Identification of Oil Spills by Satellite

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Content

– Oil spill problem & behaviour
– Techniques & methodologies for surveillance and detection
– CleanSeaNet service
– Next steps - Modelling
– Outlook & Conclusions
EMSA in a nutshell

EMSA’s mandate refers to “ensuring a high, uniform and effective level of maritime safety, maritime security [...], prevention of pollution and response to pollution by ships within the Community”

Set up of EMSA under Regulation (EC) Nº 1406/2002 of 27.6.2002
Legal Basis for CleanSeaNet


2. In accordance with its tasks as defined in Regulation (EC) No 1406/2002, the European Maritime Safety Agency shall:

a) work with the Member States in developing technical solutions and providing technical assistance in relation to the implementation of this Directive, in actions such as tracing discharges by satellite monitoring and surveillance;
The oil pollution issue

- Some 270,000 to 6.3 mio. tonnes of oil are released into the ocean every year.
- UN led “Group of Experts on Scientific Aspects of Marine Environmental Protection (GESAMP):
  1.2 mio. tonnes/yr.

- PriceWaterhouseCooper has calculated the annual costs (2005 prices):
  - European spills estimated to 50,100 tonnes/yr
  - for clean-up around €120 million
  - for environmental degradation and all other economic and societal costs €149,600 per tonne;
  Multiplied with the estimated volume of oil spillage in European waters: €7.5 billion per year.
Oil spill behaviour: Processes

Source: ITOPF

- Spreading
- Evaporation
- Oxidation
- Spreading
- Emulsification
- Dissolution
- Dispersion
- Sedimentation
- Biodegradation
### Oil spill behaviour: Weathering

<table>
<thead>
<tr>
<th>Group</th>
<th>Density</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group I</td>
<td>less than 0.8</td>
<td>Gasoline, Kerosene</td>
</tr>
<tr>
<td>Group II</td>
<td>0.8 - 0.85</td>
<td>Gas Oil, Abu Dhabi Crude</td>
</tr>
<tr>
<td>Group III</td>
<td>0.85-0.95</td>
<td>Arabian Light Crude, North Sea Crude Oils (e.g. Forties)</td>
</tr>
<tr>
<td>Group IV</td>
<td>greater than 0.95</td>
<td>Heavy Fuel Oil, Venezuelan Crude Oils</td>
</tr>
</tbody>
</table>
Transition from R&D to operational services

Institutional demands
- Int. agreements (e.g. MARPOL)
- European Directives and Regulations

R&D products
- National research (e.g. Universities)
- EU Framework Program
- Int. research co-operations

Operational services to serve inst. demands
- EMSA
  - CleanSeaNet satellite surveillance
- Nat. Activities
  - Aerial surveillance, combating, enforcement
- GMES
  - Marine Core Services

solutions
Scope of the CleanSeaNet oil spill monitoring service

- **European system for detecting oil slicks** at sea using satellite surveillance on request of Coastal States (EU, EU candidate countries and EFTA) and of the Commission.
- To achieve a system that **links into the national/regional response** chain (aerial/naval surveillance) and strengthens routine, operational pollution surveillance of illicit discharges and response for accidental spills.
- CleanSeaNet provides a **complete service chain** from the collection of coverage requirements to the provision of operational results.
- **Identification of potential polluters** by combining CleanSeaNet and vessel traffic information and models.
Integrated system to strengthen the national/regional response chain for accidental spills and deliberate discharges from ships.

**Vision for an integrated system**

- **Oil spill**
  - **Aircraft**
  - **Satellites**
  - **Models**
  - **Tracking**

**Efficiency**

**Real time**

**Response support**

**Collecting evidence**

**MS-bodies:**
- Coastguards
- Frontier guards, ...

**Early warnings, response & clean-up operations**

**Deterrent Prosecution**
Airborne systems
- SLAR, IR/UV, vis. inspection, (MWR, LFS)

Satellite SAR

Integration of the systems

Complementing with vessel tracking data, models
Techniques & methodologies:

Air-borne

- SLAR/SAR
- LFS
- FLIR
- MWR
- IR/UV
- camera + video

Satellite

- SAR

Visual

EMSA CleanSeaNet service is operational since 04/2007
EMSA-CSN is providing approx. 2000 satellite SAR images with a growing tendency:
\[ 2.6 \times 10^8 \text{ km}^2 = 728 \times \text{Area of Germany (357.000 km}^2) \]

More than 16 of the 24 European and EFTA Coastal States operate aircraft
- aircraft are equipped differently
- flight hours per year vary strongly from CS to CS
Oil Slick Detection in S(L)AR images

- S(L)AR emits electromagnetic pulses and measures the level of the backscattered signal. Doppler history along track is used for azimuth resolution and signal modulation for range resolution.

- S(L)AR sensors provide information on the surface roughness of the ocean. Ocean’s roughness is driven by the wind which creates ripples at the sea surface.

- The presence of a film on the sea surface damps out small waves and reduces the measured backscattered energy which results in darker areas in the S(L)AR image. Low wind: Weak backscattered signal - No contrast between oil slicks and surrounding waters. Moderate winds favourable for oil detection – Oil Slicks appear as dark features. High winds: Useful signal lost in the ambient noise - Oil slicks often broken and dispersed into the water column.

2-3 m/s < WIND < 12-15 m/s
EMSA CleanSeaNet
ENVISAT-ASAR 2007-06-23 09:32:02 UTC, Baltic Sea
CleanSeaNet satellite Network

- ENVISAT (01/03/2002*)
- RADARSAT 1 (04/11/1995*)
- RADARSAT 2 (14/12/2007*)
- Sentinel 1 a/b (in 2013 ff.)
Satellite Temporal Coverage

ENVISAT: From 2 images per week in the South to nearly 1 per day in the North.

RADARSAT 1 or RADARSAT 2: From 3 images per week in the South to more than 1 per day in the North.

ENVISAT Wide Swath 400x400 km²

RADARSAT 1
RADARSAT 2
ScanSAR Narrow 300x300 km²
CleanSeaNet Service Flowchart

1. Coverage Requirements
2. Images allocation
2. Planning
2. Satellite Planning
2. Ordering
3. Satellite acquisition and processing

EMSA

COASTAL STATES

EMSA contracted Service Provider (Consortium)

Web Browser

4. Oil Spill Alerts
4. CleanSeaNet Products
   (Images, Oil Spill Reports, Ancillary products)
5. User Feedback
Areas of interest and coverage requirements for each area are defined by the Coastal States on a monthly basis.

As an example, NL may require 4 scenes per month covering their waters.
Near Real Time Service – 30 Minutes (3 & 4)

Acquisition and Processing

T0 = End of scene acquisition

Planning

Oil Spill Analysis

T = T0 + 30 min

Alert & Product Delivery
(Web Browser, EMSA)

Phone and email alert

Oil Service Report

Image (LR, HR)

Ancillary data

P l a n n i n g

F e e d b a c k
Products delivered by CleanSeaNet

- Satellite images (both in full-resolution and in reduced-resolution) and image data such as acquisition date, geographic coordinates, etc...

- “Oil Spill Reports” or “Clean Sea Reports” containing the indication of the oil spill detected from that image. Reports are delivered in the email alert and are available via the web browser.

<table>
<thead>
<tr>
<th>Oil Spill number</th>
<th>Confidence</th>
<th>Possible sources</th>
<th>Country (E.U.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>HIGH</td>
<td>N/A</td>
<td>Cyprus</td>
</tr>
<tr>
<td>2</td>
<td>MEDIUM</td>
<td>N/A</td>
<td>Cyprus</td>
</tr>
<tr>
<td>3</td>
<td>MEDIUM</td>
<td>N/A</td>
<td>Cyprus</td>
</tr>
<tr>
<td>4</td>
<td>LOW</td>
<td>NA</td>
<td>Turkey</td>
</tr>
<tr>
<td>5</td>
<td>MEDIUM</td>
<td>N/A</td>
<td>Denmark</td>
</tr>
<tr>
<td>6</td>
<td>LOW</td>
<td>NA</td>
<td>Denmark</td>
</tr>
</tbody>
</table>

Potential oil spills with 3 Confidence levels (low, medium and high) are reported as well as “Clean Sea” reports.

- Associated ancillary data: meteorological wind and wave data, SAR wind and SAR swell data derived from the image.

- Other ancillary data when available from external providers like AIS information.
The EMSA CleanSeaNet Web Browser

This centralised interface allows:

- Viewing the acquisition plan
- Viewing and downloading CSN products
- Providing Feedback
Follow-up and Feedback by Coastal States (5)

Coastal States are responsible for follow-up actions on oil spill indications. According to the CleanSeaNet conditions of use, they should verify spills as completely as possible and provide feedback to EMSA.

Verified oil slick
10/07/2008
Baltic Sea
28 August 2008 - 12 detections all confirmed as oil spills
Pollution resulting from ship operations: discontinuous discharge from ship, manoeuvres, traffic lanes
Influence of wind and sea surface currents
Oil Slick Detection in SAR images – Look-alikes

SAR sensors detect all **films on the sea surface that damp out small waves generated by the wind.**

CleanSeaNet detections are **not “Oil Spills” but “Potential Oil Spills”**. Discrimination between Oil Spills and Look-alikes require more information and most often in-situ verification.

How to reduce the number of false alarms?: good knowledge of local conditions (Winds, currents, vessel traffic,...), improvement of the oil detection chain by a thorough analysis of feedback and by gathering experience

**Look-alikes:**

- Other man-made substances: fish or vegetable oil, chemical, sewage, other...
- Natural phenomena: low wind area, algae, current front, upwelling area...

![Current fronts](image1)
![Low wind, rain cells and oil seepage](image2)
![Algae](image3)
![Land breeze](image4)
Low wind speed

DEM (Digital Elevation Model) of Corsica with wind speed arrows.

Wind shadow areas and the presence of natural films on the sea surface are indicated.
Boundaries of water masses

Areas of convergence or divergence modulate the sea surface roughness

ENVISAT
2004-06-29 21:19:30 UTC

AVHRR Sea Surface Temperature
2004-06-29 12:00 UTC
Algae bloom
EMSA-CSN results of the first operational year
- 3296 potential in the 2333 images
- 27% spills confirmed (875 checked)
- many of the detected potential spills could not be assessed correctly due to
  - evaporation and
  - physical degradation of oil

=> The time between the satellite overpass and the check via aircraft is crucial.
08/01/2009, Canary Islands
Feedback and Port State Control request

- After the CSN alert Spanish authorities sent “Sasemar 103” aircraft to investigate the case

- The oil slick was verified and documented by SLAR, IR and MWR. The amount of discharged oil was at least 3.9 m³

- AIS data and oil drift model results were analysed by SASEMAR and the evidence confirmed that the potential source indicated in the CSN report was actually the polluter

- Spain sent a Port State Control request and a flag state report
Support in case of accidental spills

In case of accidental spills, EMSA has the capacity to support the affected Coastal State with additional satellite coverage:

- Envisat and Radarsat 1 and 2 images: emergency planning and ordering via CleanSeaNet.
- Other SAR or optical data: in case of major disasters via the activation of the “International Charter for Space and Major Disasters”.

A close cooperation between the CleanSeaNet team and the affected Coastal State allows optimising satellite planning and ordering.

For each accidental situation, EMSA issues tailor-made products, briefings, reports... to better fulfil Coastal States authorities expectations.
Emergency support: examples

Grounding of the MS New Flame off Gibraltar in September 2007

CleanSeaNet Briefing: New Flame, Gibraltar

Introduction

Following the head-on collision between the double-hulled oil products tanker New Flame (30600 DWT, built 2005, IMO 9140065, DNV class A1, Danish flagged, owned and managed) and the bulk carrier New Flame (1994 go-
ing, 14000 DWT, MMSI 247063700, Italian flagged, owned, Greek managed) off Gibraltar in 12th August and the subsequent weather damage to the partially submerged hull of the latter, the Spanish authorities (SEGEMAR) requested EMSA to acquire any available satellite images via the CleanSeaNet service for monitoring of the possible oil spill. The satellite images concerned were of Envisat (ENVISAT-1, 09/09/2007) which included the analysis of two scenes acquired on the 9th and 10th of September, this report focuses on the next set of images acquired and delivered by EMSA.

Image Analysis

The following sequence of images was acquired between the 9th and 10th of September from the ENVISAT and RADARSAT satellites. Both low and high resolution images were examined, no oil was detected in the vicinity of the New Flame and clean sea images were obtained which showed strong echoes indicating that no large oil spills are available via the CleanSeaNet database.

ENVISAT 08 September 2007 Image

The bright features on the sea surface are vessels which are strong point radar reflectors giving a very bright signal. The surrounding vessels were detected 100km east of Gibraltar which are clearly unrelated to the New Flame accident.

ENVISAT 09 September 2007 Image

In the ENVISAT scene the areas of very low wind are clearly visible (as darker patches), as are the internal wave patterns (described below).

RADARSAT-1 09 September 2007 Image

The pattern seen in the RADARSAT scene illustrates bands of rough and smooth sea represent internal waves generated by the interaction between tidal currents and topographic features.
Emergency support examples
Grounding of the MS Fedra off Gibraltar in October 2008

CleanSeaNet Quick Look Report no. 1
EMSA CleanSeaNet satellite monitoring of the Bay of Gibraltar: Report no. 1
(14/10/2008)

Satellite: ENVISAT
Sensor: Advanced Synthetic Aperture Radar (ASAR)
Mode: ScanSAR Wide
Date: 2008-10-13
Time: 22:09:06 UTC

No major oil pollution could be identified.
This Synthetic Aperture Radar image (ASAR, max. resolution 150 m) shows several dark patches with the easterly wind with a force of around 5-10 m/s allows a good detection of possible spills.

Blue (1): The sea effect of Gibraltar introduces reduced surface waves leading to the dark pattern. Moreover, in this area could be oil originated from the vessel, but there is no specific contrast, which allows the identification of oil.

Yellow (2): This feature could be potentially been oil released from MS Fedra as the origin of this patch is linked to the Europa Point. However, due to its vicinity to the shore line this information is of low confidence and has to be verified by local authorities.

Greens (3): According to the pattern structure, this feature could be oil, but due to the...

CleanSeaNet Quick Look Report no. 6
EMSA CleanSeaNet satellite monitoring of the Bay of Gibraltar: Report no. 6
(22/10/2008)

Satellite: RADSAT-1
Sensor: Synthetic Aperture Radar
Mode: Standard Image Mode
Date: 2008-10-22
Time: 06:26:17 UTC

No major oil pollution could be identified.
No major potential oil spills are identified in this Synthetic Aperture Radar image (RADSAT-1, max. resolution 50 m). Wind conditions permit detection of possible oil slicks.

Blue: This dark patch could be due to the wind shadow generated by the elevation of the Europa Point.

Green: According to the pattern structure, these features could be oil. However, due to its vicinity to the shore line this information is of low confidence and has to be verified by local authorities.
The CleanSeaNet polluter identification activities

Directive 2005/35/EC on ship sourced pollution and on the introduction for penalties for infringements:

Article 10.1(b): establish common practices and guidelines on the basis of those existing at international level, in particular for:

- the monitoring and early identification of ships discharging polluting substances in violation of this Directive, including, where appropriate, on-board monitoring equipment,
- reliable methods of tracing polluting substances in the sea to a particular ship, and
- the effective enforcement of this Directive.

- Work programme 2009 (p.54):
  In 2009, a new platform will be created for the second generation of CleanSeaNet. The service offered to Member States should be more flexible to include new satellite sources and new applications. A robust and modular Data Management and Data Dissemination System will be developed in 2009. One of the improvements should be that vessel position data from the SafeSeaNet project (AIS and LRIT data) should be available on a structural basis in CleanSeaNet for all participating States to help identify suspected polluters. Where possible, existing regional and local fore- and hind-cast models will be connected to CleanSeaNet. This will provide the capability to link an individual illegal discharge with individual ship tracks.
Linking a vessel to a slick

Theoretical example of the use in combination of:

- Satellite detection
- Oil drift modelling
- Vessel Monitoring
- CSN to provide a ‘first analysis’ of modelling results to CS users
- Backtracking for polluter identification (min. 24 hours)
- Forecasting for pollution response activities (min. 96 hours) incl. weathering
- Distributed architecture where external models ‘link’ to CSN
- MS oil spill models shall be used which are tailored and appropriate for individual sea basins
- Possibility to choose more than 1 model for a particular sea area (ensemble)
- The intention is to setup a close co-operation and bi-directional data exchange between EMSA and the MS models

More Information:

**Non-paper:**
**EMSA’s view on further development of oil spill modelling**
21/11/2008

CSN and GMES

Marine Core Service elements

Upstream service elements

Downstream service elements

CSN was the first fully operational maritime GMES at all!!
Model implementation guideline

- The models will be available only according to the distribution policy by model operators. A sophisticated user management is foreseen.
- Any investigation results will remain exclusively with the Coastal State
- EMSA wants to provide the operational entities with Near Real Time information (30 min.) to support
  - the decision making process on follow up activities
  - the Coastal States with immediate links between spill and potential polluters
- It is up to the CS/model operators to co-operate on this issue with EMSA to improve the CSN information content and to promote the model
- Pilot Projects
  - MEDSLICK
  - SeaTrackWeb
CSN 2nd generation: a complete approach

- An integrated maritime surveillance platform: comprehensive, flexible and advanced system; providing
  - meteorological and sea state information, SST, algae, ...
  - vessel traffic information (AIS, LRIT, STIRES)
- Oil drift modelling: links to forecast and backtracking models tailored for specific sea areas
- Static information (Nautical charts, bathymetry, borders, ...)  
- Optical, hyper-, multispectral images
- Sat. vessel detection

- Fusion of data
  - Vessel tracking with backtracking data for polluter identification
  - wind and wave for improving the confidence
Conclusions – what we have achieved

- Sustainability
- Cost Sharing
  - Reduced price for a large amount of images
  - Satellite surveillance is an indispensable tool to achieve the basic European coverage.
- Co-Operation
  - “Oil spill surveillance is a cross border activity”
  - Mutual benefits for coastal states
  - Sharing of images and aerial surveillance
- European standardised service
  - All European waters
  - Comprehensive, quick and easy to access information
  - easy to compare
Conclusions – what’s next

- Remote sensing provides a unique technology to identify potential (illicit) pollutions, but with
  - integration of modelling and vessel information
  the systems become tools
  - to determine potential polluters,
  - to provide elements for the chain of evidence,
  - to support clean-up operations

- Co-operation and co-ordination with law enforcement has to be intensified to improve prosecution and deterrence

- CleanSeaNet’s 2nd generation service will provide a very extended and unique portfolio and as such could be an extremely relevant source of information for other EU Agencies and MS.
Thank you very much!
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http://cleanseanet.emsa.europa.eu