Miljø- og Planlægningsudvalget (2. samling)
MPU alm. del - Bilag 130
Offentligt

Online Environmental Surveillance

Test Report

Response vessel

Gunnar Seidenfaden

Q3 2007

Online Environmental Surveillance

Ørsted • DTU
Technical University of Denmark

To whom it may concern

December, 2007

Subject: OSIS

The Osis sensor system is based on one X-band low-power, short-range radar and a 36 GHz microwave radiometer. The radar will detect any spills day and night in all weather with good resolution and coverage. It will give a good overview over the surveyed area, and will detect thin as well as thick layers of oil. The microwave radiometer estimates the oil volume through the relation between sea surface brightness temperature and oil thickness and will in ideal cases detect oil films of a thickness larger than some 0.2 mm.

The two microwave sensors represent well known and proven technology, which has previously been operated successfully in airplanes designed to monitor offshore oil spills. The innovative application of the technology in the OSIS system provides a reliable, low cost alternative, which can be permanently installed on locations where online monitoring is relevant.

The OSIS sensor system has been subject to a comprehensive test programme, ranging from relatively controlled environments in swimming pools and harbours to realistic environments on a platform amidst the North Sea, and on the response vessel Gunnar Seidenfaden. In all cases known amounts of oil were spilled and subsequently detected and quantified by the sensor system. Detection capabilities were excellent and also quantification performed very well. In addition to the data analysis carried out and reported by OSIS international, a fully independent analysis was carried out on selected cases at the Technical University of Denmark. The findings of OSIS International were confirmed.

Yours sincerely

Niels Skou

Professor

Ørsted•DTU
Electromagnetic Systems

Ørsteds Plads
DTU - Building 348
DK-2800 Kgs. Lyngby
Denmark

Tlf +45 4525 3800
Tlf dir. +45 4525 3768
Fax +45 4593 1634

ns@oersted.dtu.dk
www.emi.dtu.dk
VAT reg. no. 63 39 30 10

TABLE OF CONTENT

Summary

The OSIS sensor system was developed as an efficient tool for naval pollution prevention by offering 24hours a-day surveillance against oil spills from offshore structures, ports and vessels within marine areas characterised as "Special Areas" by IMO.

The system has been further developed to enable installation on response vessels for enhancing the efficiency of contingency operations by identifying, tracking and quantifying in real-time the oil spill to be collected by the response vessels and then guide the vessels to the thicker part of the oil slick.

The objective of the final OSIS test programme in Q3 2007 has been to verify sensor performance after upgrading the system significantly to feature (1) fully automatic identification and quantification of oil on the water surface and (2) gyro compensation for vessel movements and geographic reference of the spill. The tests were carried out onboard the Danish environmental response vessel "Gunnar Seidenfaden" within Danish territorial waters.

During the final offshore vessel test programme 7.900 litres of margarine and rape seed oil was discharged in 5 controlled spills. They were all identified and tracked by the sensor and the response vessel was able to approach the spills appropriately using the OSIS Onsite Data Viewer. In all 5 test cases the polluted area was estimated and the discharged oil spill volume calculated with 6-95 percent deviation depending on weather conditions, time from discharge and distance to the spill. The thicker part of the oil spill were clearly differentiated and displayed by the system making recovery much easier.

The test program concluded that the OSIS Oil Spill Identification System is well suited for automatic monitoring of oil spills when mounted on response vessels and provides real time information with accuracy sufficient to estimate the scale of the oil spill and the position of the thicker layers of oil within the spill.

The system operates automatically, under all weather conditions, securing continuous cleanup operations day and night. In case of major oil pollution, this will enable highly efficient corrective actions and secure efficient deployment of onboard cleanup equipment.

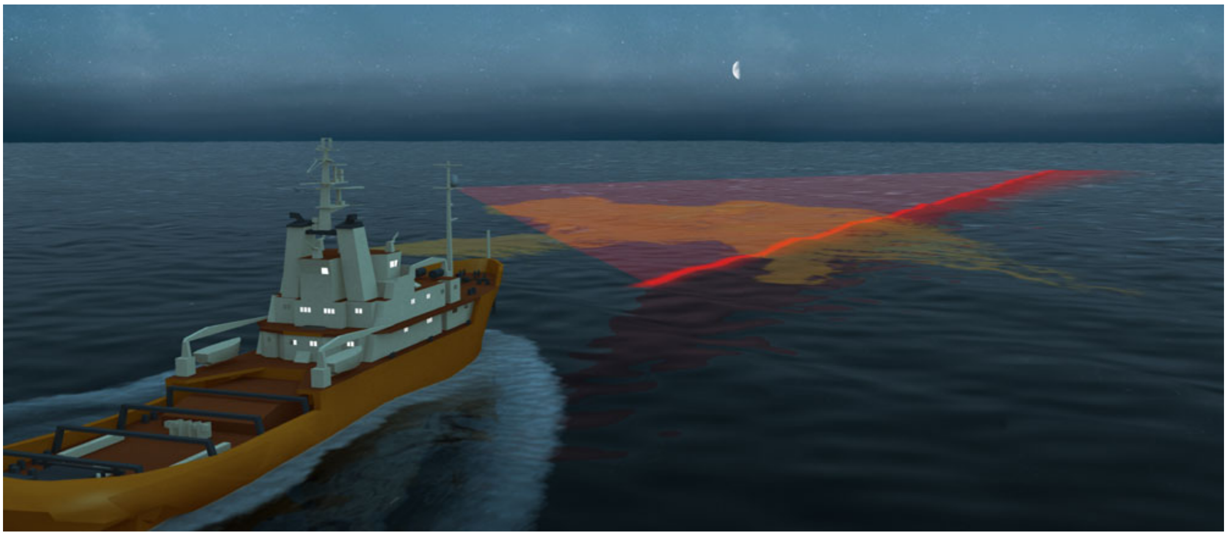
The OSIS system functionality and user interface, together with its ability to identify, locate thicker areas and quantify the spills are key factors in making the system a highly efficient tool to enhance operational efficiency during response operations.

The test programme and all test result has been verified by Professor Niels Skou, Electromagnetic Systems Department, Technical University of Denmark (Ørsted -DTU). The accreditation letter is inserted in the beginning of this document.

1 Introduction

The OSIS sensor was initially designed to provide an efficient tool for naval pollution prevention by offering 24hours a-day surveillance against oil spills from offshore structures and vessels operating within sensitive marine areas characterised as “Special Areas” by IMO. The sensor system has now been significantly modified to target installation on response vessels. The online environmental surveillance system used as a forward looking instrument during clean-up operations is illustrated in figure below.

The OSIS sensor is based on X band radar and dual Microwave radiometers which will identify oil films on the water surface as well as estimate oil spill layer thickness and calculate the minimum amount of oil discharged into the marine environment.



Sensor mounted on response vessel

During the development process a comprehensive test program has been completed. The final offshore vessel test programme was carried out during Q3 2007 on the Danish Navy response vessel “Gunnar Seidenfaden”.

This test report describes objective, test method and relevant conclusions following the final offshore vessel test. Test result related to earlier test sequences (2004-2005) are available in a separate test report.

2 Scale and Objective of the test program

The objective of the test program was to verify sensor performance and validate the ability to identify, track and quantify oil on the water surface together with the sensors ability to define the thicker parts within an oil spill.

As opposed to earlier tests, the final offshore vessel test verified the automated and gyro compensated sensor version specifically designed for response vessels. The best possible way to verify system functionality in a real life environment was to test the system when mounted on the response vessels “Gunnar Seidenfaden”.

OSIS Sensor – Test Program			
Date	**Test**	**Configuraton**	**Description**
Q3 2007	Offshore Vessel Test	Automated	Tests with Danish EPA on “Gunnar Seidenfaden”

Additionally, the objective of the offshore vessel tests carried out in Q3 2007 was not only to verify continuous technical performance and proof-of-technology. The tests were also carried out to verify the overall system functionality in a real maritime environment and to achieve proof-of-concept with a possible end-user.

Since the earlier offshore vessel test (Q2 2004) the system functionality has been significantly improved in relation to the following issues.

- **Wave compensation module**
  The implementation of the wave compensation module has provided a system robust to a moving installation sites. This means that the sensor can compensate for a vessels movement on the water surface and still position the scanned area accurately. This is a features which have been specifically designed for clean-up and response vessels.
- **Automated detection and quantification**
  In contrast to earlier tests, the system is now fully automated which mean that it will automatically detect and present sensor measurements on the screen. Improved software algorithms and the use of advanced filters have been applied. The automated data analysis process is further explained in appendix 1.
- **Onsite Data Viewer**
  The Onsite Data Viewer layout has been upgraded significantly and the system is now fully functional for use on oil spill response vessels. The presentation system has been updated to an extent where it can geographically refer an oil spill to a water surface while the vessel moves independently around the spill. This is specifically developed for response vessels to enhance efficiency during clean-up operations.

The tests are analysed and evaluated with respect to the following sensor system features:

1. **Oil Spill Identification and Tracking**
2. **Oil Spill Area estimate**
3. **Oil Spill Volume estimate**

The test results are listed for each test in accordance with the headings below. The test results are commented after each individual test.

Description of Headings	
Heading	**Description**
Date	Date of the spill
Test	Test number
Height	Height of the sensor above water level in meters
Start (GMT)	The time when the oil is discharged onto the water surface
Recorded Time	The time when the illustrated sensor reading is recorded – Rec.
Identify & Track	The oil slick is positively identified and tracked until drifting out of range
Polluted Area	Total Area identified by the sensor to be covered by oil or a film of oil
Discharged Volume	The actual amount of oil in liters discharged onto the water surface
Measured Volume	The amount of oil based on measured oil layer thickness within Base Area
Deviation	Deviation between discharged and measured volume of oil

3 Test Conditions

The sensor was mounted on a special plate welded to the front mast of “Gunnar Seidenfaden” (see the pictures below). The two different expeditions carried out in Q3 2007 are described below.

Expedition 1: Focused exercise North of Zealand
From July 2^{nd} to July 6^{th} 2007, OSIS took part in an expedition north of Zealand where a significant amount of margarine and rape seed oil was discharged in various quantities over a two day period. The tests were carried out by discharging predefined quantities of oil while the sensor continuously monitored the water around the vessel.

Expedition 2: Focused exercise North of Zealand
From September 17^{th} to September 21^{st} 2007, OSIS took part in an expedition north of Zealand where a significant amount of margarine and rape seed oil was discharged in various quantities over a two day period. The tests were carried out by discharging predefined quantities of oil while the sensor continuously monitored the water around the vessel.

During the test missions both margarine and rape seed oil were used. By using two different viscosities, oil slicks including both thicker and thinner layers could be generated for testing the system ability to track a large surface area as well as to quantify the oil slick.

Sensor installation in the front mast

Sensor installation in the front mast

The slicks were discharged in two sequences as illustrated in the picture below. As seen in the picture, the thick margarine (light yellow) was discharged, followed immediately by the thinner rape seed oil (dark yellow). This generated a large oil slick with a well defined core.

Margarine (light) discharged followed by rape seed oil (dark) during tests

Sensor in the front mast and measuring the oil on the water surface

An overview of the 5 tests carried out on “Gunnar Seidenfaden” is illustrated in the table below. The table summarizes the time and quantity of the spills.

Date	Test	Height	Start (GMT)	Discharged (l)	Wind (m/s)	Precipitation	Clouds
03.07.07	1	16 m	09.14	900	6-10	None	Light
03.07.07	2	16 m	11.56	1.000	2-7	None	Light
04.07.07	3	16 m	06.55	2.000	3-8	None	Light
17.09.07	4	16 m	16.38	2.000	0-3	None	Moderate
18.09.07	5	16 m	09.38	2.000	10-13	None	Moderate
Total				7.900			

Test Program, Outline and Conditions on “Gunnar Seidenfaden”

In line with earlier offshore tests, all measurements were logged and stored. The data will serve to continuously improve system performance and software algorithms.

To secure compliance between actual spill location and sensor system identification, a comprehensive mission planning procedure was applied. During each oil spill, the spill vas visually mapped out and compared with the corresponding sensor registration every 5 minutes during the missions. Apart from the first spill (test 1), all spills were logged both by camera pictures, hand drawings and screen dumps from the Onsite Data Viewer. For every screen dump from the Onsite Data Viewer a "real life" picture was taken of the spill. This enables the test crew to verify that the area presented as oil in the Data Viewer is in fact an accurate representation of the oil slick on the water surface.

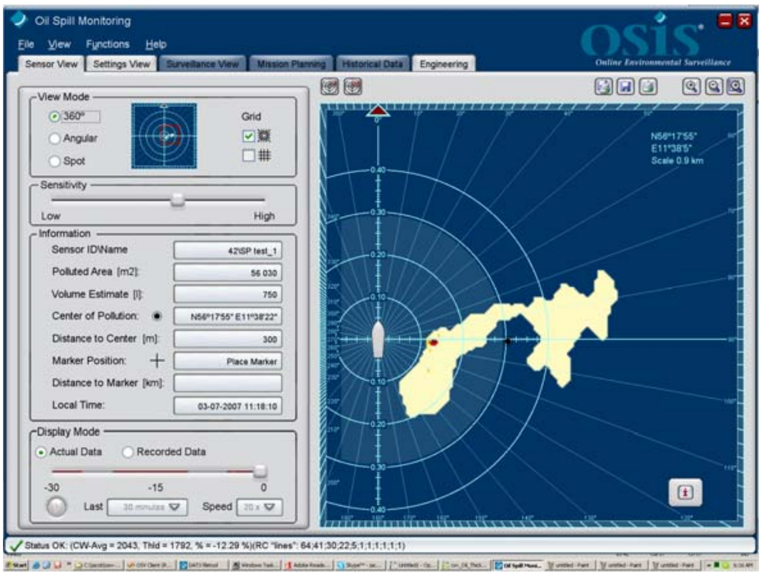
4 Test Results

To validate the ability to monitor and quantify volumes of oil using the proprietary Onsite Data Viewer, screen dumps from all 5 tests are presented in the following chapter with regards to the following subjects.

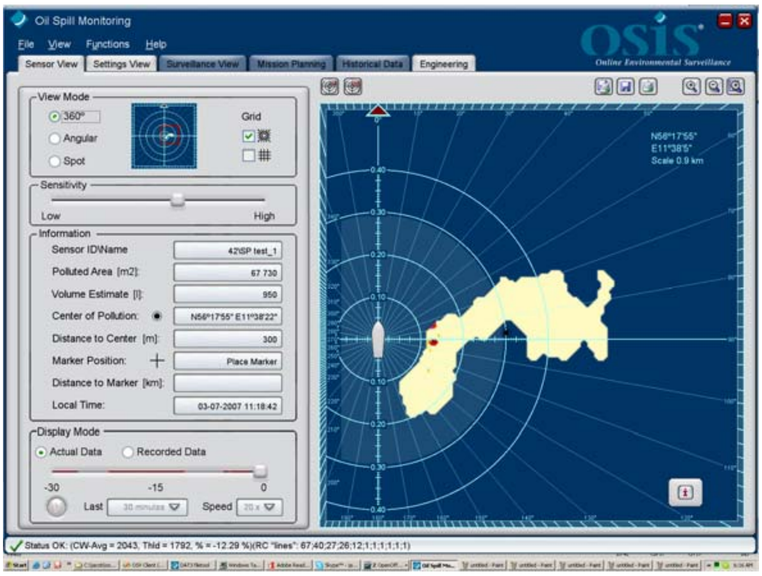
1. **Oil Spill Identification and Tracking**
2. **Oil Spill Area estimate**
3. **Oil Spill Volume estimate**

Test 1

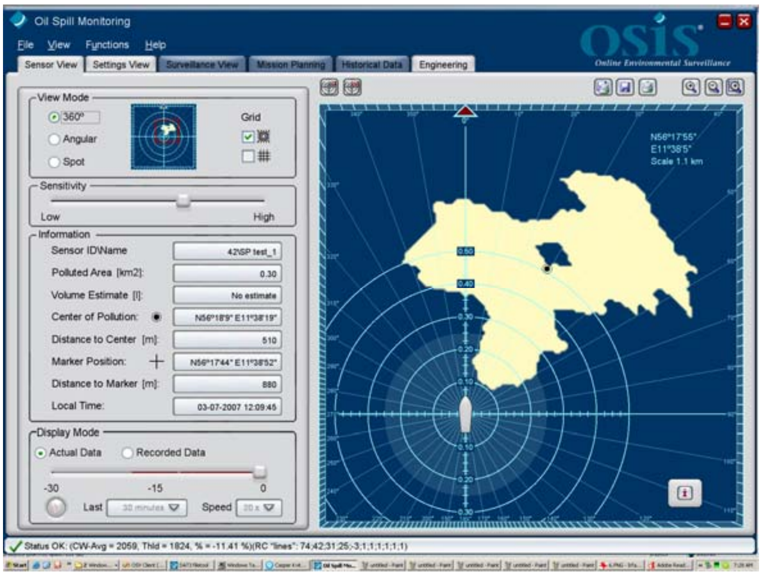
Test 1 was carried out under conditions with moderate winds and light clouds. Screen dumps from the Onsite Data Viewer are illustrated below. No mission planning drawings were made during this first test. The first two screen dumps are taken within the first 5 minutes of the spill and indicate oil thickness. The third screen dump is taken almost 1 hour after the spill and illustrates the polluted area at a distance of up to 1km.



Test 1 – 03.07.07 – 09.18 (GMT)



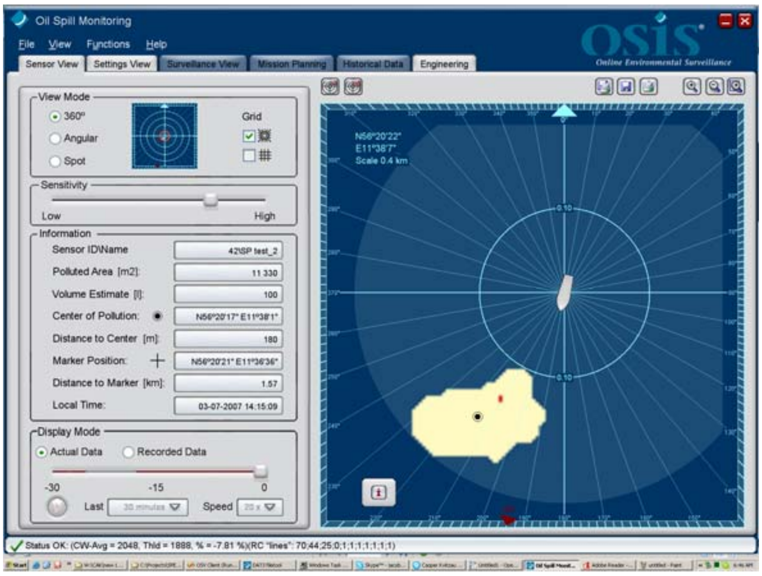
Test 1 – 03.07.07 – 09.18 (GMT)

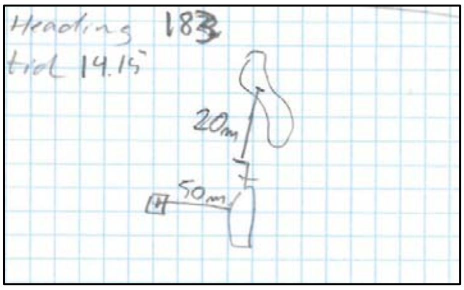


Test 1 – 03.07.07 – 10.09 (GMT)

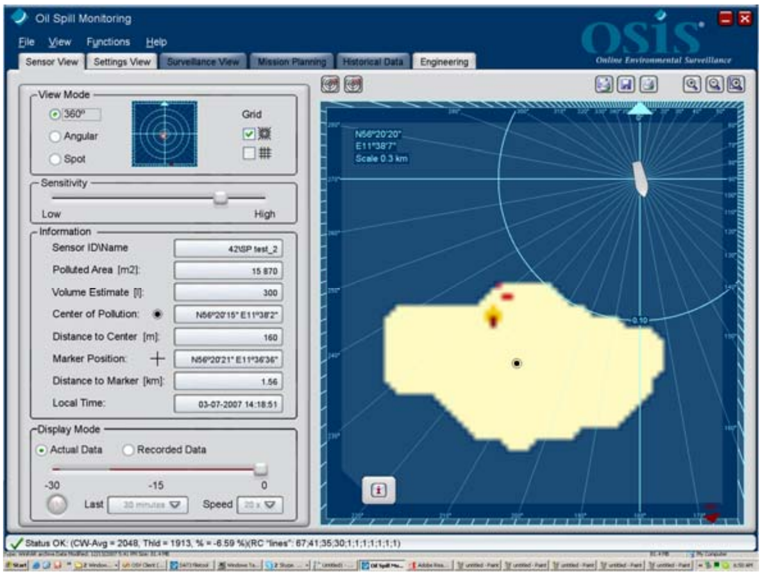
Test 2

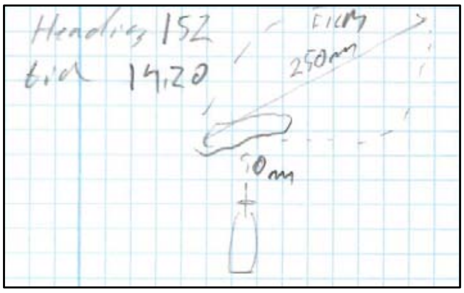
Test 2 was carried out under conditions with light winds and light clouds. Screen dumps from the Onsite Data Viewer are illustrated below together with the mission planning drawings from the particular spill. Although, the screen dumps below are taken between 20 and 25 minutes after the spill was discharged, the thicker parts of the oil slick are still illustrated.





Test 2 – 03.07.07 – 12.15 (GMT)

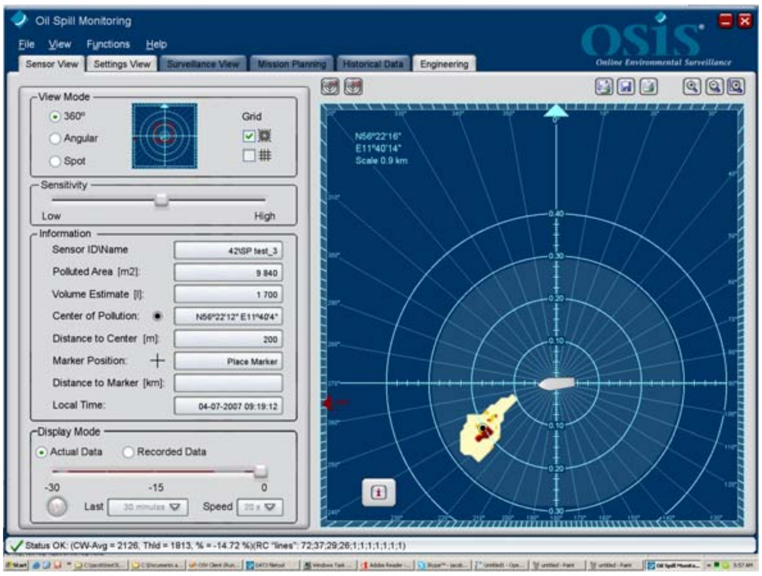


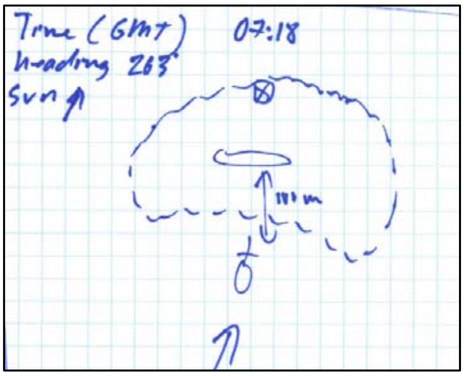


Test 2 – 03.07.07 – 12.18 (GMT)

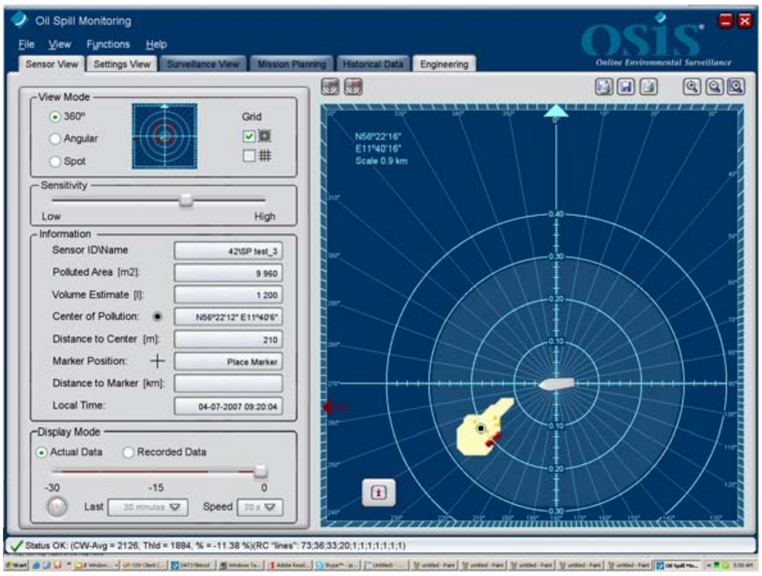
Test 3

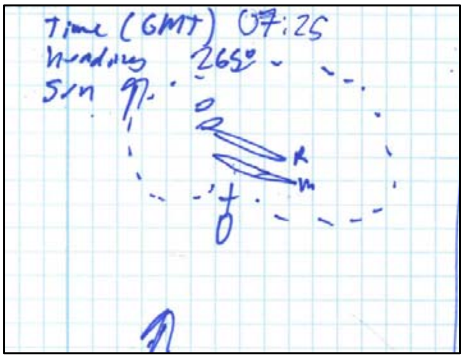
Test 3 was carried out under conditions with light winds and light clouds. Screen dumps from the Onsite Data Viewer are illustrated below together with the mission planning drawings from the particular spill. The thicker parts of the oil slick are clearly illustrated in the first two screen dumps below. The latter screen dump, taken more than 1 hour after the spill was discharged, does not provide thickness indication, only the polluted area.



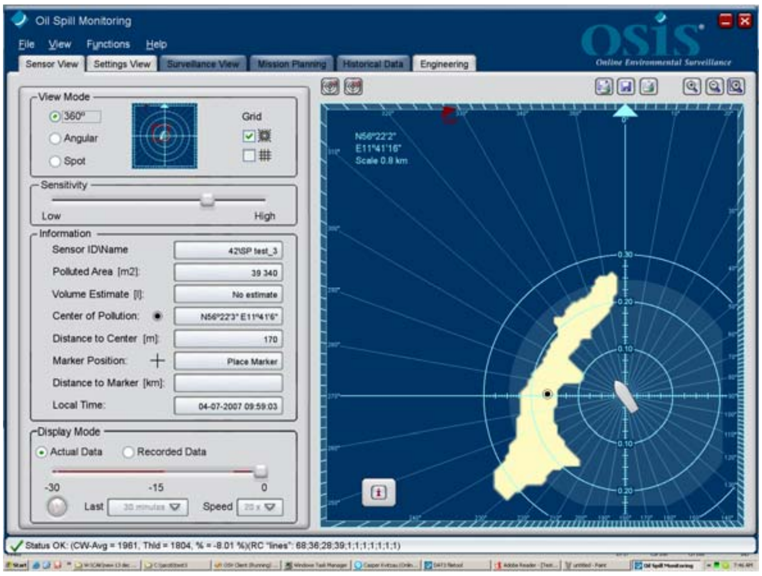


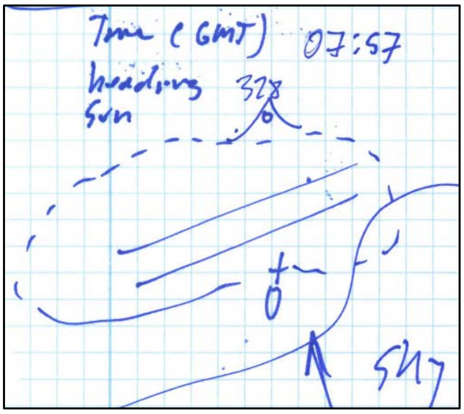
Test 3 – 04.07.07 – 07.19 (GMT)





Test 3 – 04.07.07 – 07.20 (GMT)

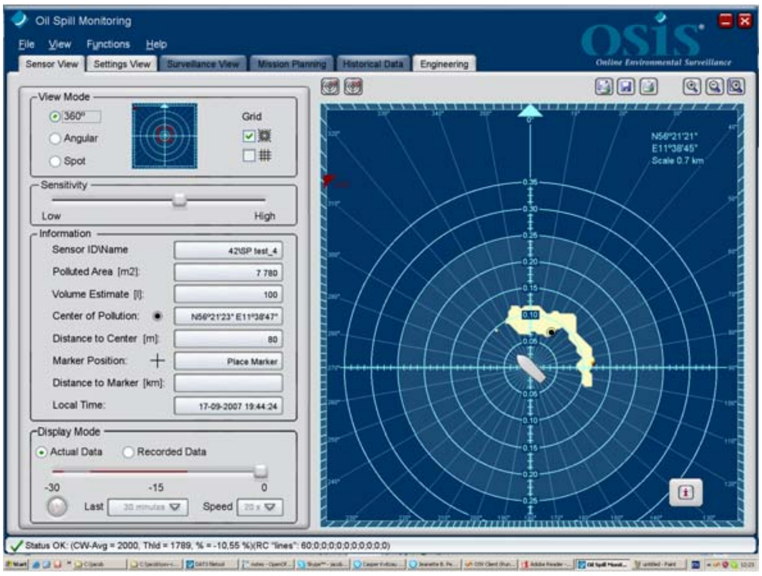


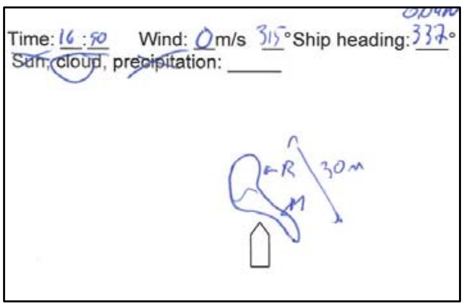


Test 3 – 04.07.07 – 07.59 (GMT)

Test 4

Test 4 was carried out under conditions with very low winds and moderate clouds. A screen dump from the Onsite Data Viewer is illustrated below together with the mission planning drawings from the particular spill. After the first couple of minutes, the wind totally disappeared which made the detection of oil using the radar very difficult as the radar will not pick up any backscatter. However, we were able to make the screen dump below in the beginning of the spill and relied on the microwave radiometer which performs well during calm conditions.

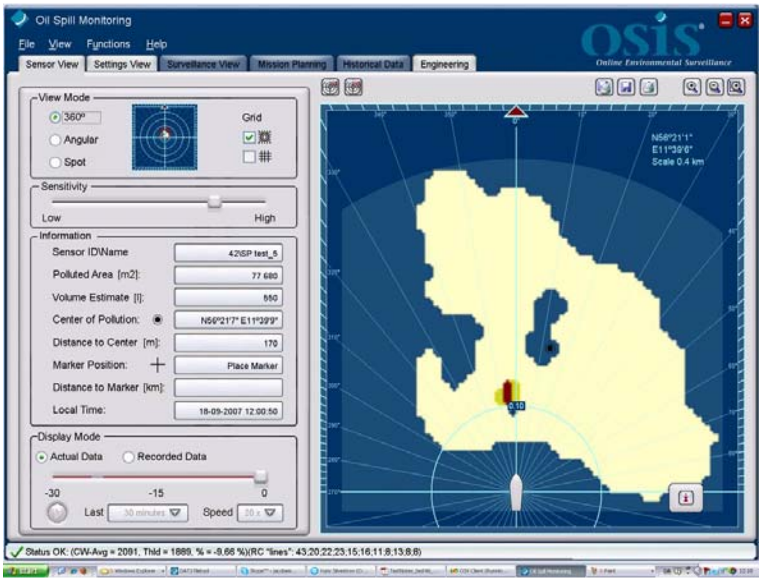


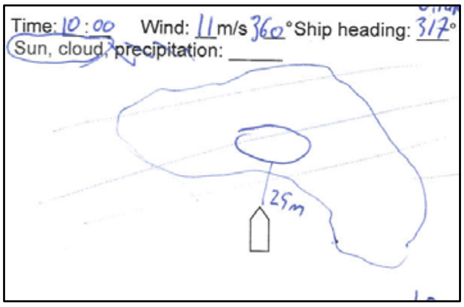


Test 4 – 17.07.07 – 16.44 (GMT)

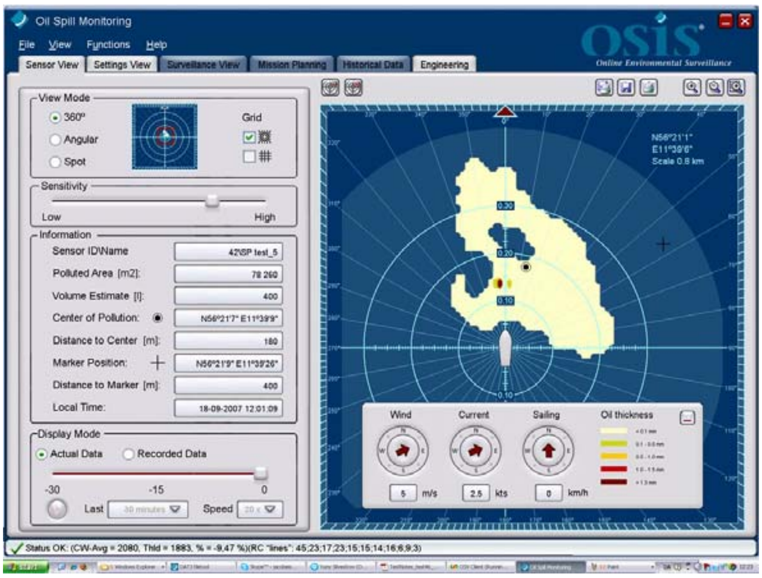
Test 5

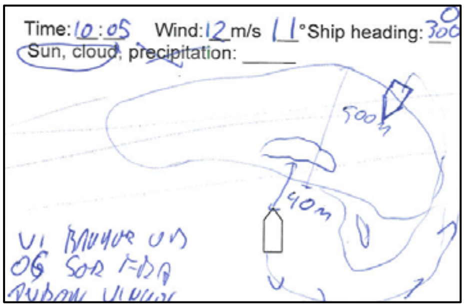
Test 5 was carried out under conditions with high winds and moderate clouds. Screen dumps from the Onsite Data Viewer are illustrated below together with the mission planning drawings from the particular spill. In the first two screen dumps, taken 22-33 minutes after the spill was discharged, the thicker parts of the spill are clearly seen. The third screen dump taken almost 1 hour after the spill was discharged states the polluted area at a distance of more than 750 m.



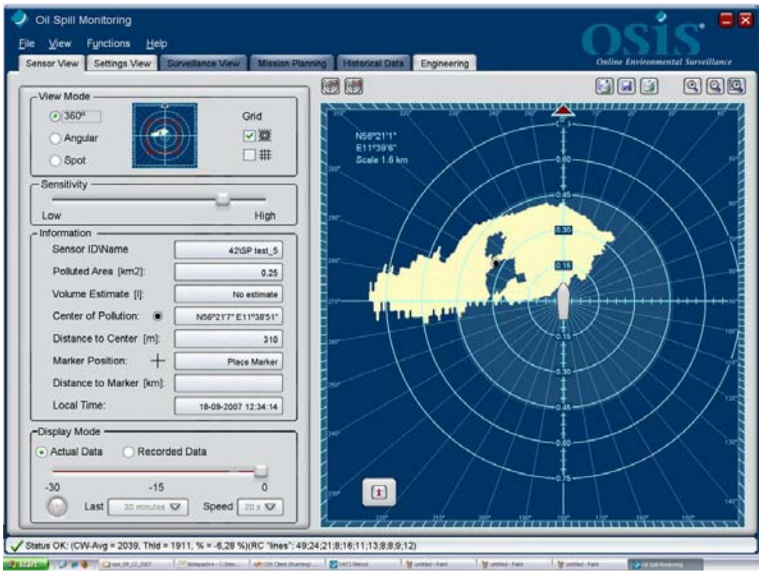


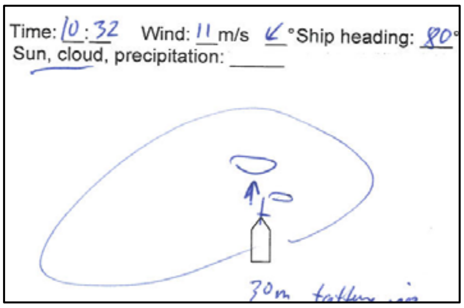
Test 5 – 18.09.07 – 10.00 (GMT)





Test 5 – 18.09.07 – 10.01 (GMT)





Test 5 – 18.09.07 – 10.34 (GMT)

The table below summarizes the test data for the spills discharged during the two missions in Q3 2007. A comparison between discharged and measured amount of oil is presented as well as the polluted area associated with the spill. The method of calculating the oil volume from the test sequences is described in appendix 1.

Date	Test	Height	Start (GMT)	Rec. (GMT)	ID.	Area estimate	Volume estimate (l)		
						Polluted Area	Discharged	Meas.	Dev.
03.07.07	1	16 m	09.14	09.18	OK	56.030 m2	900	750	17%
03.07.07	1	16 m	09.14	09.18	OK	67.730 m2	900	950	6%
03.07.07	1	16 m	09.14	10.09	OK	0,300 km2	900	n/a	n/a
03.07.07	2	16 m	11.56	12.15	OK	11.330 m2	1.000	100	90%
03.07.07	2	16 m	11.56	12.18	OK	15.870 m2	1.000	300	70%
04.07.07	3	16 m	06.55	07.19	OK	9,840 m2	2.000	1.700	15%
04.07.07	3	16 m	06.55	07.20	OK	9.960 m2	2.000	1.200	40%
04.07.07	3	16 m	06.55	07.59	OK	39.340 m2	2.000	n/a	n/a
17.09.07	4	16 m	16.38	16.44	OK	7.780 m2	2.000	100	95%
18.09.07	5	16 m	09.38	10.00	OK	77.680 m2	2.000	550	72%
18.09.07	5	16 m	09.38	10.01	OK	78.260 m2	2.000	400	80%
18.09.07	5	16 m	09.38	10.34	OK	0,250 km2	2.000	n/a	n/a

Oil Spill Identification, Area estimate and Volume estimate

5 Comments on Test Results

In the following, the test results illustrated above are commented as regards Identification and Tracking, Area Estimate and Volume Estimate.

Oil Spill Identification and Tracking

All spills were positively identified and tracked. The oil was observed on the Onsite Data Viewer for a significant amount of time and tracking was verified up to a distance of 1km, after which the test sequences were ended. Earlier tests have verified that the oil can be detected at a range of up to 1NM when mounted in 16 meters height on a response vessel. The gyro compensated sensor proved to be appropriate for response vessels as the oil was placed and visualized in the Onsite Data Viewer independently of how the response vessel moved around the spill. On several occasions, the spill visualized on the Onsite Data Viewer was used to navigate the vessel towards the spill and place the vessel in the appropriate position for cleanup operations.

Oil Spill Area estimate

The polluted area from all the spills was detected and measured. For the illustrated spills the polluted areas were estimated to between 9.840 m2 and 300.000 m2. This was in line with crew observations and the GPS fix points used. The polluted areas are clearly seen on all the screen dumps above. Generally, the areas increased in size as the time went by and the oil layer continuously got thinner.

Oil Spill Volume estimate

In Test 1, a total of 900 liters rape seed oil was discharged on the starboard side of the vessel. The sensor recordings provided an estimate of volumes of 750 liters and 950 liters shortly after the spill was discharged. The result is between 6% and 17% deviation from the actual amount discharged which is within expectations for normal operations in good weather conditions.

In Test 2, a total of 1.000 liters of margarine was discharged on the starboard side of the vessel. The sensor recordings provided volumes estimate of 100 liters and 300 liters retrospectively 20 and 25 minutes after the spill was discharged. The result derivates 70% to 90% from the actual amount discharged which reflects the long time from discharge and the corresponding rapid spreading of the high viscosity oil. In this context, the result is within expectations.

In Test 3, a total of 1.000 liters of margarine and 1.000 liters of rape seed oil were discharged on the starboard side of the vessel. The margarine and the rape seed oil was not fully detached and drifted apart causing the sensor to estimate volumes of 1.700 liters and 1.200 liters approximately 20 minutes after the spill was discharged. The resulting deviation of 15% to 40% from the actual amount discharged is within expectations.

In Test 4, a total of 1.000 liters of margarine and 1.000 liters of rape seed oil were discharged on the starboard side of the vessel. The sensor recordings provided an estimate of volumes of 100 liters shortly after the spill was discharged. This test was carried out under very difficult conditions in that the wind speed was 0 m/s. When the water surface is completely flat, the radar part of the sensor system does not detect the oil, leaving the volume calculation to the Microwave radiometer which by definition under estimates. Taking the weather situation into account, the mere fact that we were able to make a screen dump with oil thickness indication based exclusively on Microwave radiometer measurements is very satisfactory.

In Test 5, a total of 1.000 liters of margarine and 1.000 liters of rape seed oil were discharged on the starboard side of the vessel. The sensor recordings provided an estimate of volumes of 550 liters and 400 liters approximately 22 and 23 minutes after the spill was discharged. This indicates that the rape seed oil had already drifted into a thin film on the water surface and that half of the 1.000 liters of margarine had still not drifted into a thin film. Bearing in mind that the measurements are 22 and 23 minutes after the spill was discharged the results between 72% and 80% deviation from the actual amount discharged are within expectations.

6 Conclusions

The results from the final tests verified that the OSIS sensor system mounted on a response vessel is a fully functional tool for oil spill identification and quantification during cleanup operations. The deviations from the actual amounts discharged are found to be within expectations.

The system was able to clearly identify the thicker parts of the oil slicks thereby providing valuable information for the crew onboard the response vessel during cleanup operations. This significantly enhances the efficiency of existing contingency equipment in that cleanup operations can be initiated where the oil layer is the thickest.

Captain inspecting the Onsite Data Viewer onboard "Gunnar Seidenfaden"

The results from the test program carried out together with the Danish Navy and their response vessel "Gunnar Seidenfaden" can be summarized as:

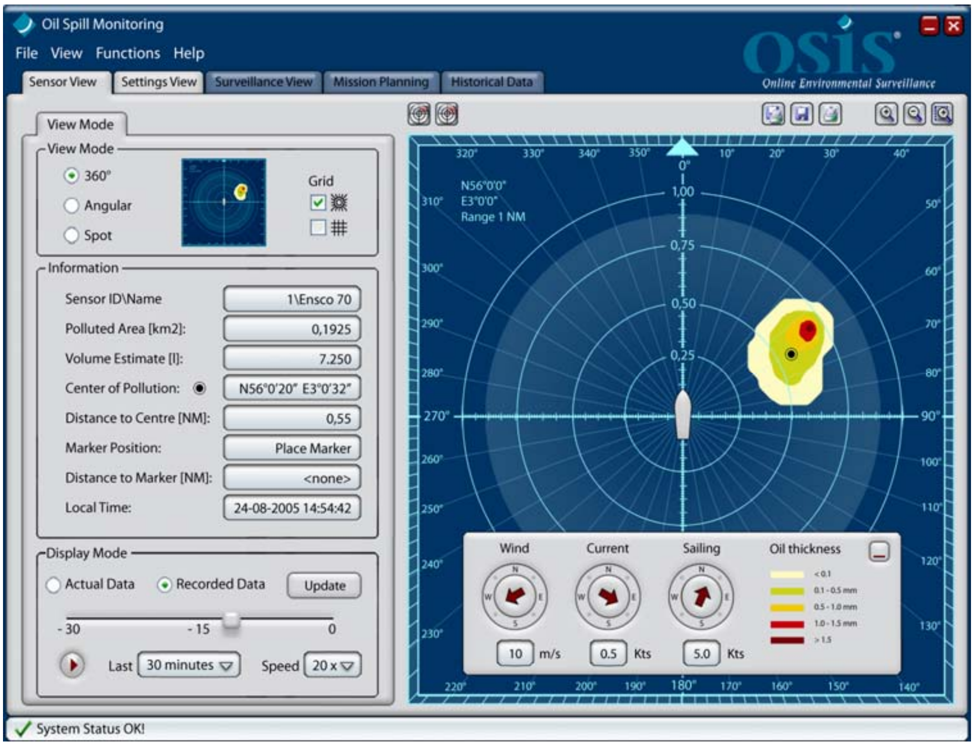
- Proof of Concept using SP 1.6 (short range)
- Proof Of Short range system performance (1km)
- Oil spill surface area identified with high accuracy
- Oil spill layer thickness identified from 0.1mm to 1.5mm
- Oil spill Volume estimated with 6-95 percent deviation. Deviation caused by weather conditions, time from discharge and distance to the spill

The OSIS sensor system could identify and track the oil slick in all 5 test cases. In all 5 tests completed, the polluted area and spill volumes were automatically detected and quantified by the Onsite Viewer. Tracking of the oil was verified at distances up to 1km.

The OSIS system functionality and user interface, together with its ability to identify, locate thicker areas and quantify the spills are key factors in making the system a highly efficient tool to enhance operational efficiency during response operations.

Appendix 1 – Automated Data Analysis

The OSIS SensorPack and the corresponding OSIS Onsite Data Viewer can be installed where the risk of oil spill pollution is presumed substantial. The product can be used on a broad range of structures including offshore structures, commercial vessels, tanker loading sites, harbor protection, desalination plants, vessel emission control and clean-up operations.



OSIS Onsite Data Viewer

The OSIS Onsite Data Viewer provides real-time information in the sensor modes selected on the screen. The contaminated area and volume is displayed with other essential information. The latest hour of recordings is stored automatically and can be replayed upon request.

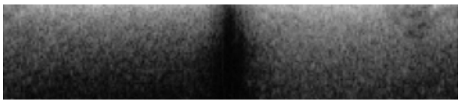
The functionality of the Onsite Data Viewer has been developed together with potential end users including the Danish Navy.

The Oil Spill Detection (OSD) module used to identify and quantify oil on the sea surface is a proprietary system developed in-house. In order to identify oil in the raw data a long list of sequences are done to extract the information needed. Different filters are used to clean up the raw material and intelligent parallel processes are carried out to determine whether or not oil is within sensor range.

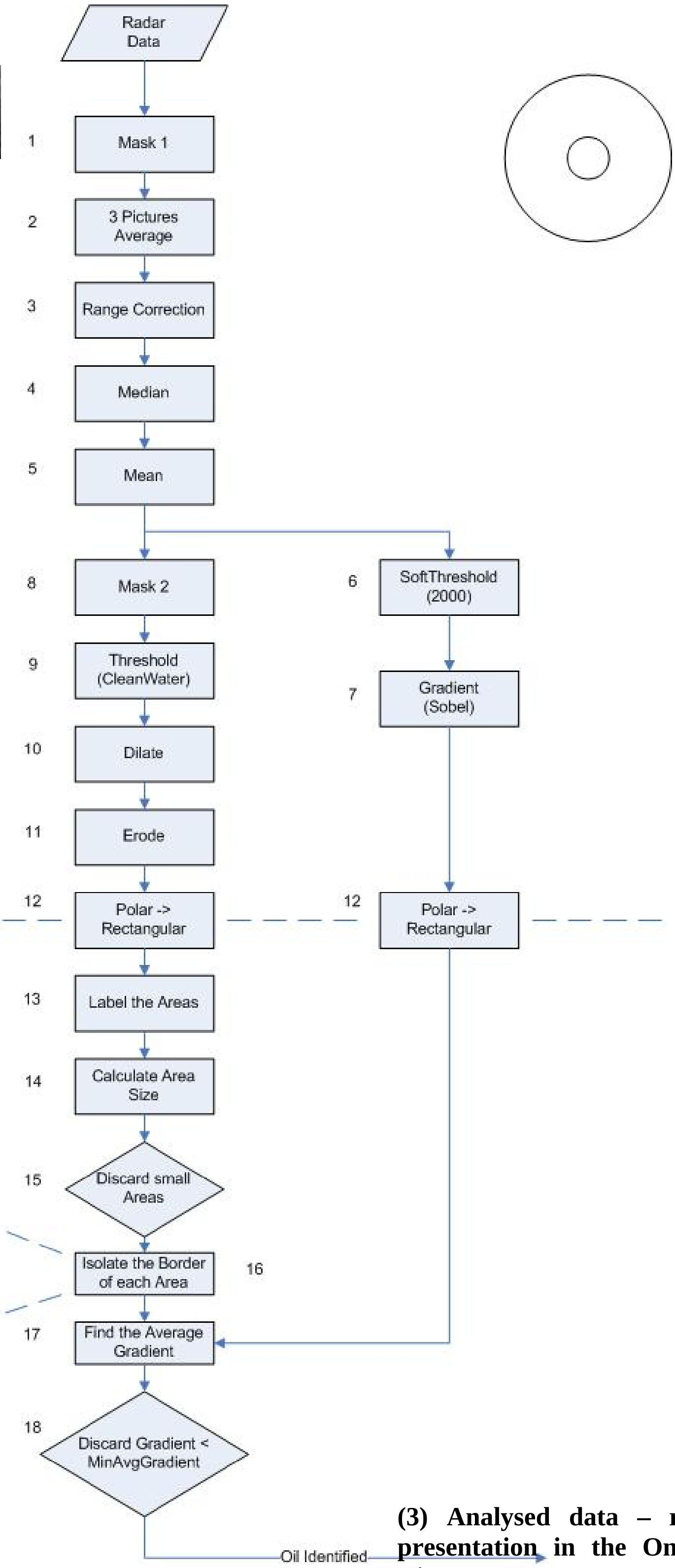
Below is illustrated a diagram showing the different sequences that are carried out automatically during the data analysis going from raw data as recorded by the sensor to analysed data visualised and presented using the Onsite Data Viewer illustrated above.

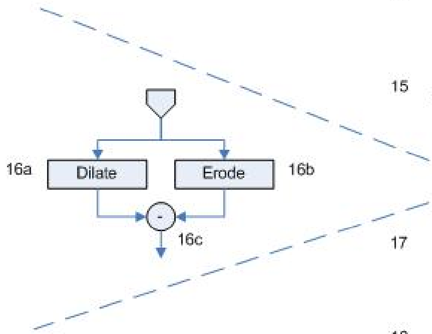
OSD module, Data analysis sequences

(1) Raw Data



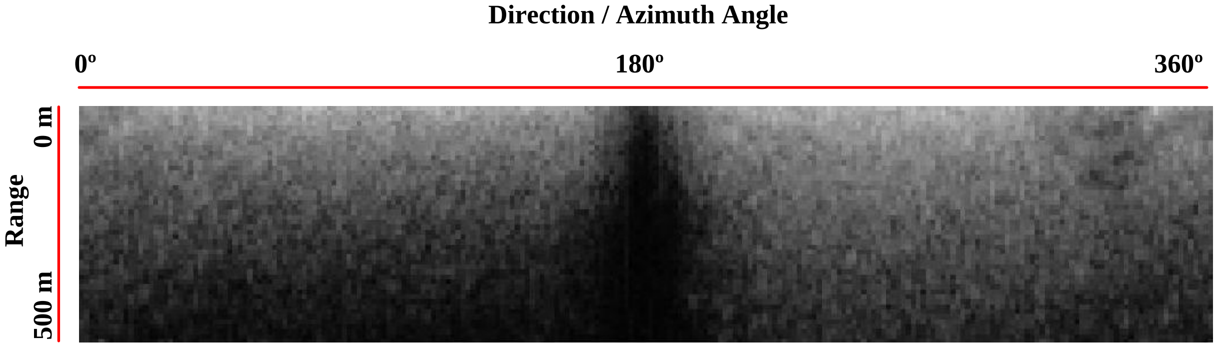
(2) Data filtered and Range corrected



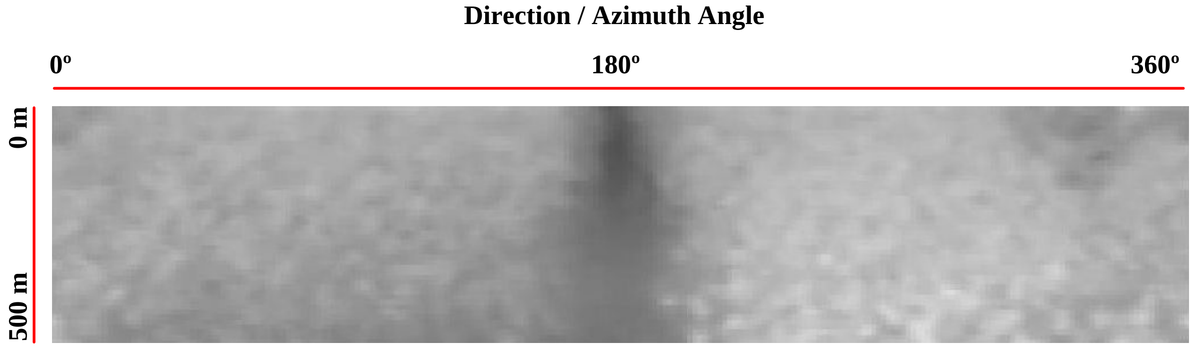


(3) Analysed data – ready for presentation in the Onsite Data Viewer

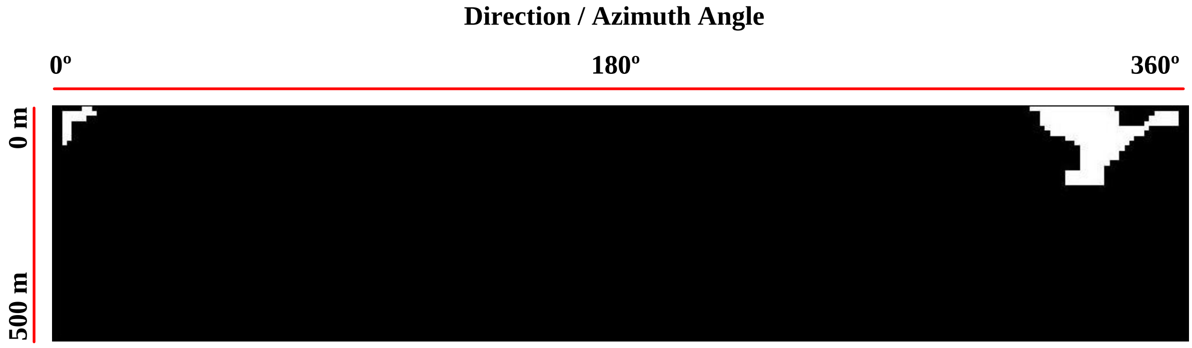
In order to illustrate the effect from the data analysis carried out above, real data pictures of selected steps are visualised below using Matlab. However, it is important to emphasise that the user of the system does not have access to these data. Everything is calculated and analysed before the information is presented in the Onsite Data Viewer. The illustrations below are presented in rectangular grid whereas the data presented in the Onsite Data View is presented intuitively in a polar grid.



(1) Raw data



(2) Data filtered and range corrected



(3) Analysed data – ready for presentation in the Onsite Data Viewer