RADARSAT-2 new modes

Tonje Nanette Arnesen Hannevik

Norwegian Defence Research Establishment (FFI)

10 July 2012

FFI-rapport 2012/01094

1210

P: ISBN 978-82-464-2129-2
E: ISBN 978-82-464-2130-8

Keywords

Syntetisk Aperture Radar (SAR)

Skipsdeteksjon

RADARSAT-2

Nye moduser

Høy-oppløselig

Polarimetri

Approved by

Richard B.Olsen	Project Manager
Johnny Bardal	Director

English summary

RADARSAT-2 has provided new and better opportunities for spaceborne monitoring of vessel traffic and fishing activities because of better flexibility in choice of resolution, polarisation and look direction. Due to user demand, five new modes were installed on the satellite in 2011. The new modes give the possibility to order images with better resolution and quad-polarisation (for some of the modes). This may be better for some scenarios in operational ship detection due to the increased swath width and coverage area for the new modes. Until the new modes on RADARSAT-2 were installed, high resolution and quad-polarisation images only covered small areas. For ship detection these images have mainly been used for research purposes, harbor areas or over a known small area of interest.

The report presents an overview of RADARSAT-2's original and new modes. Original and new swath widths are compared and image examples are shown. In addition ship length formulas are used to calculate theoretical nominal minimum detectable ship sizes for different combinations of modes, incidence angles, wind speeds and radar resolutions.

Sammendrag

RADARSAT-2 har gitt nye og bedre muligheter for rombasert overvåking av skipstrafikk og fiskeaktiviteter på grunn av bedre fleksibilitet i valg av oppløsning, polarisering og om satellitten ser til høyre eller venstre. På grunn av brukeretterspørsel ble fem nye moduser installert om bord på satellitten i 2011. De nye modusene gir muligheten for å bestille bilder med bedre oppløsning og full-polarisasjon (for noen av modusene). Dette kan fungere bedre for noen operasjonelle skipsdeteksjons-scenarioer på grunn av større sporbredde og dekningsområde. Inntil de nye modusene på RADARSAT-2 ble installert dekket høyoppløselige bilder og fullpolariserings-bilder kun små områder. Disse bildene har derfor mest blitt brukt for forskningsformål, i havneområder eller over et kjent lite interesseområde.

Denne rapporten presenterer en oversikt over RADARSAT-2s opprinnelige og nye moduser. Opprinnelige og nye sporbredde er sammenliknet og bildeeksempler er vist. I tillegg brukes skipslengdeformler for å beregne teoretiske nominelle minimum detekterbare skipsstørrelser for forskjellige kombinasjoner av moduser, innfallsvinkler, vindhastigheter og radaroppløsninger.

Contents

1 Introduction

Five new modes were installed on the Canadian RADARSAT-2 Synthetic Aperture Radar (SAR) satellite in 2011. This report gives a brief presentation about the original modes and a presentation of the five new modes. It also presents images that were acquired using some of the new modes.

Previously high resolution and/or quad-polarisation (quad-pol) images only covered small areas, and were mainly useful in harbour areas or over a known small area of interest. To be able to image vessels of interest in the open ocean with high resolution and/or quad-pol before, detailed information in advance was necessary to locate where the images should be acquired, i.e. where the vessels are located. Now the new modes open up new opportunities to use high resolution and quad-pol images for operational ship detection due to increased coverage area.

This report gives an overview of RADARSAT-2's original and new modes in chapter 2. Chapter 3 shows image examples of the new modes. In addition original and new modes are compared. Graphs showing the dependence between the nominal minimum detectable ship length and the incidence angle for different modes are shown in the discussions section in chapter 4. Conclusions and recommendations are given in chapter 5.

2 RADARSAT-2 modes

RADARSAT-2 is a Canadian Earth Observation (EO) SAR satellite that was launched in 2007. The satellite is used daily by the Norwegian authorities to monitor ship traffic, oil spills and sea ice in the High North. RADARSAT-2 has improved spatial resolution (see appendix A), more imaging modes and the ability to image the Earth either to the right or to the left of the satellite. For more information about RADARSAT-2 and the original modes on the satellite see [1].

2.1 Original modes

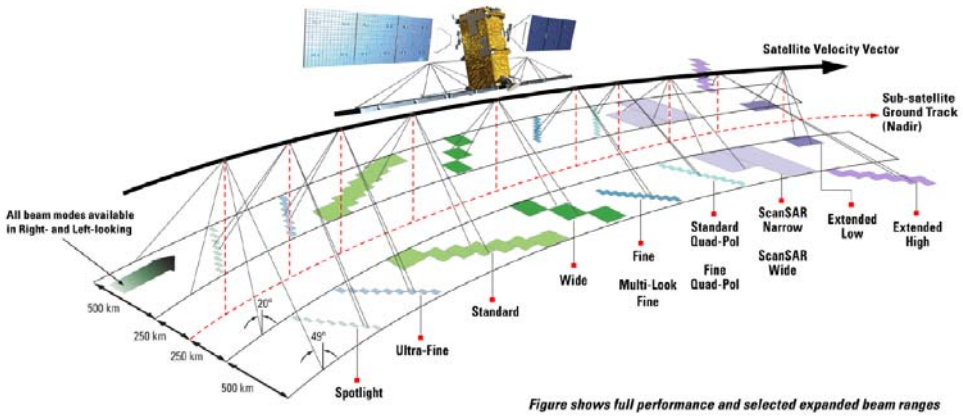

Figure 2.1 RADARSAT-2 original modes and the capability of looking both to the right and to the left. © MacDonald, Dettwiler and Associates Ltd (MDA).

Beam mode	Appr. nominal swath width	Appr. resolution		Appr. incidence angle	Polarisation (pol)
		Range	Azimuth		
Spotlight	18 km	1.6-4.6 m	0.8 m	20º - 49º	Single-pol (HH,VV,HV or VH)
Ultra-Fine	20 km	1.6-4.6 m	2.8 m	20º - 49º	
Multi-Look Fine	50 km	3.1-10.4 m	4.6-7.6 m	30º - 50º	
Fine	50 km	5.2-10.4 m	7.7 m	30º - 50º	Single-pol or dual-pol
Standard	100 km	9-26.8 m	7.7-24.7 m	20º - 49º	
Wide	120-170 km	13.5-40 m	7.7-24.7 m	20º - 45º	
ScanSAR Narrow	300 km	37.7-79.9 m	60 m	20º - 47º	
ScanSAR Wide	450-500 km	72.1-160 m	100 m	20º - 49º	
Extended High	70 – 80 km	13.5-18.2 m	7.7-24.7 m	49º - 60º	Single-pol (HH)
Extended Low	170 km	9-52.7 m	7.7-24.7 m	10º - 23º	
Fine Quad-Pol	25 km	5.2-16.5 m	7.6 m	18º - 49º	Quad-pol
Standard Quad-Pol	25 km	9-28.6 m	7.6 m	18º - 49º	

Table 2.1 RADARSAT-2 original beam modes [2].

For operational purposes in the High North, wide area coverage is of primary interest. Now dual-polarisation (dual-pol) ScanSAR images are being used to monitor the vast ocean areas. The original modes, with their swath widths and coverage, are shown in Figure 2.1. Table 2.1 gives more information about the original RADARSAT-2 modes.

2.2 New modes

The RADARSAT-2 SAR sensor is very flexible. It is possible to reprogram the sensor for example according to resolution and swath width. Five new modes have now been made due to user demand. The new modes open up new opportunities to use images with good resolution and relatively wide swath width at the same time. The Wide Fine Quad-Pol and Wide Standard Quad-Pol modes give the opportunity to choose quad-pol images with wider swath widths compared to the original modes. Earlier, high resolution and quad-pol images only covered small areas, and were mainly useful in harbor areas or over a small well-known area of interest. Earlier, to image vessels of interest in the open ocean with high resolution and/or using quad-pol, detailed information in advance was necessary to be able to know where to plan the SAR acquisitions.

Quad-pol images give many advantages when doing ship detection analysis compared to dual-pol or single-pol images, so if possible quad-pol images are preferable.

The new modes have wider swath width while offering the same resolution as before. Figure 2.2 shows original and new modes on RADARSAT-2 in the same figure. The new modes are described in table 2.2. They are all single beam modes (see Figure 2.3), which is a stripmap SAR mode. This means that the beam elevation and profile are constant while collecting data. A presentation of the five new beam modes follows below [2].

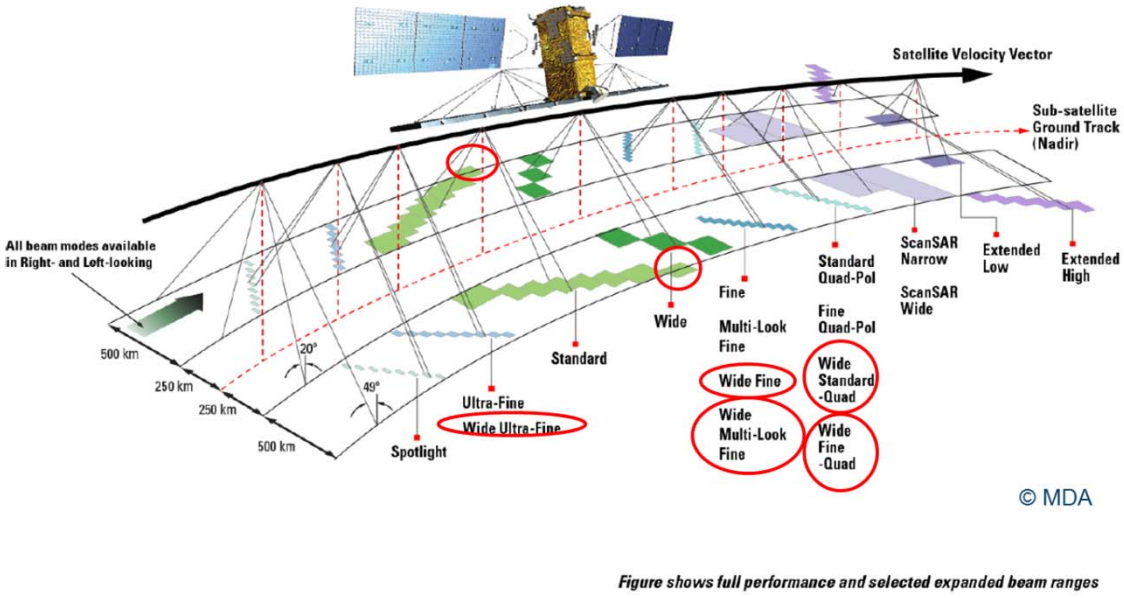

Figure 2.2 Original and new modes (with red circles) on RADARSAT-2. © MDA.

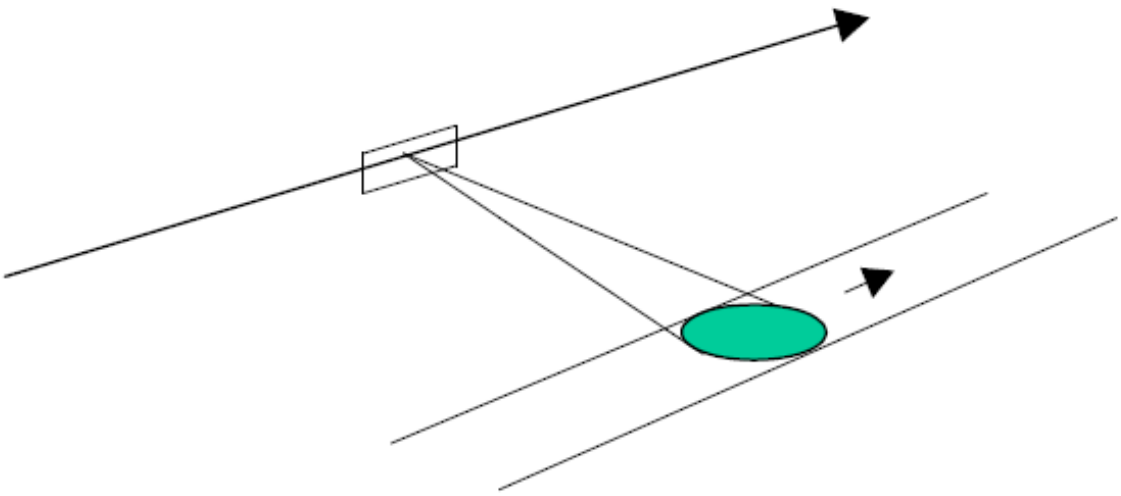

Figure 2.3 Single beam mode. © MDA.

Beam mode	Appr. nominal swath width	Swath width for regular corresponding mode	Appr. resolution		Appr. Incidence angle	Polarisation (pol)	Applications
			Range	Azimuth			
Wide Ultra-Fine	50 km	20 km	1.6-3.3 m	2.8 m	30° - 50°	Single-pol (HH,VV,HV or VH)	Same spatial resolution as Ultra-Fine Mode, but wider swath width.
Wide Multi-Look Fine	90 km	50 km	3.1-10.4 m	4.6-7.6 m	29° - 50°		Wider coverage than Multi-Look Fine, but same spatial and radiometric resolution. 50 % overlap between the individual swaths.
Wide Fine	120-170 km	50 km	5.2-15.2 m	7.7 m	20° - 45°	Single-pol or dual-pol	Good resolution (same as for Fine Beam) and a wider swath width (same as for the Wide Beams)
Wide Fine Quad-Pol	50 km	25 km	5.2-17.3 m	7.6 m	18° - 42°	Quad-pol	21 beams. Wider swath width. Same spatial resolution as for the original modes. 50 % overlap between the modes.
Wide Standard Quad-Pol	50 km	25 km	9-30.0 m	7.6 m	18° - 42°		

Table 2.2 RADARSAT-2 new beam modes [2].

2.2.1 Wide Fine Mode

The Wide Fine modes are useful when both a finer spatial resolution (same as for the Fine Beams) and wider swath width (same as for the Wide Beams) are required. There are three Wide Fine Resolution Beams, F0W1 to F0W3, with swath widths of 170 km, 150 km and 120 km. They cover an incidence angle range of 20 to 45 degrees. A nadir ambiguity may appear as a narrow bright line parallel to the flight direction for F0W3 images. One single-pol (HH, VV, HV or VH) image or two dual-pol images (HH+HV or VV+VH) can be acquired.

2.2.2 Wide Multi-Look Fine Mode

The Wide Multi-Look Fine Beam modes offer a wider coverage than the original Multi-Look Fine beam modes (90 km compared to 50 km), but have the same spatial and radiometric resolution (see appendix A). The nine Wide Multi-Look Fine Beam modes are able to cover the incidence angle range between 29 to 50 degrees. There is more than 50 % overlap between the individual successive sub swaths. Only one single-pol image is available in this mode (HH, VV, HV or VH).

2.2.3 Wide Ultra-Fine Mode

The same spatial resolution as the Ultra-Fine Beam mode is obtained for the Wide Ultra-Fine Beam mode. These Beam modes aim at applications which require good resolution, but wider swath width (at least 50 km) as the regular Beam modes. The beams cover an incidence angle range of 30 to 50 degrees. Only one single-pol image is available in this mode (HH, VV, HV or VH).

2.2.4 Wide Standard Quad-Polarisation Mode

These 21 Wide Standard Quad-Polarisation Beam modes operates the same way as the regular modes, but have a wider swath width of approximately 50 km and the same spatial resolution. The incidence angle range of 18 to 42 degrees is covered with a 50 % overlap between the swaths.

2.2.5 Wide Fine Quad-Polarisation Mode

The Wide Fine Quad-Polarisation Beam modes have a wider swath width of about 50 km (compared to 25 km for the regular beams) and the same spatial resolution as for the original beams. There are 21 beams which overlaps 50 % overlap between the swaths, covering an incidence angle range between 18 to 42 degrees.

3 Image examples using new modes

This section presents some images that were acquired in 2011 and 2012 using the new RADARSAT-2 modes. An overview of the images is shown in Table 3.1. The first image over the Caspian Sea is a test image received from Kongsberg Satellite Services AS (KSAT). The Norwegian Defence Research Establishment (FFI) has ordered the images in December 2011 through KSAT. The images in 2012 are acquired through the EU (European Union) GMES (Global Monitoring for Environment and Security) project Dolphin that FFI is a part of.

Beam mode	Date	Where	Swath width	Earlier swath width on corre-sponding mode	Polarisation (pol)
Wide Fine	28/2-11	Caspian Sea incl. ice, land.	170 km	50 km	Dual-pol
Wide Fine Quad-Pol	4/12-11	South in the Oslofjord incl. ships, land.	50 km	25 km	Quad-pol
Wide Fine Quad-Pol	4/12-11	North of Oslofjord incl. land.	50 km	25 km	Quad-pol
Wide Fine Quad-Pol	28/12-11	South in the Oslofjord incl. ships, land.	50 km	25 km	Quad-pol
Wide Standard Quad-Pol	22/3-12	Norne Field incl. ships	50 km	25 km	Quad-pol
Wide Standard Quad-Pol	28/3-12	Norne Field incl. ships	50 km	25 km	Quad-pol
Wide Fine Quad-Pol	29/3-12	Norne Field incl. ships	50 km	25 km	Quad-pol
Wide Fine Quad-Pol	21/4-12	Norne Field incl. ships	50 km	25 km	Quad-pol

Table 3.1 Overview of images acquired with the new RADARSAT-2 modes.

3.1 Caspian Sea in Wide Fine mode

One test image is received from Kongsberg Satellite Services AS (KSAT) after the new RADARSAT-2 modes were installed on the satellite. The coverage area for the Wide Fine Beam mode image in the Caspian Sea from February 2nd 2011 is shown in Figure 3.1. The swath width is 170 km compared with 50 km on the original Fine Beam mode. The red arrow in the figure shows how long 50 km is, which the original mode would cover, and it is easy to see that the new Wide Fine Beam mode makes it easier to observe a much larger ocean area. The dual-polarisation SAR images are shown in Figure 3.2, and they include ice, land and sea.

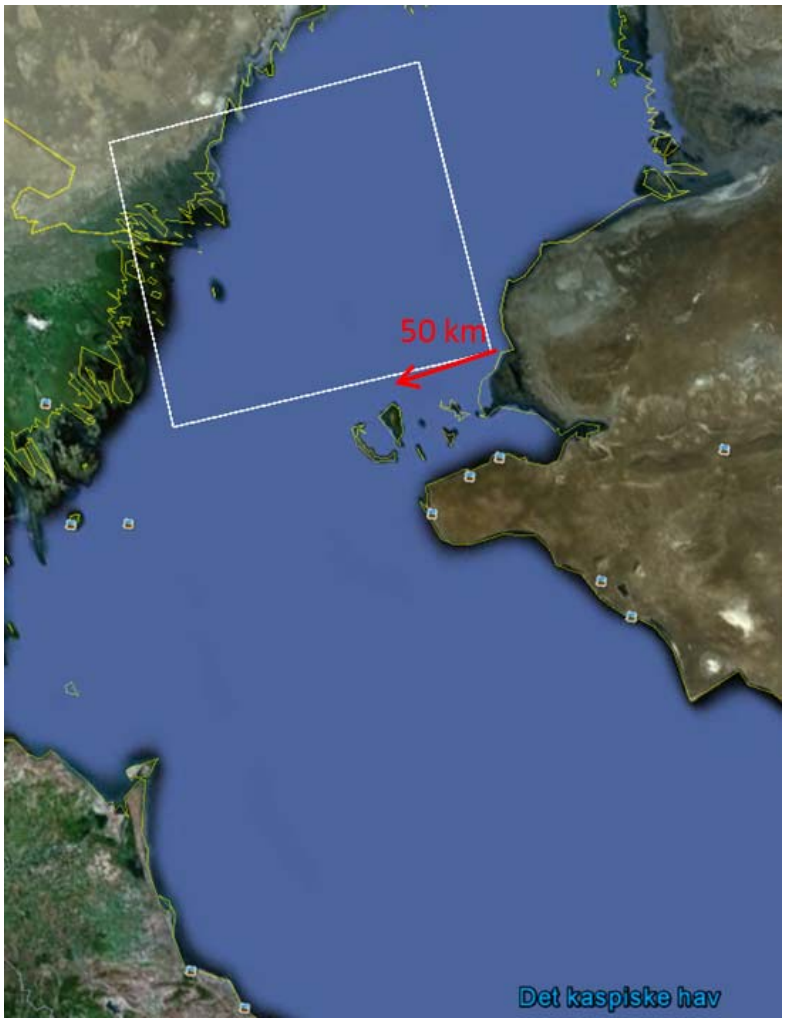

Figure 3.1 Shows the coverage area for the SAR Wide Fine mode image in the Caspian Sea from February 2nd 2011. © Google Earth.

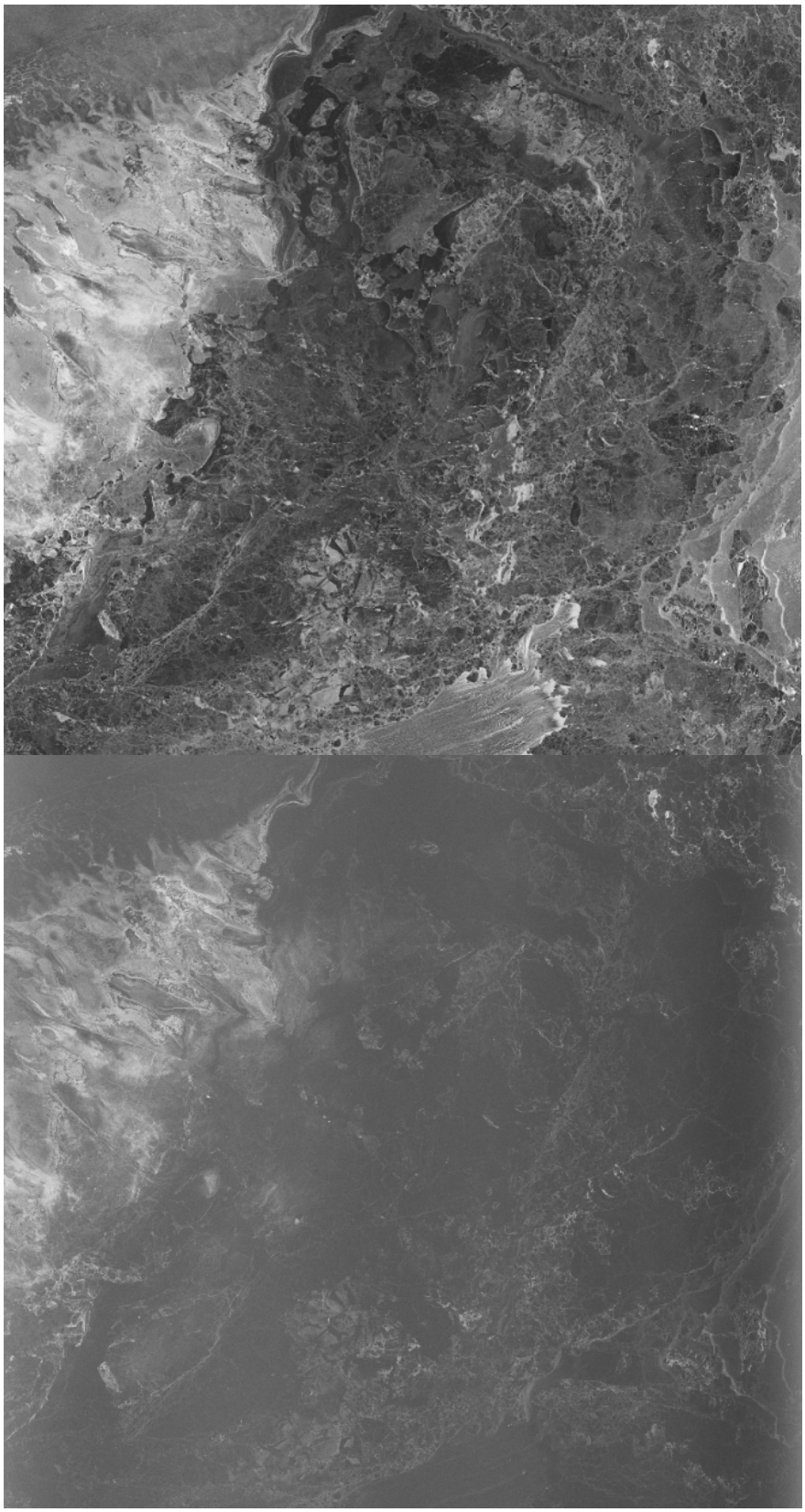

Figure 3.2 Wide Fine Beam mode images over the Caspian Sea acquired on February 28th2011. Above: HH-channel. Bottom: HV-channel.

3.2 Oslofjord in Wide Fine Quad-Pol mode

3.2.1 December 4th 2011

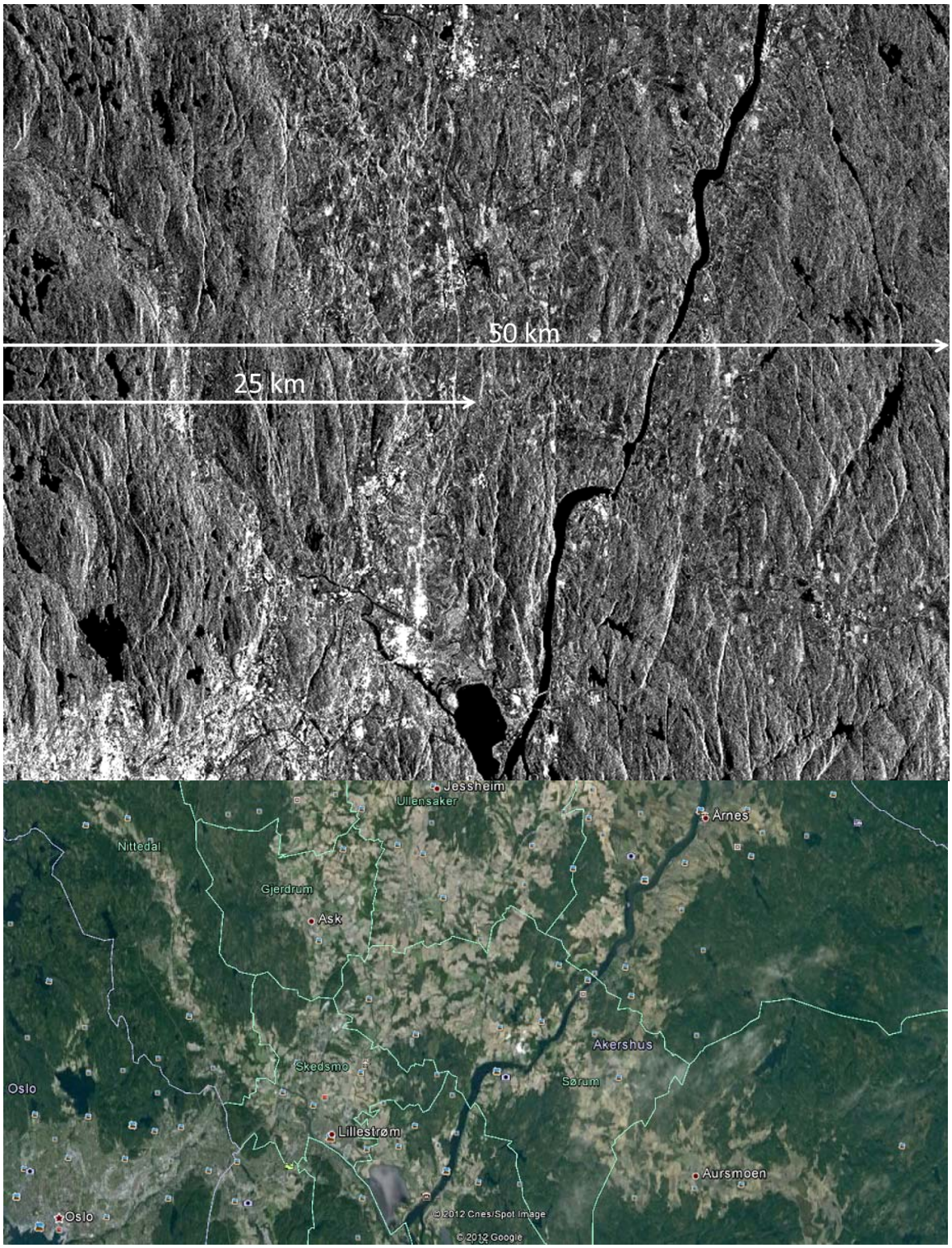

Figure 3.3 Top: Wide Fine Quad-Pol SAR image in HH-polarisation north of the Oslofjord on December 4th 2011. Bottom: Google Earth showing where the SAR image is acquired.

The first Wide Fine Quad-Pol image from December 4th 2011 is shown in Figure 3.3. The image includes an area north of the Oslofjord shown at the bottom of the figure. The SAR image shows the swath widths of the original (25 km) and the new mode (50 km).

The second Wide Fine Quad-Pol image from December 4th 2011 is shown in Figure 3.4. The image includes the area of the Oslofjord between Moss and south of Tønsberg. AIS (Automatic Identification System) detections from aisonline.com [3] are shown to the right with arrows pointing to the detections in the SAR image. The swath width of the image is 50 km, as shown in the image. The swath width of the original mode, Fine Quad-Pol Beam mode, is 25 km, and this is marked out in the SAR image. Figure 3.5 shows a close-up of the ferry vessel Crown of Scandinavia detected in the SAR image in HH-, VV- and HV-polarisation.

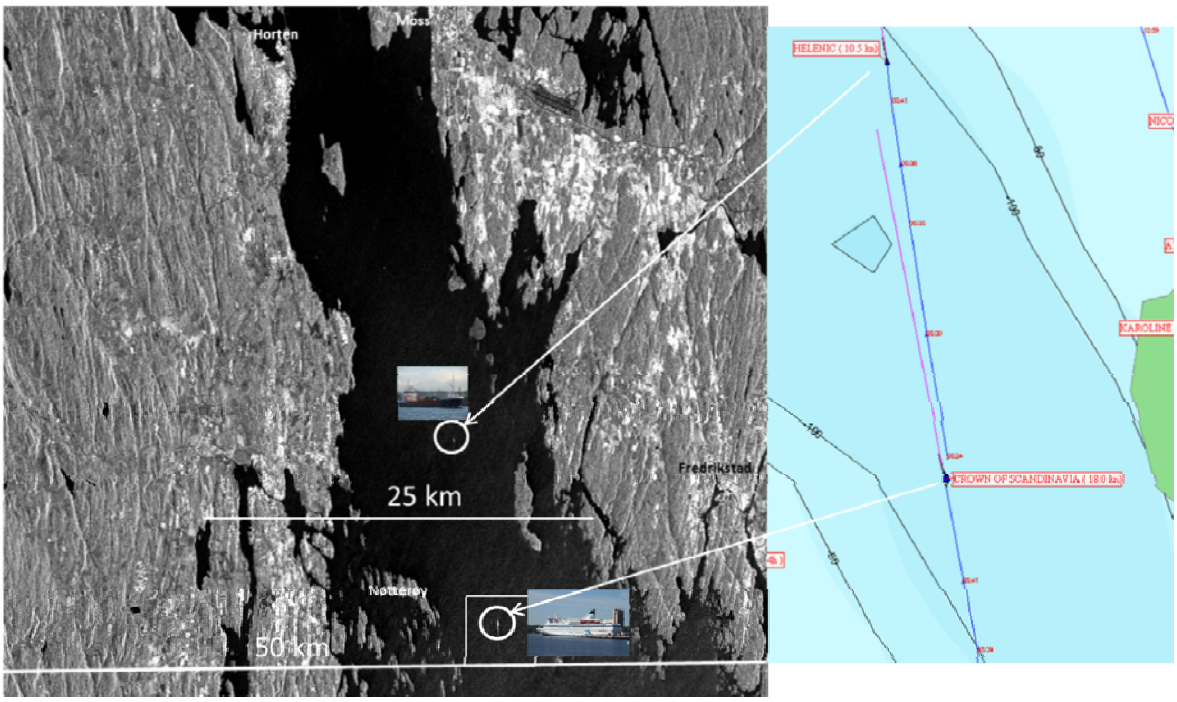

Figure 3.4 Left: Wide Fine Quad-Pol image south in the Oslofjord on December 4th 2011. Right: AIS detections from aisonline.com [3].

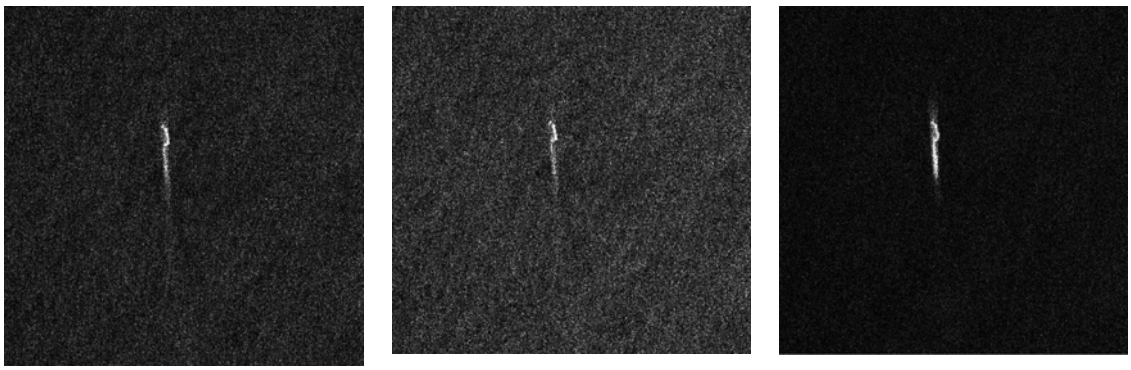

Figure 3.5 Close-up of the ferry Crown of Scandinavia detected December 4th 2011 in HH- (left), VV- (middle) and HV-polarisation (right).

3.2.2 December 28th 2011

On December 28th 2011 another Wide Fine Quad-Pol image over the Oslofjord was acquired. The image, shown in Figure 3.6, shows approximately the same area as the southernmost image on December 4th 2011. The SAR image shown in Figure 3.6 also includes the ferry vessel Crown of Scandinavia. The detection is shown inside the white circle. Figure 3.7 shows a close-up outside Tønsberg, also shown in the white square in Figure 3.6. Seven detected vessels are shown as white against dark ocean background in the SAR image (top of figure). At the bottom of the image the same seven detected vessels in addition to Crown of Scandinavia are shown reported by aisonline.com [3].

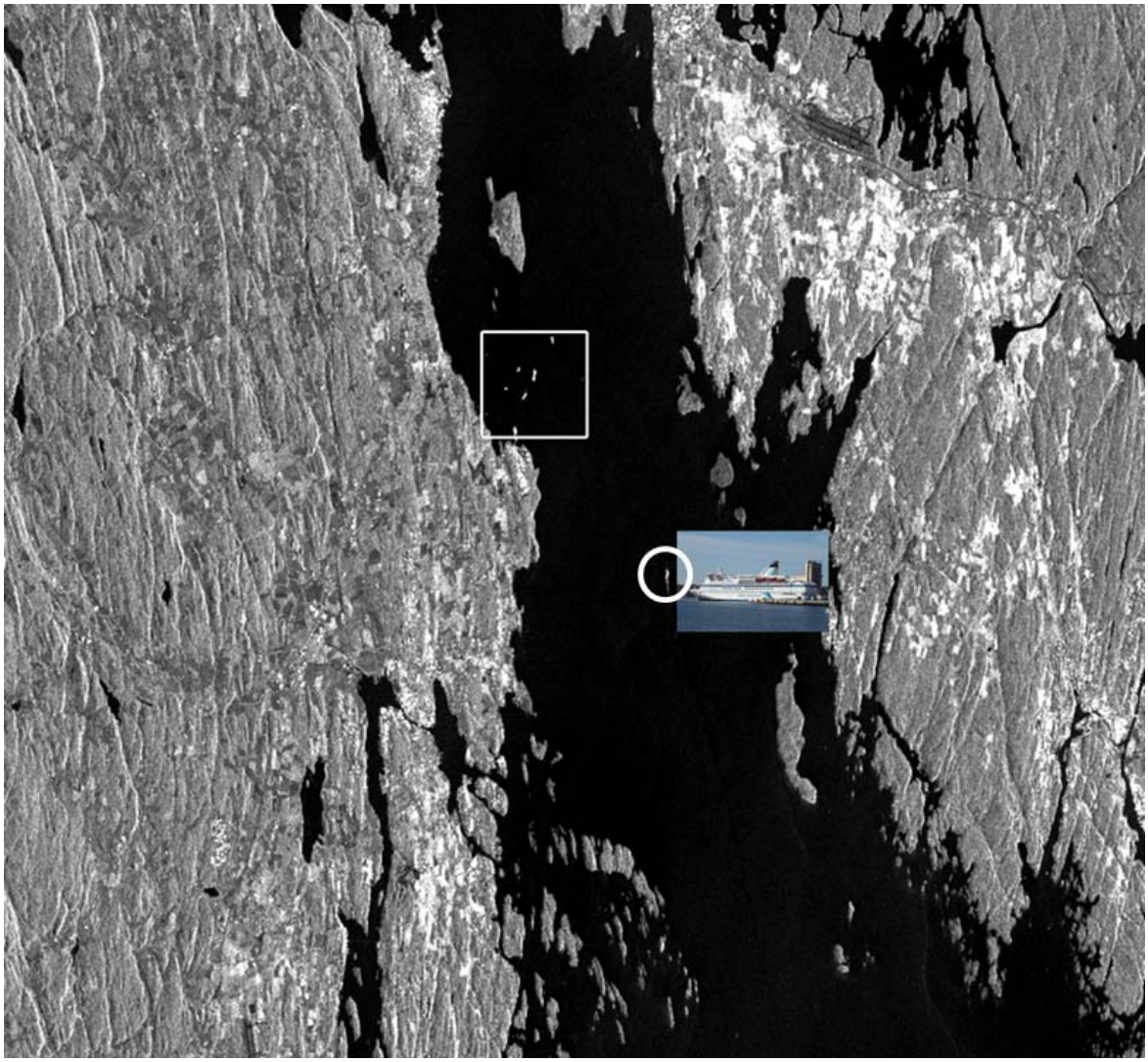

Figure 3.6 Wide Fine Quad-Pol mode south in the Oslofjord on December 28th 2011.

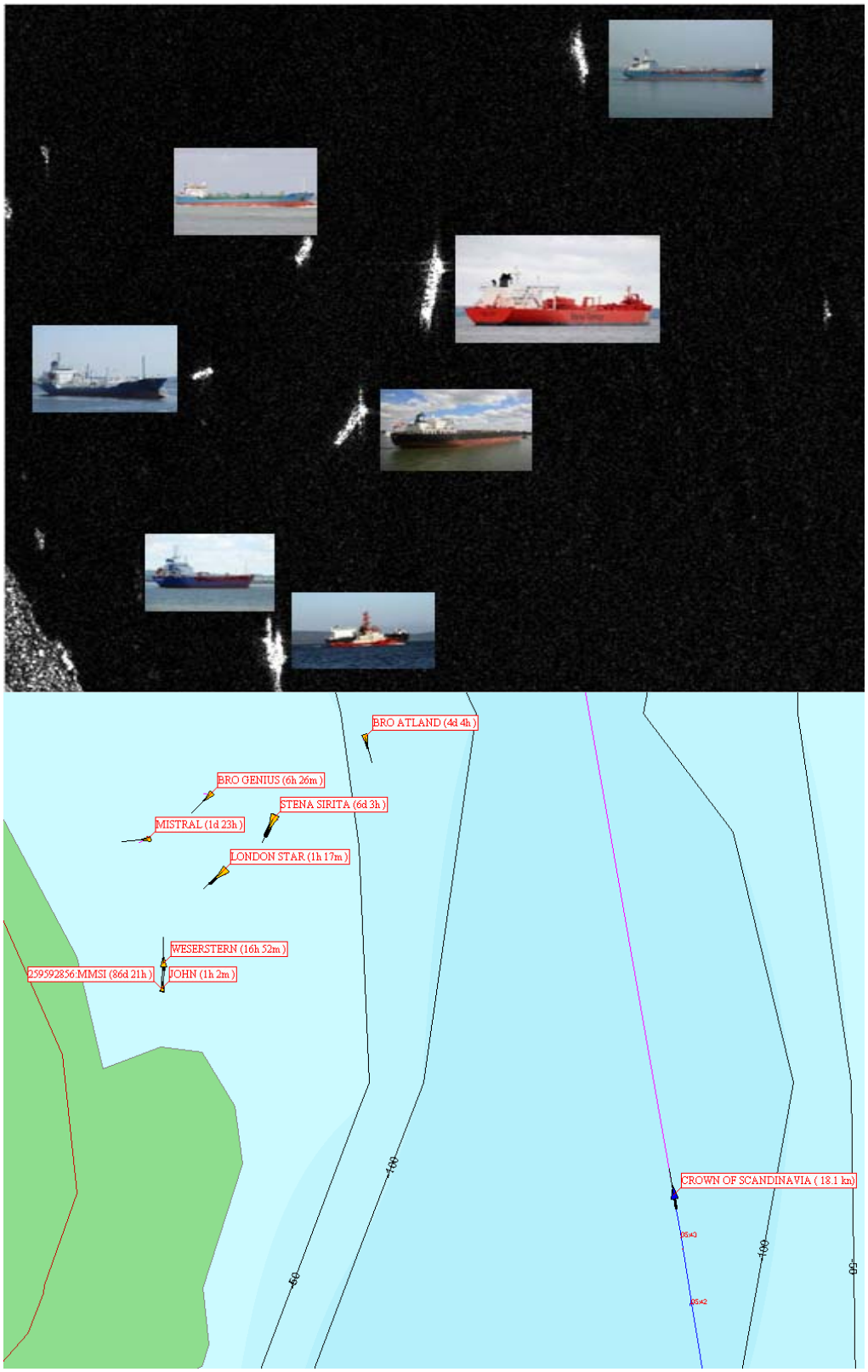

Figure 3.7 Top: Seven detected vessels in the SAR image. Bottom: The same seven detected vessels in addition to Crown of Scandinavia reported by aisonline.com [3].

3.3 Norne Field in Wide Standard and Fine Quad-Pol modes

Four SAR Wide Quad-Pol images were ordered over the Norne Field in March and April 2012. The coverage areas for the images are shown in Figure 3.8. The square to the left is March 29th, in the middle shows both March 28th and April 21st and to the right is March 22nd. The Norne Field is a good test area since it is possible to image the same vessel, Norne FPSO, in multiple SAR images. The vessel is moored to the ocean ground and is shown in Figure 3.9. It is also possible to image other vessels and an oil platform multiple times. See Table 3.2 for an overview of the ship lengths and widths of the vessels detected in the Norne Field the four dates the SAR images are acquired.

The following sections will look at the different SAR images and AIS data from the four dates. A Pauli decomposition image will be shown for each day. The different channels have been combined and represented with different colours. The Pauli decomposition highlights surface scattering (|HH+VV|), volume scattering (|HV| or |VH|) and double bounce (|HH-VV|). The three scattering mechanisms are shown in blue, green and red, respectively. It is usual that ships appear as brighter targets compared to the ocean background. In the surface scattering case, it is expected to see more ship wakes, surface waves and other oceanographic phenomena. In the double bounce and volume scattering case, the vessels appear brighter against a suppressed ocean background. For more information see [1].

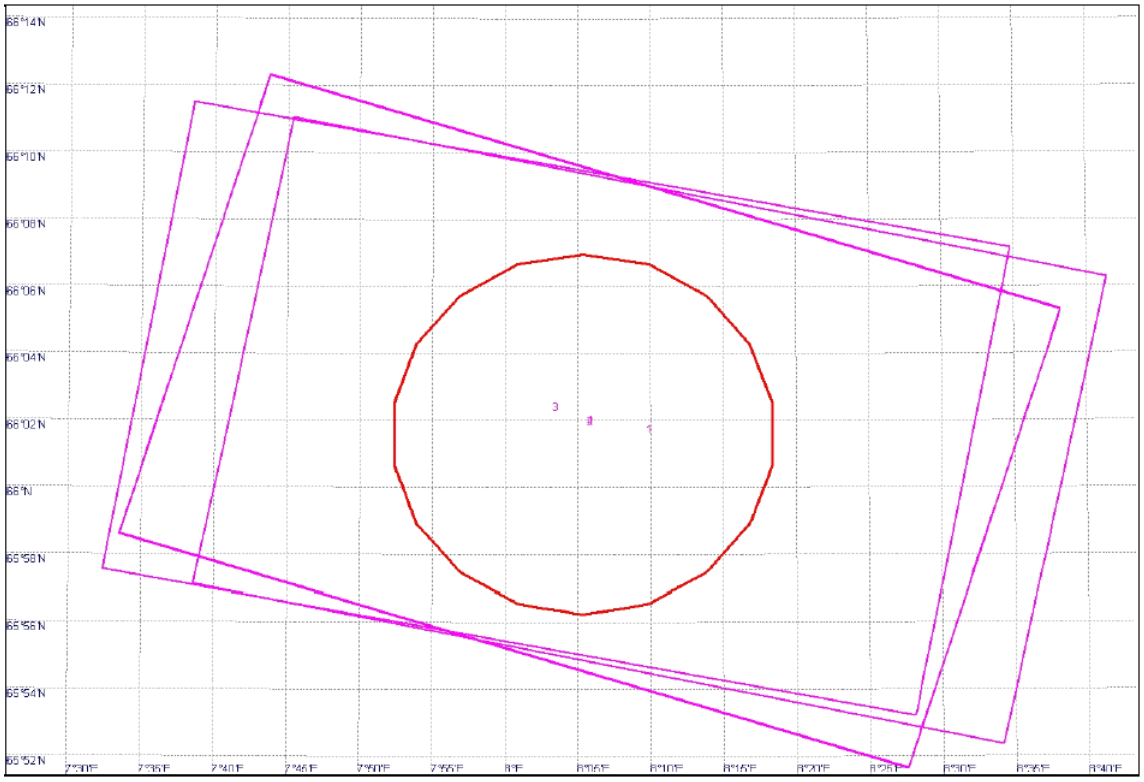

Figure 3.8 Coverage area for the four SAR images over the Norne Field in March and April 2012. © MDA/ESA (European Space Agency).

Figure 3.9 The oil production vessel, Norne FPSO, moored to the ocean bottom. © Statoil.

Ship name	Length (m)	Width (m)	Type
Aker Spistbergen	120	77	Oil Platform
Eddy Fauna	108	23	Vessel
Island Wellserver	116	26	Vessel
King Mob Boat	6	2	Vessel
Norne FPSO	260	41	Vessel
Ocean King	75	16	Vessel
Skandi Mongstad	97	22	Vessel
Stornes	175	26	Vessel
To Spitsbergen	See Aker Spitsbergen		

Table 3.2 Ship lengths and ship widths of the detected vessels and oil platform in the Norne Field.

3.3.1 March 22nd 2012

Figure 3.10 shows the Wide Standard Quad-Pol Mode image on March 22nd 2012, where the Pauli decomposition method is applied. Beam 18 is used, which gives an average incidence angle of 37 degrees. The figure also shows the swath width of the original beam mode (25 km) compared with the swath width of the new wide beam mode (50 km). Figure 3.11 shows AIS data for March 22nd 2012.The SAR data and the AIS data fit well together. Skandi Mongstad and To

Spitsbergen are lying so close together that it is not possible to distinguish the two vessels. It is easy to see the vessels in the SAR Pauli image as bright targets.

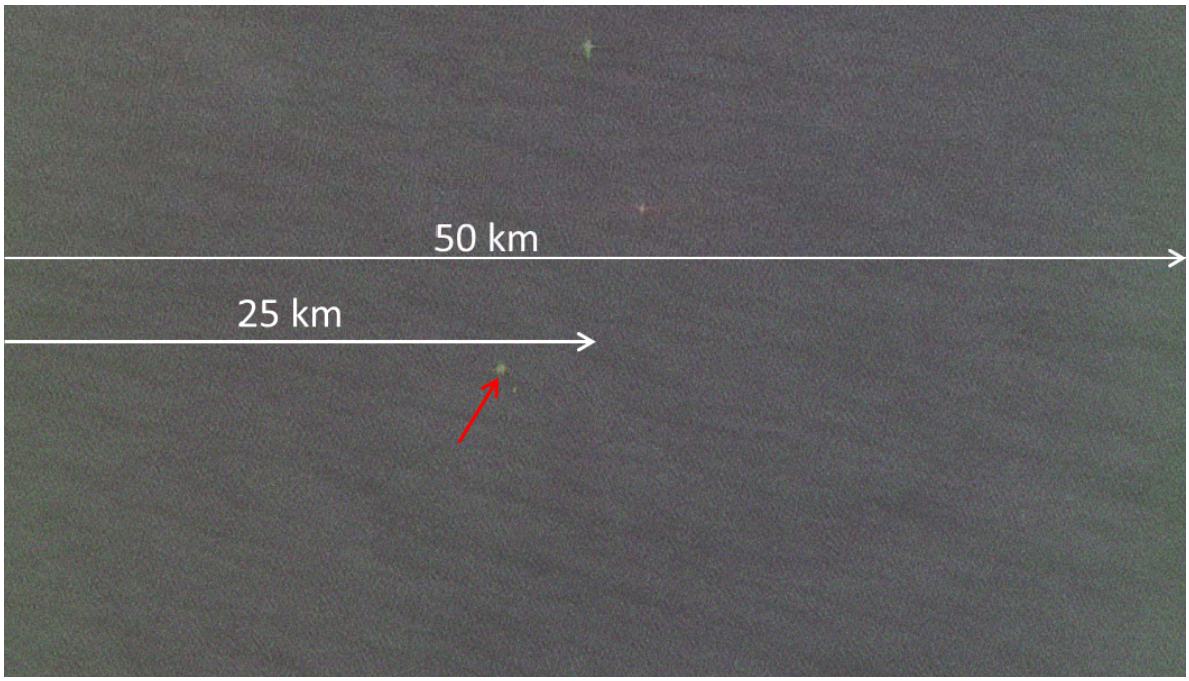

Figure 3.10 Pauli decomposition image on March 22nd 2012. The position of Norne FPSO is shown with the red arrow.

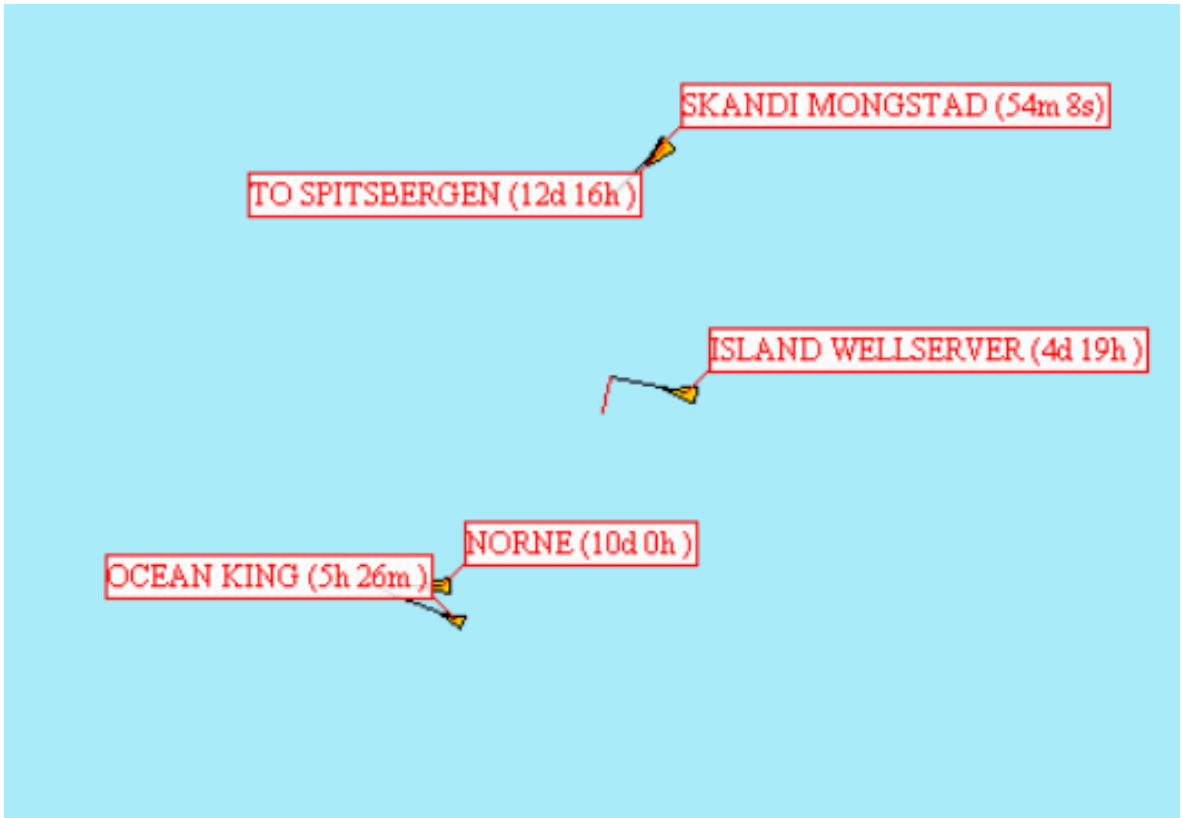

Figure 3.11 AIS data on March 22nd 2012. © aisonline.com.

3.3.2 March 28th 2012

Figure 3.12 shows the Wide Standard Quad-Pol Mode image on March 28th 2012, where the Pauli decomposition method is applied. Beam 2 is used, which gives an average incidence angle of 19.32 degrees. AIS data is shown in Figure 3.13, and the SAR data and the AIS data fit well together.

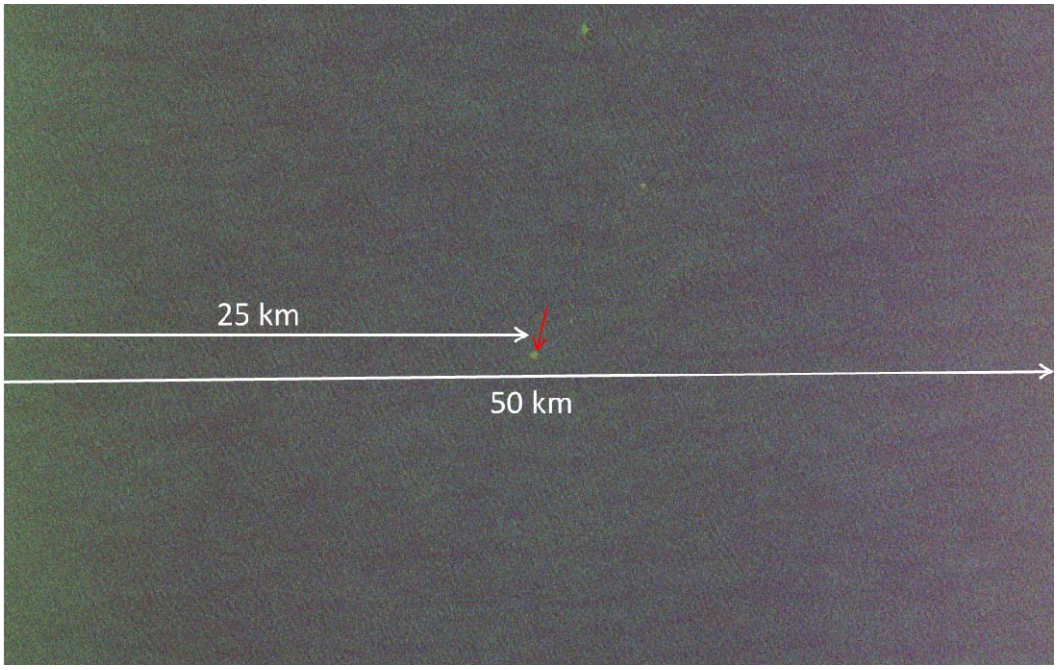

Figure 3.12 Pauli decomposition image on March 28th 2012. The position of Norne FPSO is shown with the red arrow.

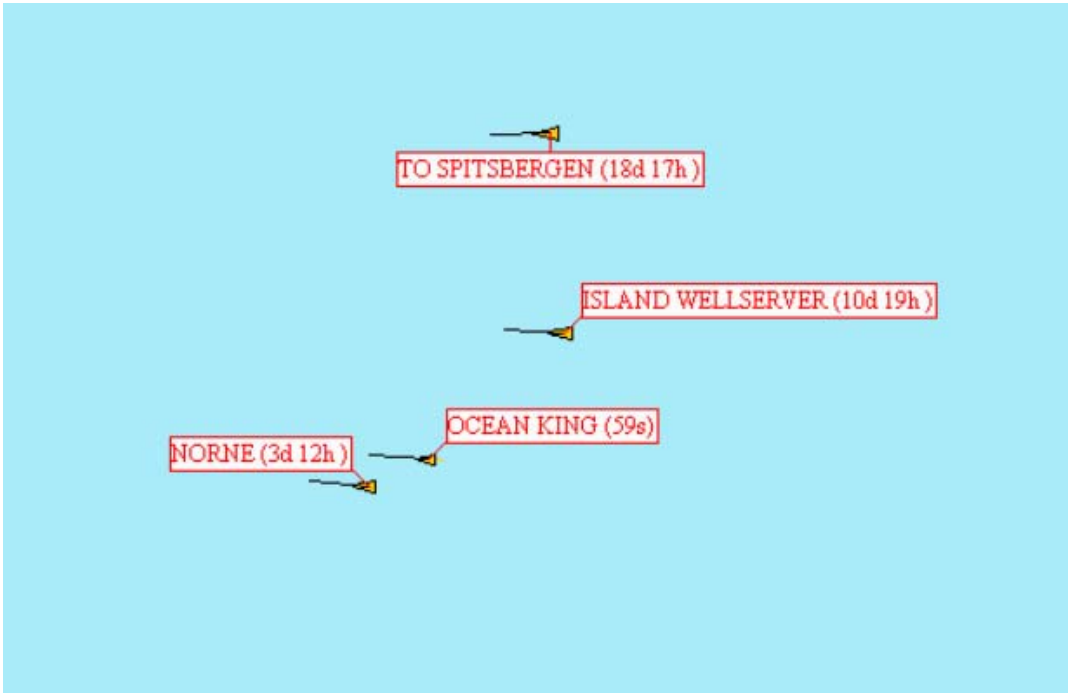

Figure 3.13 AIS data on March 28th 2012. © aisonline.com.

3.3.3 March 29th 2012

Figure 3.17 shows the Wide Fine Quad-Pol Mode image on March 29th 2012, where the Pauli decomposition method is applied. Beam 21 is used, which gives an average incidence angle of 39.81 degrees. AIS data is shown in Figure 3.15, and the SAR data and the AIS data fit well together.

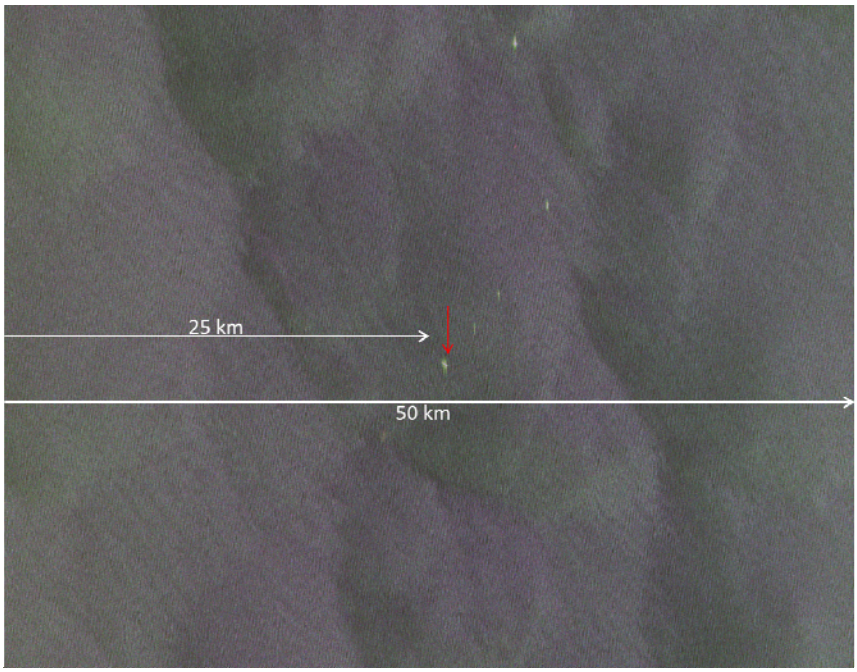

Figure 3.14 Pauli decomposition image on March 29nd 2012. The position of Norne FPSO is shown with the red arrow.

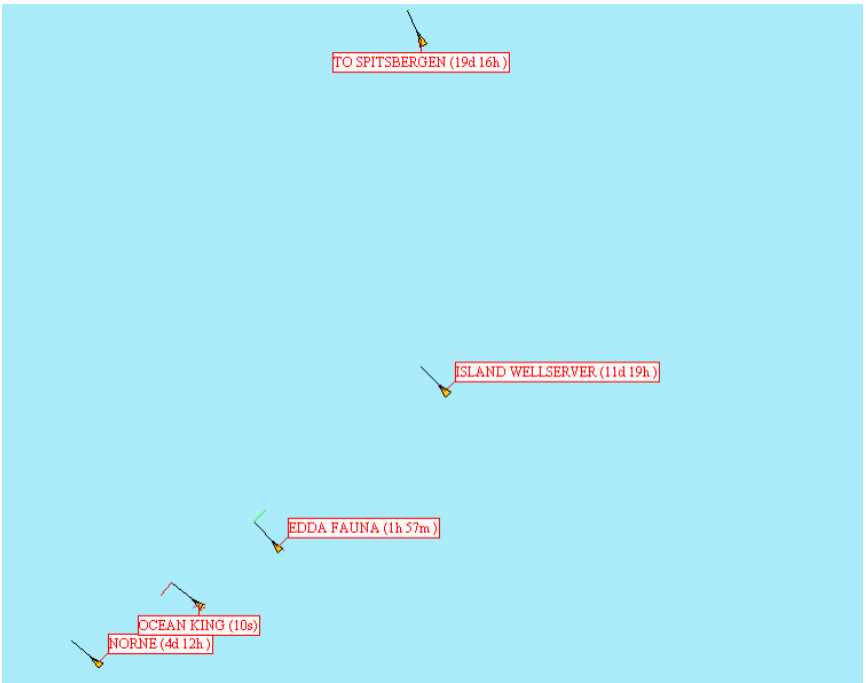

Figure 3.15 AIS data on March 29th 2012. © aisonline.com.

3.3.4 April 21st 2012

Figure 3.17 shows the Wide Fine Quad-Pol Mode image on April 21st 2012, where the Pauli decomposition method is applied. Beam 2 is used, which gives an average incidence angle of 19.32 degrees. AIS data is shown in Figure 3.16. The bottom half of the figure shows a close-up of the vessels that are very close together. The SAR data and the AIS data fit well together.

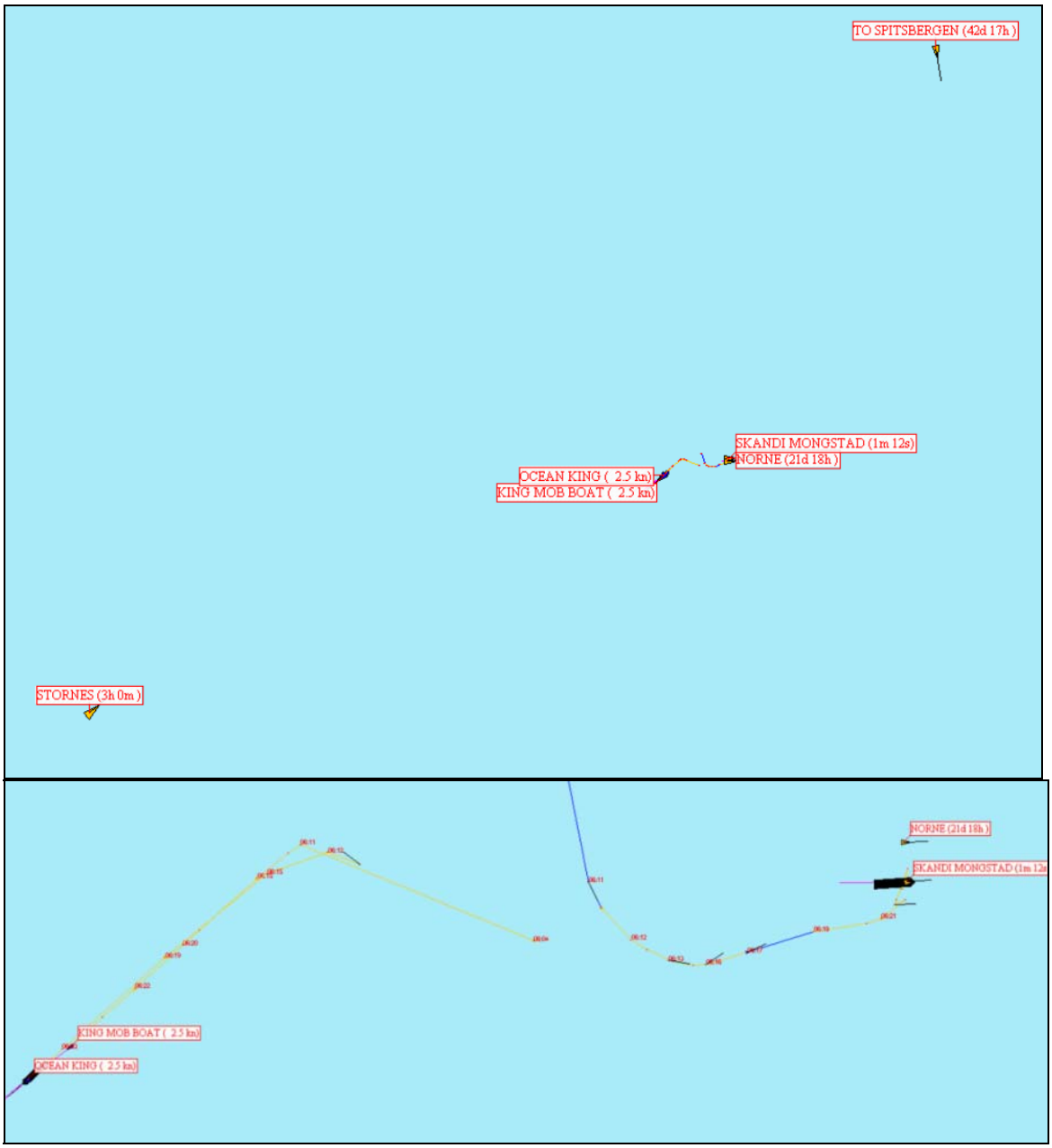

Figure 3.16 AIS data April 21st 2012. Top: Overview of the area. Bottom: Close-up of the vessels that are very close together. © aisonline.com.

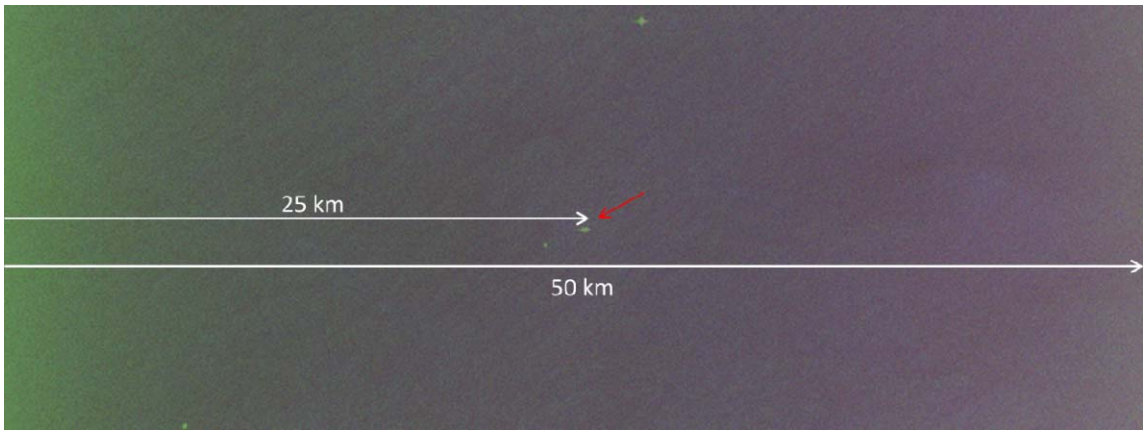

Figure 3.17 Pauli decomposition image on April 21st 2012. The position of Norne FPSO is shown with the red arrow.

4 Discussions

Ship length formulas [4] can be used to calculate theoretical nominal minimum detectable ship sizes for different combinations of modes, incidence angles, wind speeds and radar resolutions. This has been done at FFI, and is shown in Figure 4.1- Figure 4.4. Wind direction directly towards the radar is used, which is the worst case where it is most difficult to detect vessels due to the high reflection from the sea. The threshold for detection is 5 dB above the background sea clutter.

Figure 4.1 shows two graphs showing the dependence between the nominal minimum detectable ship length and the incidence angle. The comparison is between RADARSAT-2 ScanSAR Narrow mode and RADARSAT-2 Wide Fine mode for HH-polarisation. The Wide Fine mode performance is much better than the ScanSAR Narrow mode due to the better spatial resolution of the Wide Fine mode compared to the ScanSAR Narrow mode. The RADARSAT-2 ScanSAR Narrow mode is the mode that is used operationally today, and has average range and azimuth resolution of 50 m and 60 m and a noise floor of -28.5 dB. The RADARSAT-2 Wide Fine mode has a wide swath of 120-170 km compared to 50 km in the original Fine mode. Average range and azimuth resolution are 10 m and 8 m and the noise floor is -24 dB. Both modes are offered in both single-pol and dual-pol. Figure 4.2 shows a similar curve for RADARSAT-2 Wide Fine mode where the y-axis ranges from 0 to 50 m instead of 0 to 250 m. Then it is easier to see more details, especially for high incidence angles.

Figure 4.3 shows the dependence between the nominal minimum detectable ship length and the incidence angle for RADARSAT-2 Wide Fine Quad-Pol mode where the y-axis ranges from 0 to 50 m. The swath width is 50 km compared to 25 km in original Fine Quad-Pol mode. The average range and azimuth resolution is 11 m and 8 m in azimuth and the noise floor is -32.5 dB.

Figure 4.4 shows the same dependence for RADARSAT-2 Wide Standard Quad-Pol mode. The swath width is 50 km compared to 25 km in original Fine Quad-Pol. Approximate range and azimuth resolution are 20 m and 8 m and the noise floor is -35 dB.

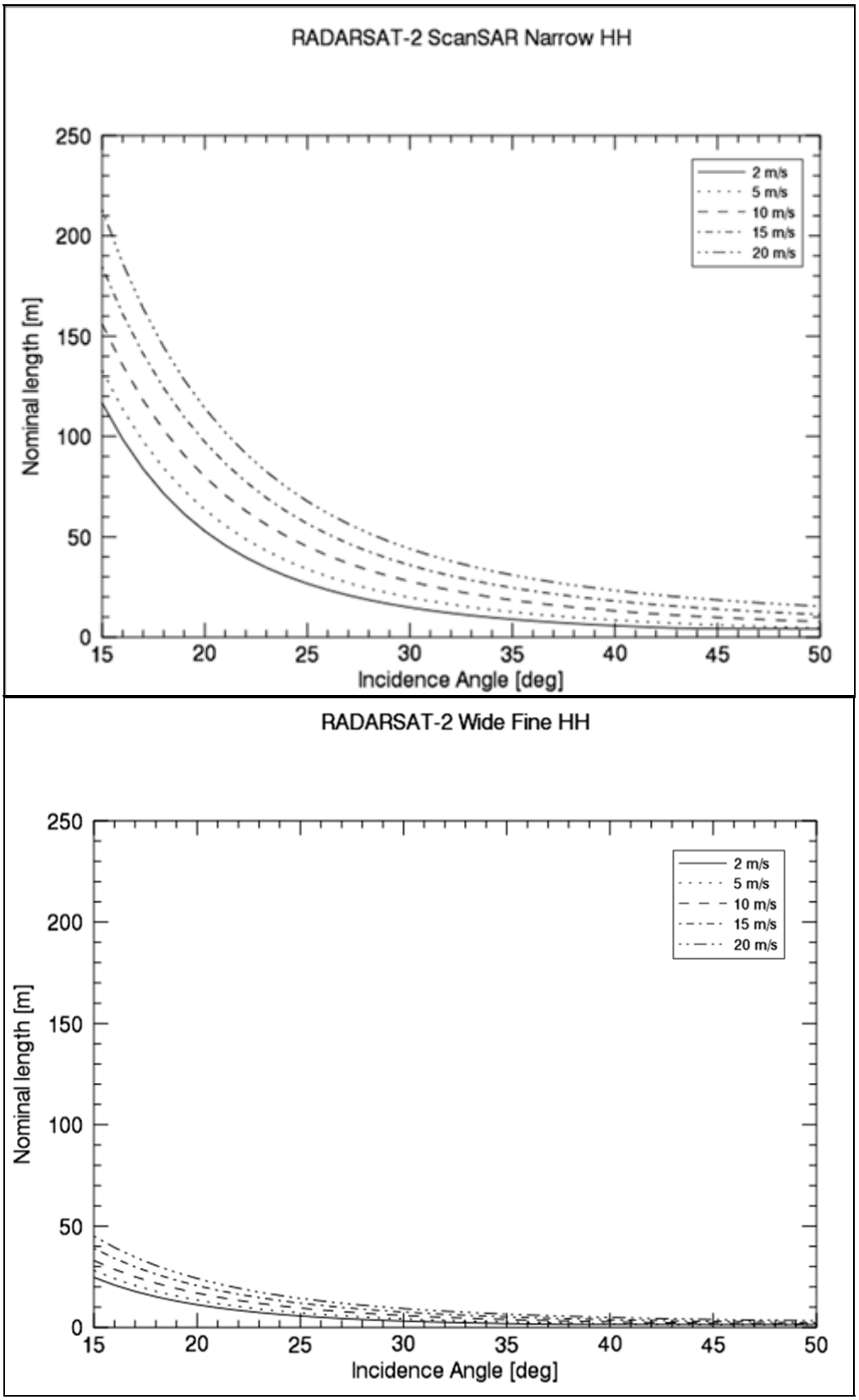

Figure 4.1 Nominal minimum detectable ship length depending on the incidence angle for HH-polarisation for RADARSAT-2 ScanSAR Narrow mode (50m resolution) at the top and RADARSAT-2 Wide Fine mode (10 m resolution) at the bottom. Five different graphs are shown for five different wind speeds from 2 m/s to 20 m/s.

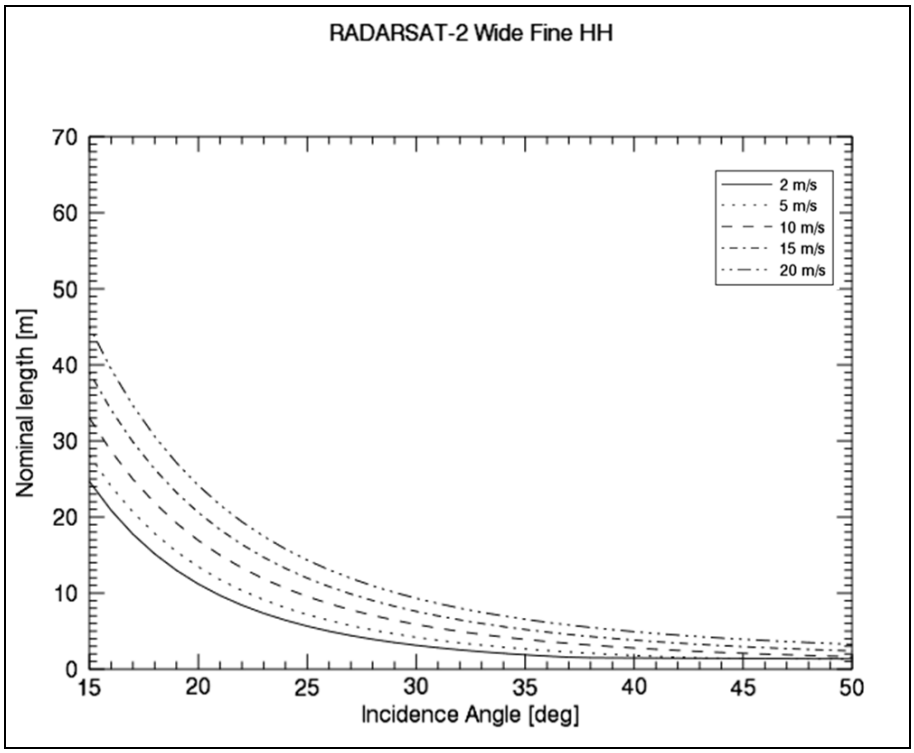

Figure 4.2 Nominal minimum detectable ship length as a function of incidence angle for HH-polarisation for RADARSAT-2 Wide Fine mode (10 m resolution). Five different graphs are shown for five different wind speeds from 2 m/s to 20 m/s.

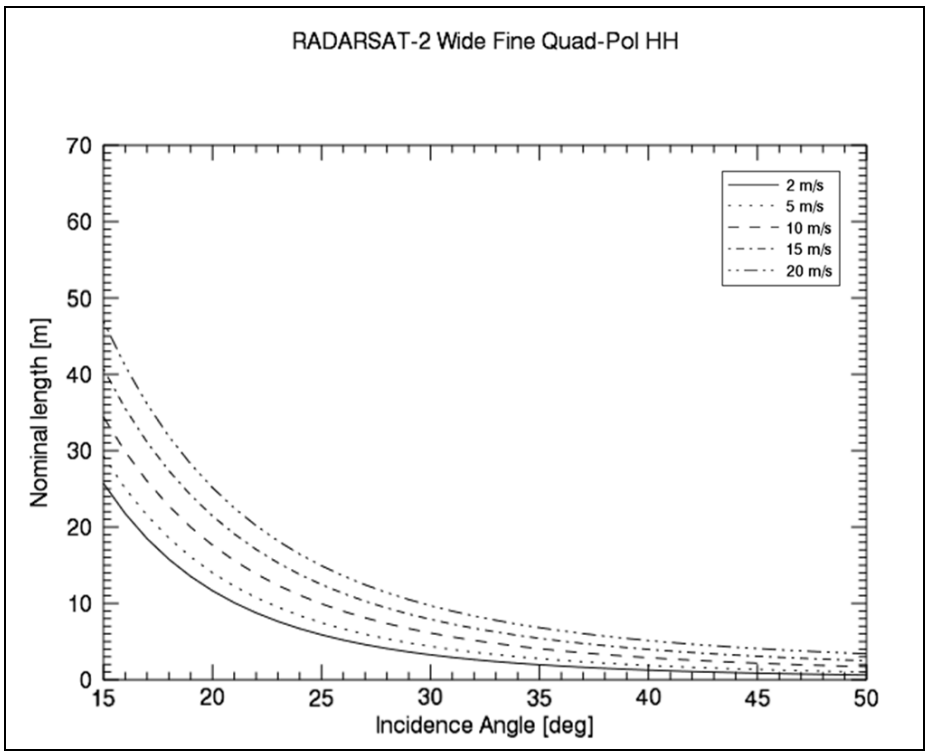

Figure 4.3 Nominal minimum detectable ship length as a function of incidence angle for HH-polarisation for RADARSAT-2 Wide Fine Quad-Pol mode (11 m resolution). Five different graphs are shown for 5 different wind speeds from 2 m/s to 20 m/s.

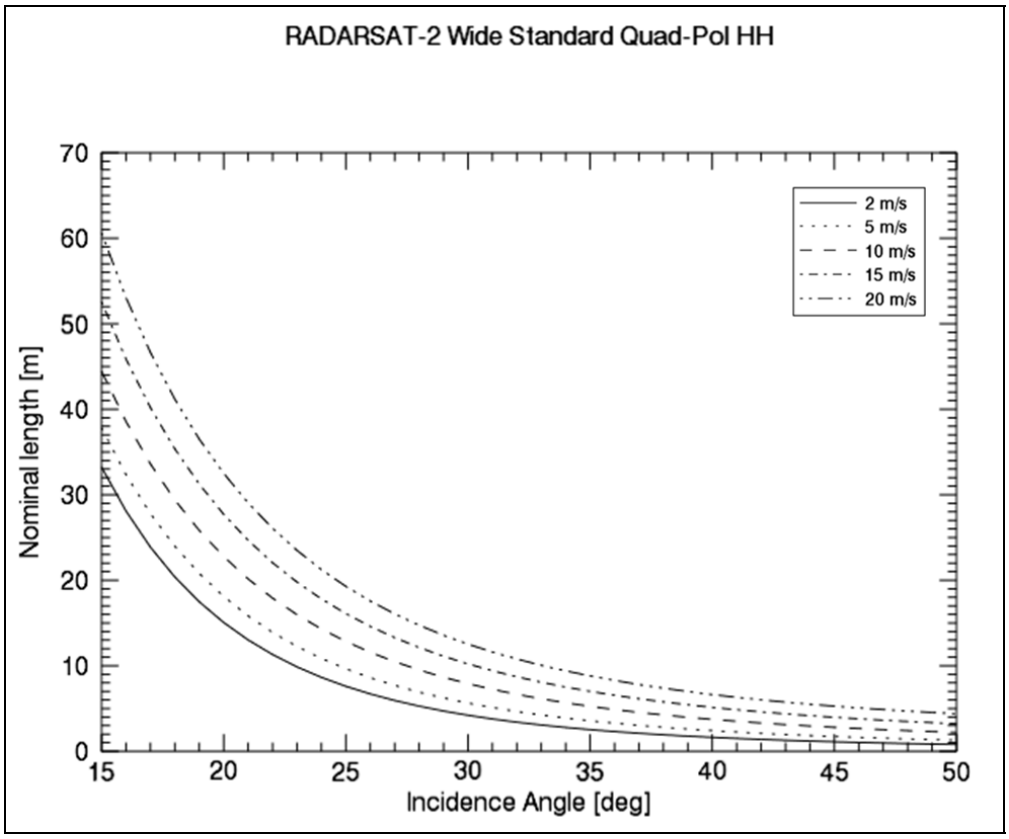

Figure 4.4 Nominal minimum detectable ship length as a function of incidence angle for HH-polarisation for RADARSAT-2 Wide Standard Quad-Pol mode (20 m resolution). Five different graphs are shown for five wind speeds from 2 m/s to 20 m/s.

5 Conclusion and recommendations

RADARSAT-2 provides new opportunities for spaceborne monitoring of vessel traffic and fishing activities. Due to user demand, five new modes were installed on the satellite in 2011. The new modes open up new opportunities to use high resolution and quad-pol images for operational ship detection due to the increased swath width and coverage area.

The RADARSAT-2 ScanSAR Wide and Narrow modes are the modes that are now daily used operationally in the Barents Sea. The RADARSAT-2 Wide Fine mode in dual-polarisation is the new mode that might be used operationally due to the wide swath width. It covers from 120 km to 170 km depending on the chosen incidence angle. Further tests should be done with RADARSAT-2 Wide Fine Mode (dual-pol) in the Barents Sea to evaluate image quality, advantages and limitations of this mode compared to RADARSAT-2 ScanSAR Narrow mode.

References

[1] T. N. A. Hannevik, "Evaluation of Radarsat-2 for ship detection," Forsvarets Forskningsinstitutt,FFI-rapport 2011/01692, Dec.2011.

[2] MacDonald Dettwiler and Associates Ltd., "RADARSAT-2 Product Format Description,"RN-RP-51-2713. Issue 1/7, Mar.2008.

[3] Christian Michelsen Research, "www.aisonline.com," 2010.

[4] T. R. Grønlien, "Deteksjon av punktmål ved hjelp av ScanSAR," Universitetet i Oslo, Hovedfagsoppgave i fysikk 1998.

[5] Canada Centre for Remote Sensing, "Fundamentals of Remote Sensing. A Canada Centre for Remote Sensing Tutorial.," Canada Centre for Remote Sensing,Dec.2011.

Acronyms

AIS	Automatic Identification System
Dual-pol	Dual-polarisation
EO	Earth Observation
ESA	European Space Agency
EU	European Union
FFI	Forsvarets Forskningsinstitutt
FOW	Wide Fine
GMES	Global Monitoring for Environment and Security
H	Horisontal polarisation
HH	Horisontally transmitted – Horisontally received polarisation
HV	Horisontally transmitted – Vertically received polarisation
KSAT	Kongsberg Satellite Services AS
MDA	MacDonald, Dettwiler and Associates Ltd
Pol	Polarisation
Quad-pol	Quad-polarisation
SAR	Synthetic Aperture Radar
Single-pol	Single-polarisation
V	Vertical polarisation
VH	Vertically transmitted – Horisontally received polarisation
VV	Vertically transmitted – Vertically received polarisation

Appendix A Definitions

Radiometric resolution	Sensitivity to detect small differences in reflected energy [5]
Spatial resolution	Size of the smallest possible feature that can be detected [5]