USING AIR- AND SPACEBORNE REMOTE SENSING DATA FOR THE OPERATIONAL OIL SPILL MONITORING OF THE GERMAN NORTH SEA AND BALTIC SEA

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ABSTRACT:

Accidental or operational marine oil discharges have a strong impact on the marine wildlife, marine habitats, the economy and the public health. To detect oil spills and to guide combating efforts airborne remote sensing data is used. The German airborne surveillance system consists of two Do 228212 aircraft equipped with a Side Looking Airborne Radar (SLAR), an IR/UV Sensor, a Microwave Radiometer (MWR), a Laser-Flurosensor and a Forward Looking Infrared Camera.

Currently spaceborne remote sensing data is not operationally used for oil spill monitoring in Germany. To investigate if satellite data can enhance the operational oil spill surveillance in the German Exclusive Economic Zone (EEZ) in the North Sea and Baltic Sea a combined aircraft and satellite (Radarsat-1 and Envisat ASAR) oil spill surveillance campaign was conducted. The results allow a direct comparison between airborne and spaceborne oil spill monitoring. Possible oil slicks were announced within 1 hour after the satellite overpass. The spatial and temporal coverage of the satellites were analysed. A statistical analysis of the oil spill detection results was conducted.

During the campaign 97 possible oil slicks were detected by satellite but not all of the detected oil slicks could be checked by the aircraft (e.g. out of range, bad weather). From the 61 checked oil slicks 34 (56%) could be verified and 27 (44%) were false positives.

The spatial coverage of the SLAR on the different pollution control flight routes ranges from 33% – 65% in the North Sea and over 93% in the Baltic Sea. During one year only 32 RADARSAT-1 and 20 ENVISAT images cover the EEZ in the North Sea more than 95%. The EEZ in the Baltic Sea is covered more than 95% by 30 RADARSAT-1 and 52 ENVISAT images. A daily coverage of the territorial waters of Germany is not possible.

The integration of satellite SAR observation may strengthen the operational oil spill surveillance in terms of a exhaustive spatial coverage of the territorial areas. This requires a continuos coordination of the satellite overpasses and the schedule of the aerial surveillance flights

1. INTRODUCTION

Accidental or operational marine oil discharges from vessels have a strong impact on the marine wildlife, marine habitats, the economy and the public health. Oil tanker accidents (e.g. Prestige) receive much attention in the media and the public but a large amount of oil is also discharged from vessels during their operation. The 3 main sources of illegal operational oil pollution from ships are ballast water, tank washing and engine room effluent discharges (Pavlakis et al., 2001).

The North Sea and Baltic Sea are identified as “Special Sea Areas” according the MARPOL 73/78 convention. Within these areas the discharge of oil or oil mixture from ships is completely prohibited, with minor and well defined exceptions.

2. THE GERMAN AERIAL SURVEILLANCE SYSTEM

In the year 1986 the German Federal Ministry of Transport set up an airborne surveillance system for monitoring the German territorial waters in the North Sea and Baltic Sea for oil discharges and marine pollution. Currently the system consists of two Fairchild/Dornier Do 228-212 aircraft (figure 1) equipped with a sophisticated sensor system consisting of a side-looking airborne radar (SLAR), an Infrared/Ultraviolet scanner (IR/UV scanner), a microwave radiometer (MWR), a laser-fluoro-sensor (LFS) and photographic and video cameras. The maximum endurance time of the aircraft is 5.5 h. The cruising speed is 200 knots which allows a maximum range of approx. 2000 km. The aircraft are operated by the Third Naval Air Wing.

Figure 1. Do 228-212 aircraft

The SLAR is the primary sensor for long-range detection of oil slicks on the sea surface (swath width approx. 60 km). The radar transmits high-frequency pulses in the X-band (9.4GHz) perpendicular to the flight direction to both sides of the aircraft. The short range IR/UV scanner scans the sea surface below the

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aircraft line by line in the ultraviolet (λ = 320 nm to 380 nm) and in the thermal infrared (λ = 8.5 µm to 12.5 µm). The MWR is a passive, short-range sensor operating on three channels (18.7 GHz, 36.7 GHz, 89 GHz) and is used to measure the oil layer thickness. The LFS is an active, short range sensor used to specify the oil type and the layer thickness. To collect evidence concerning possible polluters a photographic and video camera are used. Detailed descriptions of the sensors are given by Trieschmann et al. 2001 and Trieschmann et al. 2003. Details of the sensors are depicted in table 1. The most important features of the sensors are highlighted in grey.

Table 1. Characteristic properties of the sensors

	SLAR	UV	IR	MWR	LFS
Range @ 300m flight altitude	wide, ±30km	narrow, ±250m			narrow, ±75m
Classification capabilities	no				yes
Sensitivity on oil film thickness	N.A.	>0.1µm	>10µm	50µm to 2.5mm	0.1 µm to 20 µm
Spatial resolution	60m by 30m (perp.)	3.5m	3.5m	>5m	10m pixel-to-pixel distance
Detection of oil spills below surface	no				yes
Operating at night	yes	no	yes	yes	yes
Film thickness determination	no			yes, 50µm to 2.5mm	yes, 0.1 µm to 20 µm
Measuring geometry	Line-by-line				Conical, 5Hz
Impaired by	no	clouds	clouds	no	clouds, flight altitude

The German Exclusive Economic Zone (EEZ) is depicted in Figure 1. The EEZ in the North Sea is monitored on 11 different flight routes. Assuming a SLAR swath width of 60 km between 33% and 65% of the EEZ is covered during the surveillance flights. The EEZ in the Baltic Sea is monitored on 2 flight routes. Over 93% of the EEZ is covered on both flight routes. On average 2 surveillance flights a conducted each day.

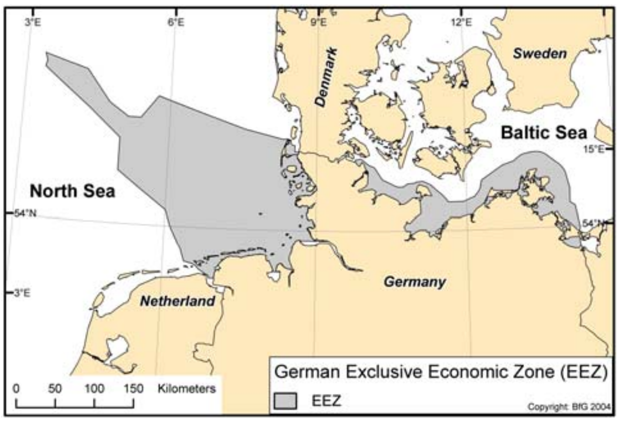

Figure 1. The German EEZ

3. COMBINED SATELLITE/AIRCRAFT CAMPAIGN

In 2003 a 5 month oil spill monitoring campaign using satellite data in near real time and aerial surveillance was conducted. This campaign was part of the EU funded project OCEANIDES.

RADARSAT-1 ScanSAR Narrow images and ENVISAT ASAR Wide Swath images (Table 2) were acquired, processed and visually analysed for oil slicks by Kongsberg Satellite Services AS (KSAT, Tromsø, Norway).

Table 2. Specifications for RADARSAT-1 and ENVISAT ASAR imagery (ESA, 2002 and RSI, 1999)

	RADARSAT-1 ScanSAR Narrow	ENVISAT ASAR Wide Swath
Spatial resolution [m]	50	150
Nominal area covered [km]	300 x 300	400 x 400
Polarisation	HH	VV

For satellite evaluation the combined aircraft/satellite campaign was conducted by using the following procedure:

1. The aircraft will take off at the time of the satellite overpass to be at the centre of the EEZ at the time the satellite analysis will be avaiable.
2. Max. 60 minutes after the overpass KSAT will inform the German Pollution Control Authority by phone and report: position, area and the confidence of the slick (Low, Medium or High)
3. The crew onboard the aircraft will immediately be informed by radio about the message from KSAT to direct the aircraft to the location of the potential oil slick.

If no oil spill is detected KSAT informs via e-mail.
The operators use the following guidelines to determine the confidence level of a slick (Solberg, et al., 2004):

<u>High confidence</u>:
- The slick has a large contrast to gray-level surroundings.
- The surroundings are homogenous, with a constant gray-level.
- The wind speed is moderate to high, i.e. approximately 6 - 10 m/s.
- Ship or platform directly connected to slick

<u>Medium confidence</u>:
- The wind speed is moderate to low, i.e. approximately 3 - 6 m/s.
- The slick has a diffuse/low contrast to the grey-level surroundings in moderate to high wind speed.
- The shape of the slick is irregular, i.e. the edges are not smooth.

<u>Low confidence</u>:
- Low wind areas are located nearby.
- Natural slicks (e.g. biological, algae or fractal streaks at very low wind) are located nearby.
- The slick has diffuse edges and/or an irregular shape.

The operator analysing the images use information about wind speed, wind direction, oil rig location, coastlines and national territory borders as auxiliary information.
After receiving the information about possible oil slicks the aircraft tried to confirm this information. Figure 2 shows an example of an oil slick from an oil rig detected on a RADARSAT-1 image and confirmed by the aircraft. The corresponding information reported from KSAT and the aircraft crew are depicted in Table 3.

Table 3. Information reported for the slick from the oil rig

	RADARSAT-1	Aircraft
Date/Time	15 July 2003 17:19 UTC	15 July 2003 19:24 UTC
Position	55°29'02'' N 5°03'25'' E	55°28'18'' N 5°06'00'' E
Length x Width	8.1 km x 0.8 km	6.6 km x 1.6 km
Area	2.316 km^2	6.86 km^2
Volume	n.a.	16.47 m^3
Wind speed and direction	n.a.	3 bft from 96°
Orientation	NW-SE	n.a.
Confidence	High	n.a.

The aircraft was at the reported position 2 hours and 5 minutes after the satellite overpass. The reported length, width and area of the slick are different. The reason for the area difference can be the modification (spreading) of the oil slick extent (wind, current) during the period between the satellite overpass and the verification. The oil volume can not be estimated from SAR data since the oil layer thickness can not be obtained
In total 40 images were acquired over the North Sea and the Baltic Sea (Table 4).

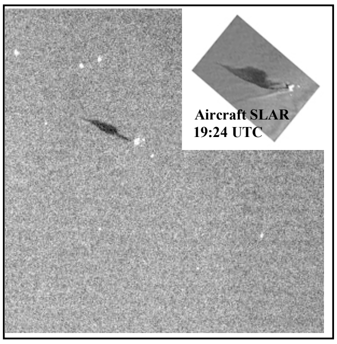

Figure 2. Oil releasing oil rig detected on 15 July 2003 by RADARSAT-1 at 17:19 UTC (large image) and by the German aerial surveillance (SLAR) at 19:24 UTC (Radarsat-1 data copyright Canadian Space Agency/agence spataile canadienne 2003, processed and distributed by KSAT)

Table 4. Acquired images of the North Sea and Baltic Sea

	North Sea	Baltic Sea
RADARSAT-1	12	10
ENVISAT	7	11

4. RESULTS OF THE CAMPAIGN

In total 97 possible oil slicks were reported from satellite observation. The average time difference between the satellite overpass and the time when the aircraft was at the reported position was 2 hours and 15 minutes. Of the 97 possible oil slicks 58 were observed in the North Sea and 37 in the Baltic Sea. The verification is classified in spills which couldn't be confirmed by the aircraft crew, spills which were confirmed, spills which couldn't be checked (e.g. out of range), reported spills when no aircraft was airborne (e.g. due to technical problems or bad weather) and some spills which were checked by a Dutch surveillance aircraft (NL) and the Danish Authorities (DK) (Table 5). The location of the slicks is depicted in Figure 3.

From the 61 checked oil slicks 34 (56%) could be verified and 27 (44%) were false positives.

Table 5. Results of the satellite/aircraft campaign 2003

Confirmation	
No	27
Yes	34
Not checked	26
No flight	10
Total	97

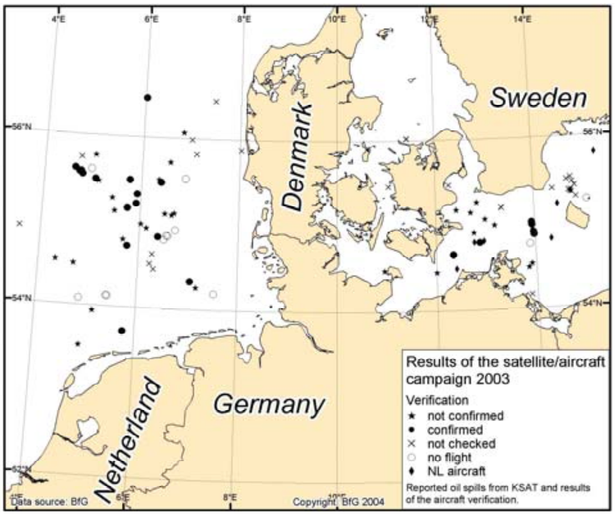

Figure 3. Results of the satellite/aircraft campaign 2003

The verification results separated into the analysis of RADARSAT-1 and ENVISAT images are shown in Table 6 and 7.

Table 6. Verification results RADARSAT-1

	RADARSAT-1 ScanSAR Narrow			
a-priori confidence	High	Medium	Low	Total
Verified	4	11	8	23
False positive	0	1	13	14

Table 7. Verification results ENVISAT

	ENVISAT ASAR			
a-priori confidence	High	Medium	Low	Total
Verified	1	1	9	11
False positive	1	3	9	13

Table 6 (RADARSAT-1) shows that of the 4 high confidence oil slicks checked all were verified as being oil. Only 1 of 12 medium confidence slicks were false positives but 13 of 21 low confidence slicks were found to be false positives. Of the 2 high confidence slicks detected in ENVISAT images and checked only 1 was found to be oil. For the medium confidence slicks checked 3 of 4 slicks were found to be false positives. For low confidence slicks 9 of 18 were found to be false positives. Comparing the analysis results from RADARSAT-1 and ENVISAT show that analysis of RADARSAT-1 images seems to have produced more reliable oil slick detection. One reason could be that the operators analysing the satellite imagery have

much greater experience in using RADARSAT-1 data (Solberg et al., 2004).
The sample size of 61 is not large enough to draw any final conclusions but further analysis of results of the planed campaign in 2004 and the currently conducted regional satellite/aircraft campaign will increase the reliability of the statistical analysis.

5. SPATIAL AND TEMPORAL SATELLITE COVERAGE OF THE GERMAN EEZ

The yearly satellite coverage of the German EEZ in the North Sea and the Baltic Sea were calculated based on query results from the ESA software DESCW 4.39 (Display Earth Remote Sensing Swath Coverage) and the RADARSAT Swath Planner Release 3.1 R1. The analysis war conducted for RADARSAT-1 ScanSAR Narrow and ENVISAT Wide Swath image modes in the year 2003.
The yearly satellite coverage of the German EEZ is depicted in Figure 4 and Figure 5. The figures shown the number of available satellite images (RADARSAT-1 and ENVISAT) versus the percentage of coverage of the German EEZ in the North Sea and Baltic Sea.

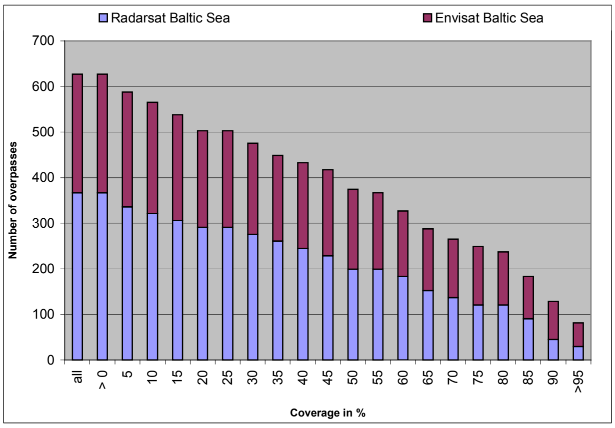

Figure 4. Yearly RADARSAT and ENVISAT coverage of the German EEZ in the North Sea

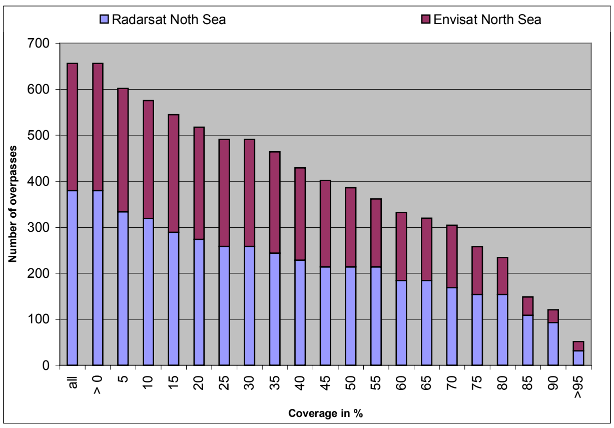

Figure 5. Yearly RADARSAT and ENVISAT coverage of the German EEZ in the Baltic Sea

Only 32 RADARSAT-1 and 20 ENVISAT images cover the EEZ in the North Sea more than 95%. The EEZ in the Baltic Sea is covered more than 95% by 30 RADARSAT-1 and 52 ENVISAT images. During each aircraft surveillance flight the EEZ in the Baltic sea is covered to 93%. The mean aerial coverage of the EEZ in the North Sea is 55%.
A daily coverage of the territorial waters of Germany is not possible. The daily coverage of the North Sea (German EEZ) in July 2004 using all images without considering the percentage of coverage is shown in Figure 6 (RADARSAT-1 ScanSAR Narrow and ENVISAT ASAR Wide Swath).

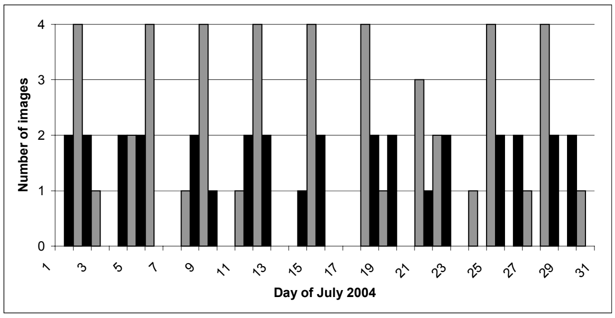

Figure 6. Number of RADARSAT-1 (black) and ENVISAT (grey) images covering the German EEZ in the North Sea in July 2004

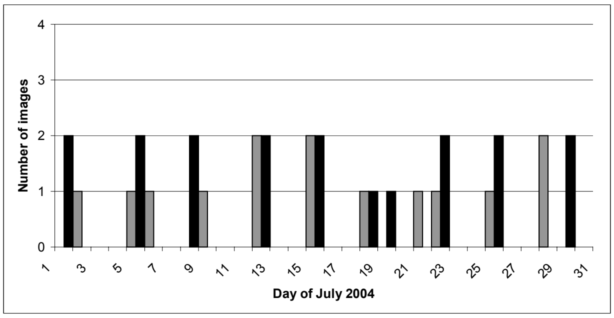

Figure 7. Number of RADARSAT-1 (black) and ENVISAT (grey) images covering the German EEZ in the North Sea more than 50% in July 2004

On certain days (e.g. 1. July, 7. July) no images are available at all. The maximum number of images is 6 images per day (2 RADARSAT-1 and 4 ENVISAT ASAR, e.g. 12. July). If only images with a coverage of more than 50% of the German EEZ in the North Sea are considered the number of available images is much smaller (Figure 7).
Satellite overpasses are at relatively fixed times. Early morning and late afternoon for RADARSAT-1 and in the morning and evening for ENVISAT. Between these times no satellite surveillance is possible.

6. CONCLUSION

One important aspect for the use of SAR satellite data for operational oil slick monitoring is the accuracy of the oil slick detection. For oil slicks detected with a high and medium confidence in RADARSAT-1 images the results are promising. For ENVISAT images the results are not so good but these are the preliminary results based on a small sample size. By the end of 2004 more results from 2 satellite/aircraft campaign will be available and this will increase the reliability of the results.

A daily surveillance of the German territorial waters can not be achieved using RADARSAT-1 and ENVISAT ASAR data. The price for the satellite data is still relative high so it is not cost-effective to buy images with a small coverage of the area of interest. Considering this the number of available images is even more reduced. However, satellites cover a large area and are independent of weather conditions (flyable weather for aircraft) and they can provide alert functionality. The costs for the images can be reduced if bordering countries buy the images that cover parts of their territorial waters together.
Aerial surveillance can not be replaced by satellite monitoring because it offers the following important features:

- Ground truth capability
- Classification of oil species
- Determination of layer thickness
- Evidence ensuring
- Communication link between aircraft and vessel (e.g. combating vessel)
- Controllable

The integration of satellite SAR observation may strengthen the operational oil spill surveillance in terms of a exhaustive spatial coverage of the territorial areas. This requires a continuos coordination of the satellite overpasses and the schedule of the aerial surveillance flights.

7. REFERENCES

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