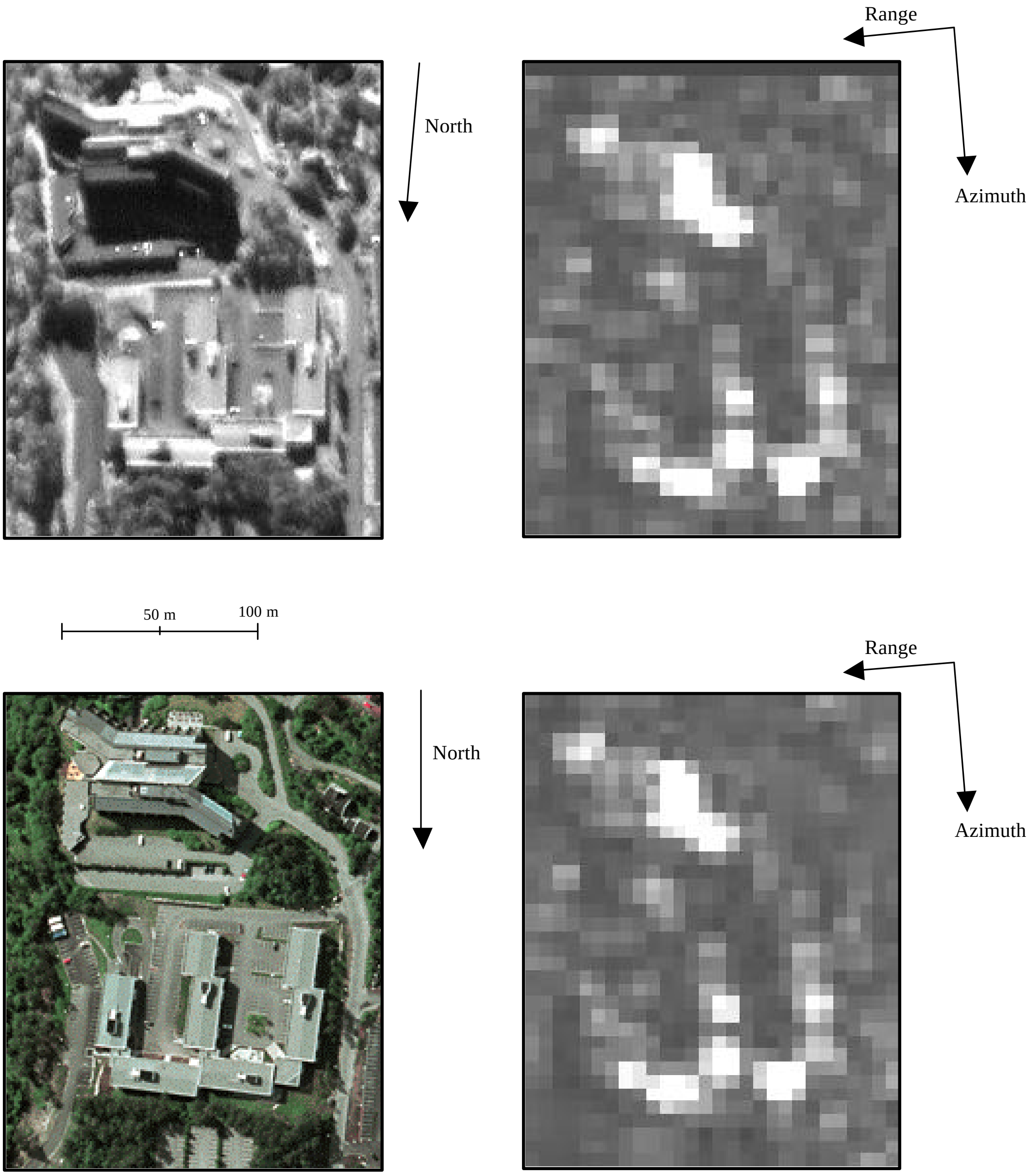

Figure 5.28 Complex shaped buildings at Sandsli Kjelandsnet. IKONOS (up left), RADARSAT from 7th October 1998 (up right), aerial photo (low left), and RADARSAT smoothed from 7th October 1998 (low right).

5.12 Road detection

A paved road is represented in figure 5.29. Figure 5.30 clearly shows three dark, linear structures in the speckle filtered SAR image. However, the image is still full of different texture variations close to,- and at the road structure. It must therefore be some other sources of backscattering like stones, pile of stones, tree trunks etc. Indeed, applying the speckle filter did not improve significantly the appearance of the road structure itself.

Figure 5.29 Roads at the northern part of Bergen airport. IKONOS image.

Figure 5.30 Roads at the northern part of Bergen airport. Speckle filtered RADARSAT image from 7th October 1998.

Figures 5.31 and 5.32 shows parts of the Bergen airport runway. The RADARSAT image has been smoothed with a speckle filter, and the homogeneous area between the runway and the taxiway seems to be almost speckling free. This allows detecting the runway in a better way.

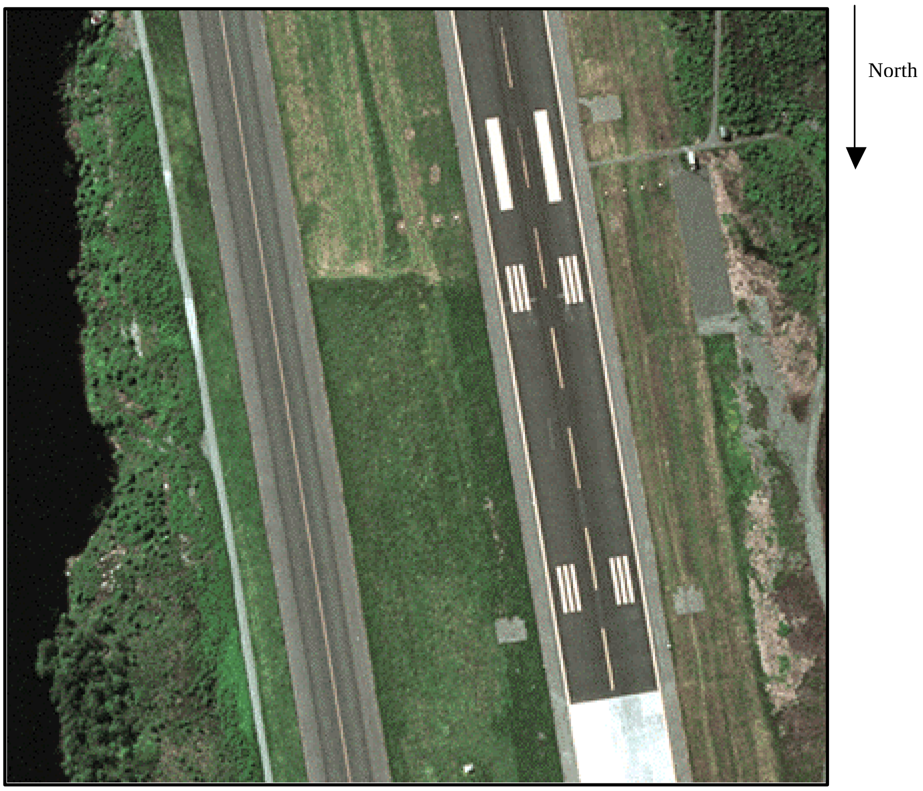

Figure 5.31 Airport Runway. Aerial photography.

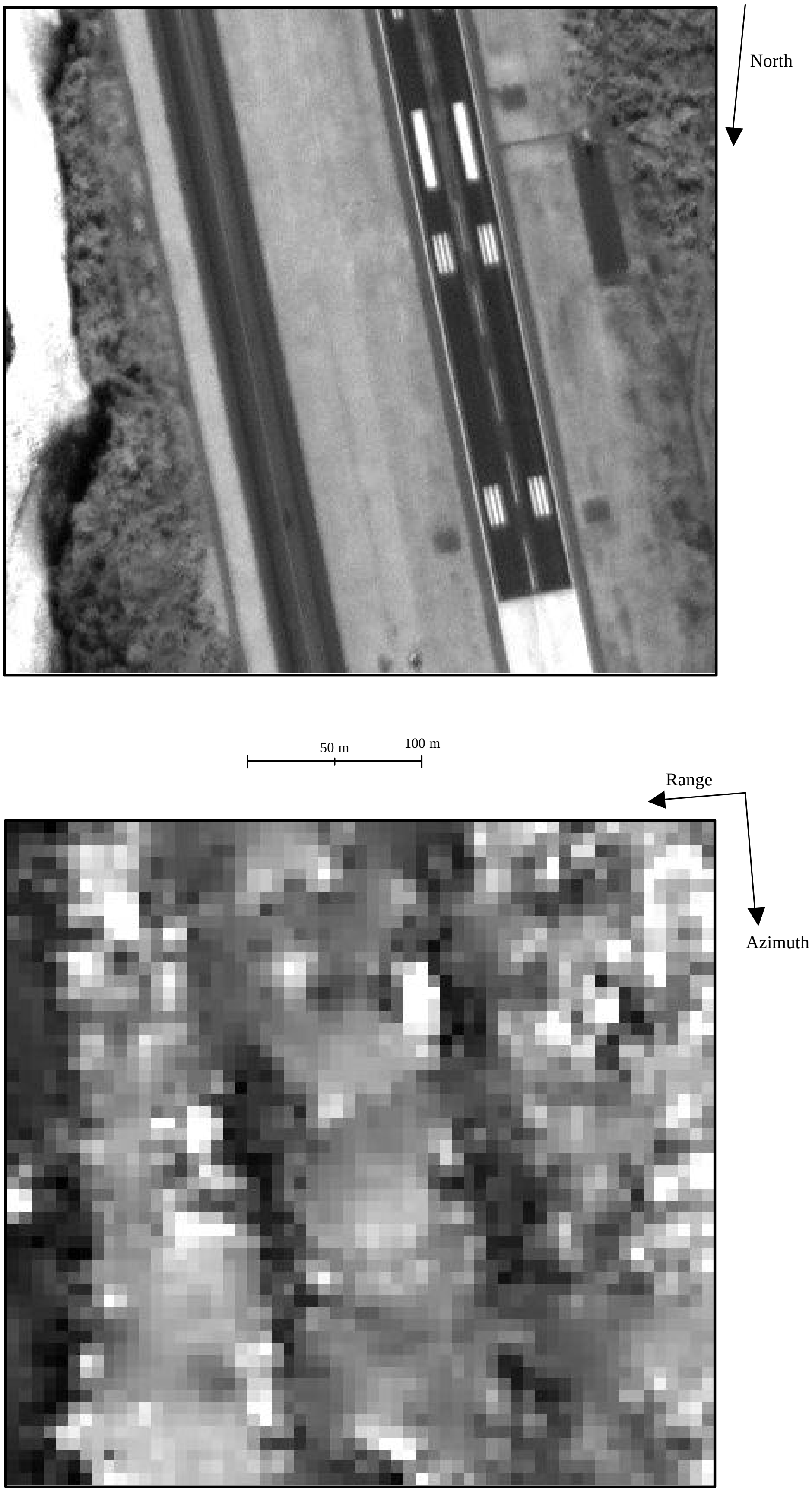

Figure 5.32 Airport's runway. IKONOS (up) and speckle filtered RADARSAT image (low) from 7th October 1998.

IKONOS allows detecting more or less compex road structures like the ones presented in figure 5.33

Figure 5.33 Road/taxiway detection at Tjukkehovden. IKONOS.

The RADARSAT image depicted in figure 5.34 shows black circles and a black curved line joining all these circles. We can count them. They represent the circular areas (aircraft parking areas) that can be seen on the IKONOS image.

The forest area is noisy and hold a lot of rough texture This reveals the presence of secondary sources of backscattering such as pile of stones, tree trunks etc.

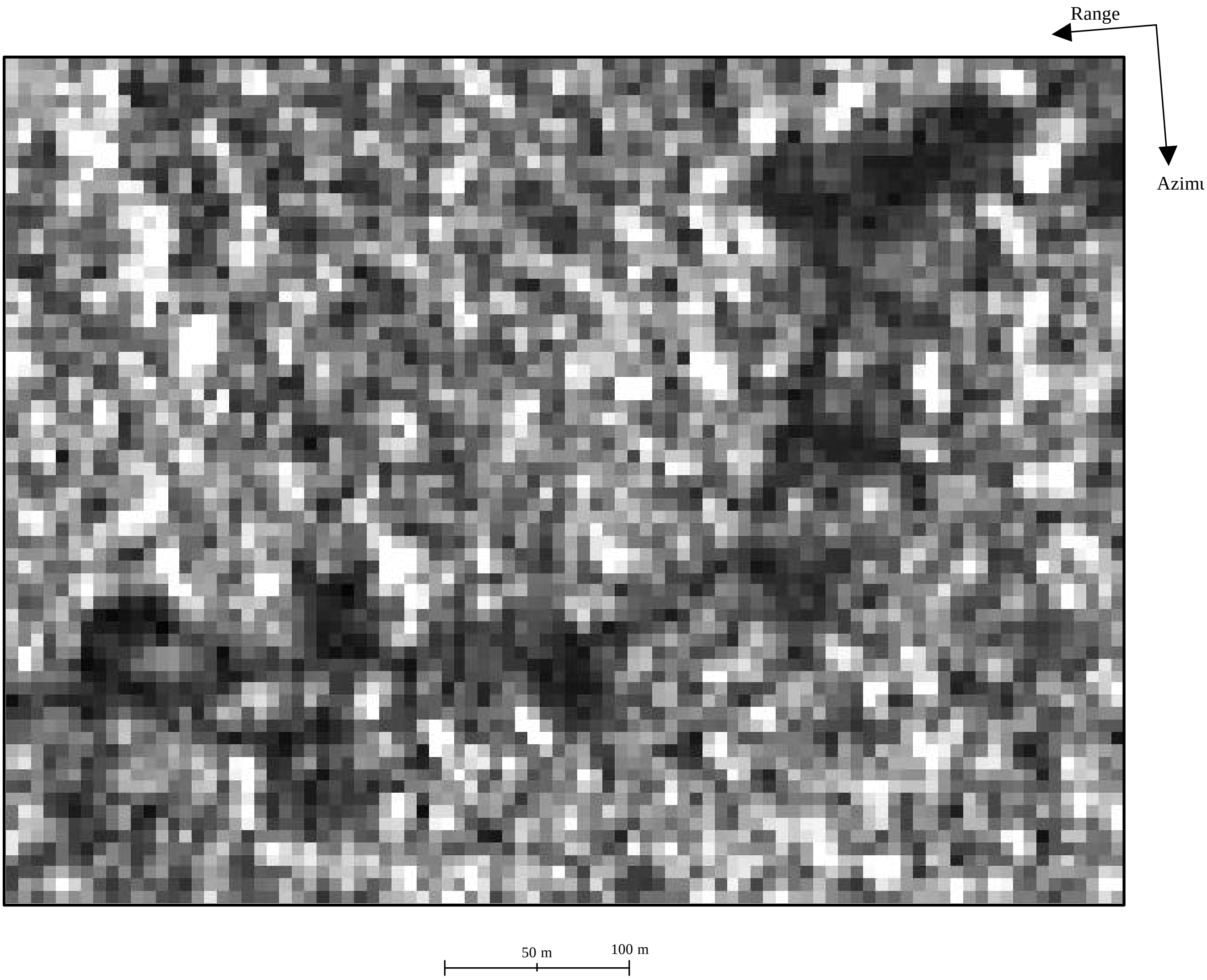

Figure 5.34 Road detection at Tjukkehovden. RADARSAT from 7th October 1998.

5.13 Lake detection

Other natural features easily detectable on RADARSAT images are lakes. Figure 5.35 presents two views from 7th and 31st October 1998 over Træsvatnet. The low response is due to the quasi-total reflection of the radar pulse in the specular direction. Note that the lake give a bright response in the IKONOS image due to sun reflection.

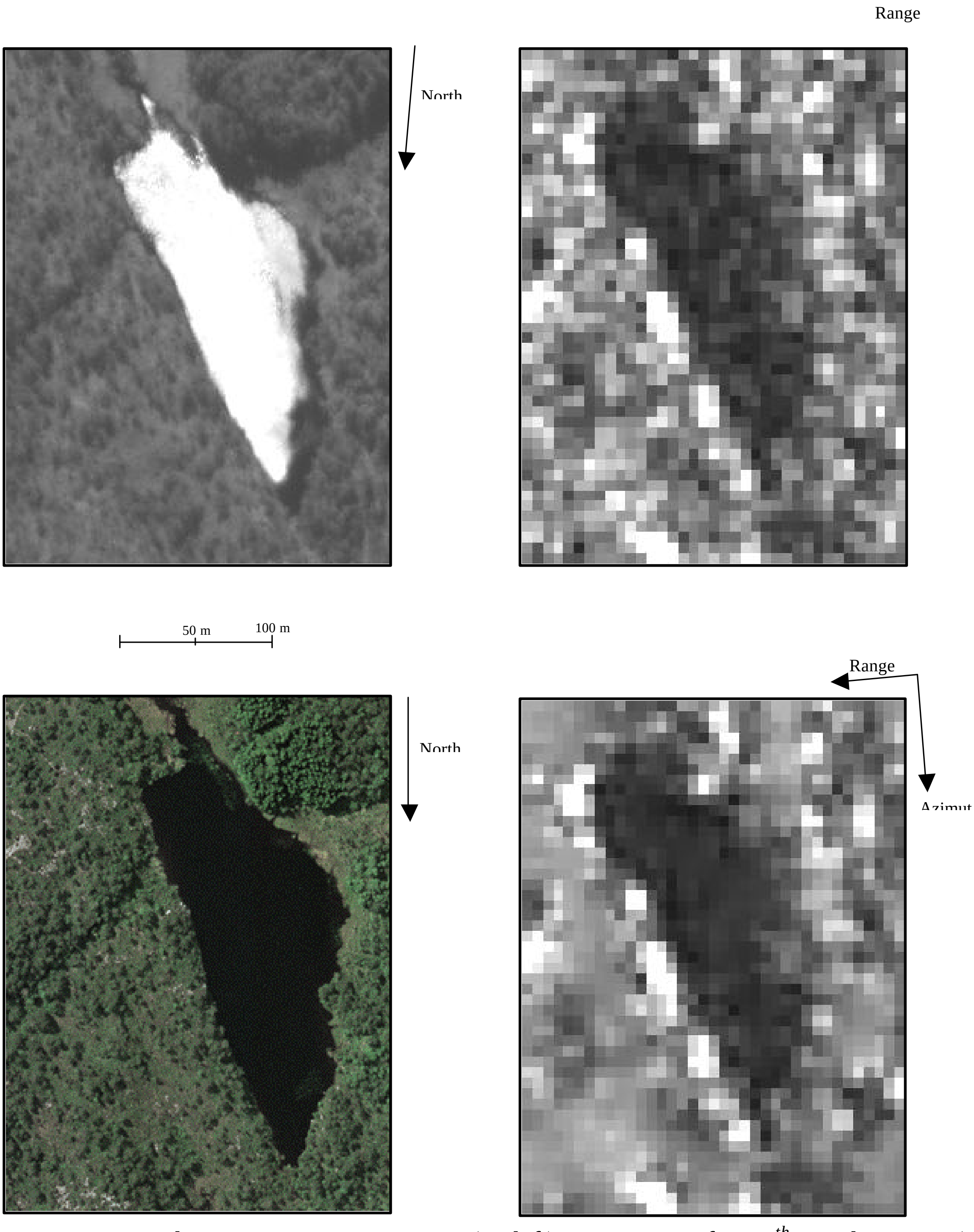

Figure 5.35 Lake at Træsvatnet. IKONOS (up left), RADARSAT from 7th October 1998 (up right), aerial photo (low left), and RADARSAT smoothed from 7th October 1998 (low right)

6 CONCLUSIONS

This report compares the visual appearance and detection of different man-made objects in an area close to Bergen city in Norway using IKONOS (1 m resolution) and RADARSAT (9 m resolution) images respectively.

In general, the results show that the RADARSAT images add very limited information to the IKONOS panchromatic image. However, this report also shows that RADARSAT may sometimes uniquely detect certain objects: some buildings gave a strong backscatter even if they were partly hidden in the forest, buoys may very well be detected on a low SAR backscatter ocean surface, parked helicopters and airplanes were represented as bright points.

It is also shown that an object next to a tall building can be hidden when viewed by the sidelooking IKONOS sensor, but detected when viewed by RADARSAT from a different incidence and aspect angle.

There are many man-made objects that are very well seen in the IKONOS image, and that also can be detected using the RADARSAT images: piers can be located and counted (but not the leisure boats attached), bridges will in most cases give a strong SAR backscatter due to its complex structure and multi-scattering properties, large oil storage tanks will very likely be imaged as bright points.

Strong backscatter from buildings and electrical wires are often governed by the cardinal direction effect. Buildings holding a lot of complex metal structures or corners (e.g. the terminal building at Bergen airport) can however give a strong radar echo regardless of building directions. On the other hand, low SAR backscatter signatures from the roof of a large industrial building may indicate the presence of a flat roof, and thereby confirm assumptions already made when analysing the IKONOS image.

One of the conclusions from this study is that IKONOS panchromatic images seem to give the necessary information about man-made objects for many mapping applications. From this perspective, there is no need for additional RADARSAT acquisitions. One explanation for the seemingly lack of information from the SAR data in this study, is that the IKONOS sensor image the Earth ground with a resolution of 1 m, while RADARSAT only has 9 m.

In the future, we will recommend that a similar study being carried out with another SAR sensor having a resolution down towards 1 m. From previous experience with backscattering from man-made objects in 25 m and 9 m resolution SAR images, it is believed that a 1 m resolution SAR system will add significant details and structural information to a high resolution optical image. It is therefore believed that SAR can work much better as a complementary, all-weather information source to the optical ones, when similar spatial resolutions are used.

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(2) Weydahl, D. J., (1994): "Change detection techniques for ERS-1 SAR images", FFI/RAPPORT-94/02914, Norwegian Defence Research Establishment, Kjeller, Norway.

APPENDIX

A SATELLITE IMAGE CO-ORDINATES OF SELECTED AREAS

The image co-ordinates given in the table underneath are given in the ERDAS image co-ordinate system (thus, the minus sign). The IKONOS image used in this analysis, was the original one with a size of 72 km^2. The two RADARSAT1 images are sub-images extracted from the 50 km x 50 km large scenes, and resampled into the IKONOS geometry. The RADARSAT1 co-ordinates below are therefore referring to these resampled sub-images.

	NAME	Figure number	IKONOS		Dimension	RADARSAT1, 7 October 1998	
			Upper Left	Down Right		Upper Left	Down Right
airport buildings	ext_aero_	Fig. 5.1	3506 -7181	3811 -7441	305 260	3463 -7160	376 -742
	build_north_aero_	Fig. 5.2	3442 -6912	3648 -7104	206 192	3391 -6864	359 -705
	build_far_north_aero_	Fig. 5.3	3425 -6630	3602 -6824	177 194	3358 -6616	353 -681
Warfs	wharf_west_aero_	Fig. 5.4	2514 -6282	2698 -6468	184 186	2514 -6282	269 -646
Car park	car_park_	Fig. 5.5	3748 -6951	3996 -7220	248 269	3672 -6929	392 -719
Houses hidden in the forest	house_west_aero_	Fig. 5.6	2700 -6338	2860 -6486	160 148	2700 -6338	286 -648
	house_in_forest_dolvik_	Fig. 5.7	5400 -4790	5600 -4966	200 176	5278 -4799	547 -497
	grimstad_	Fig. 5.8	3572 -3818	3959 -4012	387 194	3572 -3818	395 -401
Buildings urban Areas	storhaugen_west_aero_	Fig. 5.9	2633 -7292	2829 -7510	196 218	2608 -7287	280 -750
	bjørnåsen_	Fig. 5.10/5.11	5102 6463	5602 6996	500 533	5071 -6409	557 -694
	birkelandsskjenet_	Fig. 5.13	5607 -6389	5767 -6537	160 148	5526 -6345	568 -649
	black_build_rundehaugen_	Fig. 5.14	5078 -6247	5262 -6431	184 184	5035 -6202	521 -638
Harbours	harbour_dolvika_	Fig. 5.16/5.17	5520 -4178	5917 -4624	397 446	5520 -4178	591 -462
	second_harbour_north_east_	Fig. 5.18	5914 -3325	6191 -3561	277 236	5914 -3325	619 -356
Bridge	bridge_north_	Fig. 5.19	5773 -3507	5922 -3667	149 160	5780 -3499	592 -365
Electrical features	electric_lines_	Fig. 5.20	5257 -4395	5372 -4522	115 127		
	electric_lines_2_	Fig. 5.21	5044 -3391	5140 -3521	96 130		
	electrical_wire_	Fig. 5.22	5131 -3650	5353 -3956	222 306	5131 -3650	535 -395
Industrie	industrial_containers_north_	Fig. 5.23/5.24	4465 -3521	4782 -3852	317 331	4465 -3521	478 -385
Complex shaped buildings	complex_build_shape_east_	Fig. 5.25/5.26	6410 -6548	6833 -6992	423 444	6376 -6528	679 -697
	complex_build_shape_east_2_	Fig. 5.28	7170 -6619	7362 -6862	192 243	7108 -6595	730 -683
Buoy	buoy_in_sea_west_	Fig. 5.15	2075 -6938	2357 -7181	282 243	2075 -6938	235 -718
Lake	træsvatnet_lake	Fig. 5.35	4022 -6081	4274 -6420	252 339	3944 -6034	419 -637
Roads	road_detection_north_aero_	Fig. 5.29/5.30	3674 -4464	4312 -5167	638 703	3674 -4464	431 -516
	runway_ (airport)	Fig. 5.32	2814 -5704	3223 -6088	409 384	2814 -5704	322 -608
	airport_roads_	Fig. 5.33/5.34	3133 -4618	3758 -5091	625 473	3107 -4592	373 -506

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