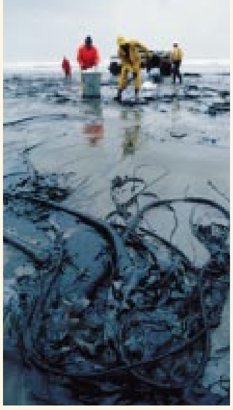
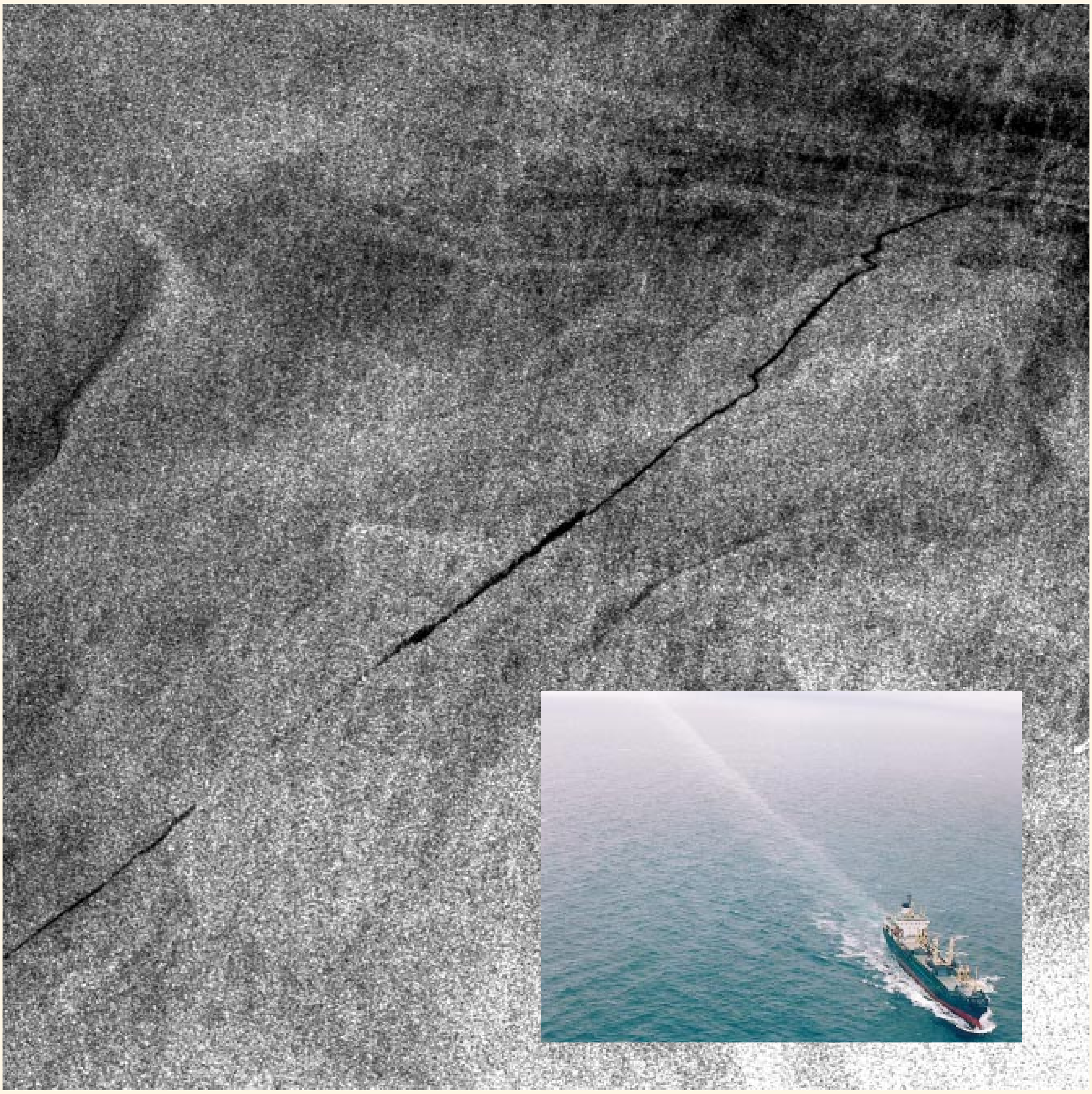
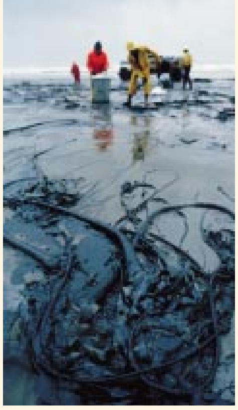
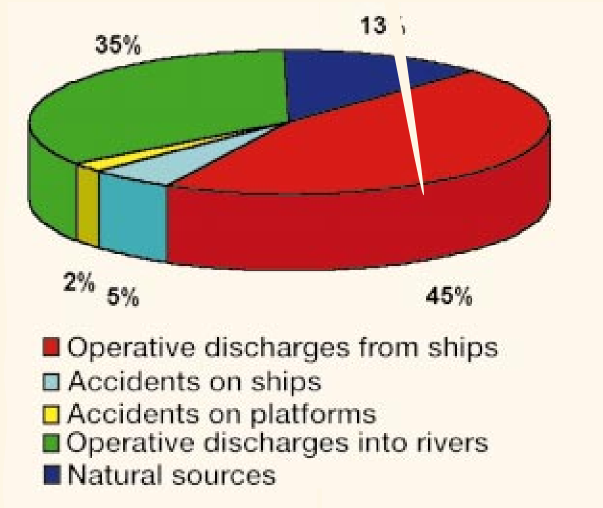


OIL POLLUTION MONITORING





OIL POLLUTION MONITORING



Estimate of the sources of oil spills at sea

The Need for Better Information

The search for oil reserves offshore is moving into deeper and deeper waters, and crude oil and oil products are being transported across the globe in increasingly larger tankers. As a result, oil spills pose a serious threat to the ecology of the World's oceans. The amount of oil spilled annually worldwide has been estimated at more than 4.5 million tons.

The biggest contributor to oil pollution in the World's oceans (some 45%) is operational discharges from tankers (i.e. oil dumped during cleaning operations). Approximately 2 million tons of oil are introduced annually by such operations, equivalent to one full-tanker disaster every week. Only 7% of the oil in the sea can be directly attributed to accidents. Land-based sources such as urban waste and industrial discharges, which reach the ocean via rivers, are also a major contributory factor.

International Commissions have been formed and Conventions agreed in an attempt to curb marine pollution. The Oslo-Paris Commission (OSPARCOM) for the environmental protection of the North East Atlantic, and the United Nations Convention on the Law of the Sea (UNCLOS) in which more than 150 countries participate, are just two examples of such co-operative efforts. All of the countries bordering the Baltic Sea and the members of the European Economic Community signed the Helsinki Commission (HELCOM) Agreement in 1992 to protect their coasts. In addition, the North Sea countries have committed themselves to intensifying the battle against oil pollution. In the framework of the Bonn Agreement (1969), almost daily surveillance is carried out to check for pollution on the North Sea Continental Shelf. The signatories of the International Convention for the Prevention of Pollution from Ships (MARPOL 73/78) Agreement are obliged to ensure that ports provide reception facilities for ships' waste, and limitations are imposed to try to protect ecologically sensitive areas against oil discharges.

Although the oil industry is fully aware of the international laws and the risks connected with marine pollution, there is still ample evidence of numerous repeat offenders. Many countries cannot afford an adequate surveillance programme. Coast-guard personnel and ship and

A ship discharging oil

aircraft crews frequently report sightings of oil spills, but the percentage of spills detected is still relatively low. Surveillance is carried out in some areas using remote-sensing aircraft. The Side-Looking Airborne Radar (SLAR) and radiometers on these aircraft detect pollution under different conditions and over wider areas than ships' observations.

National Pollution Control Authorities such as the National Coast Guard or centres for environmental protection have three main roles in terms of oil-spill detection:

- early warning
- legal prosecution
- provision of pollution statistics.

Identification of the discharge source and photographic documentation are required quickly both for the legal prosecution and the prevention of environmental damage.

The Limitations of Traditional Techniques

An operational pollution-monitoring scenario based only on aircraft and ship surveillance has several drawbacks:

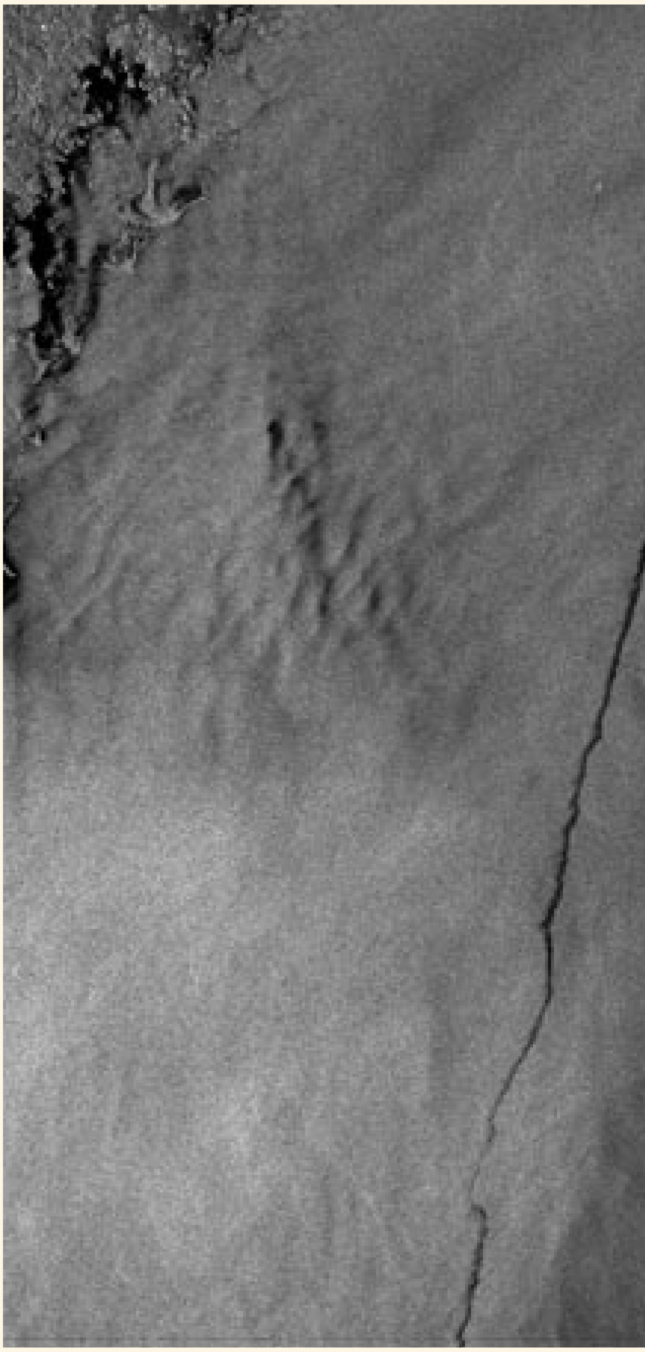
- The time delay between an illegal discharge and its detection does not permit a successful prosecution in most of the cases, unless the culprits are caught "red-handed".
- Poor weather conditions can prevent an aircraft from flying over the area.
- The resources available for airborne surveillance often allow only a small fraction of coastal waters to be surveyed.
- Evidence based only on SLAR data is often deemed insufficient in a court of law.

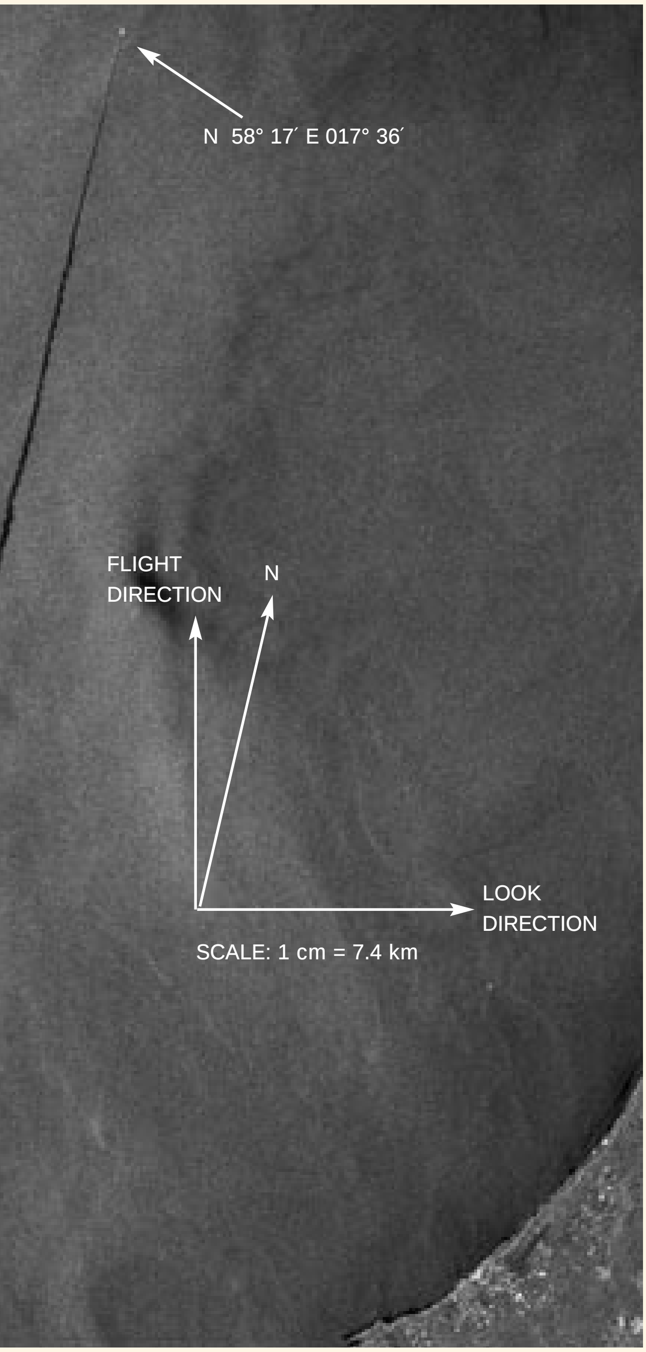
The Benefits of Space-Based Monitoring

Today, the availability of data from Earth-observation satellites offers the possibility to complement and optimise surveillance strategies, allowing a more cost-effective approach to oil-pollution monitoring. Space-acquired Synthetic Aperture Radar (SAR) data can complement current aerial surveillance strategies both by providing coverage over areas not easily surveyed with aircraft, and also by providing synoptic views of large areas. This raises the likelihood of immediate intervention being feasible, makes the operations as a whole more cost-effective, and dramatically increases the size of the area that can be routinely surveyed.

The introduction of satellite data as an additional information source has several distinct advantages:

- *The combined use of satellites, ships and aircraft for surveillance increases the chances of early detection of oil spills and fast clean-up operations, preventing further environmental damage.*
- *By regularly monitoring large areas, deeper analysis can be performed and more accurate statistics on the occurrence of oil slicks can be provided.*
- *Oil seeping naturally from the sea floor can be detected, and its occurrences carefully monitored.*
- *A better overview of oil spreading, and therefore a source of input to oil drift models, can be obtained.*





Confirmed oil slicks in the North Sea detected by the ERS-1 SAR on 31 March 1996

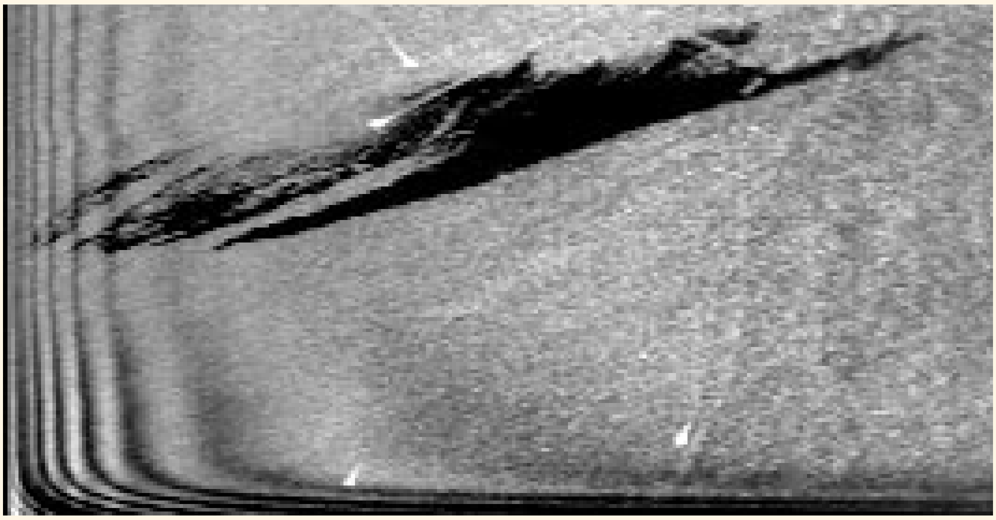
The Contribution of ERS SAR

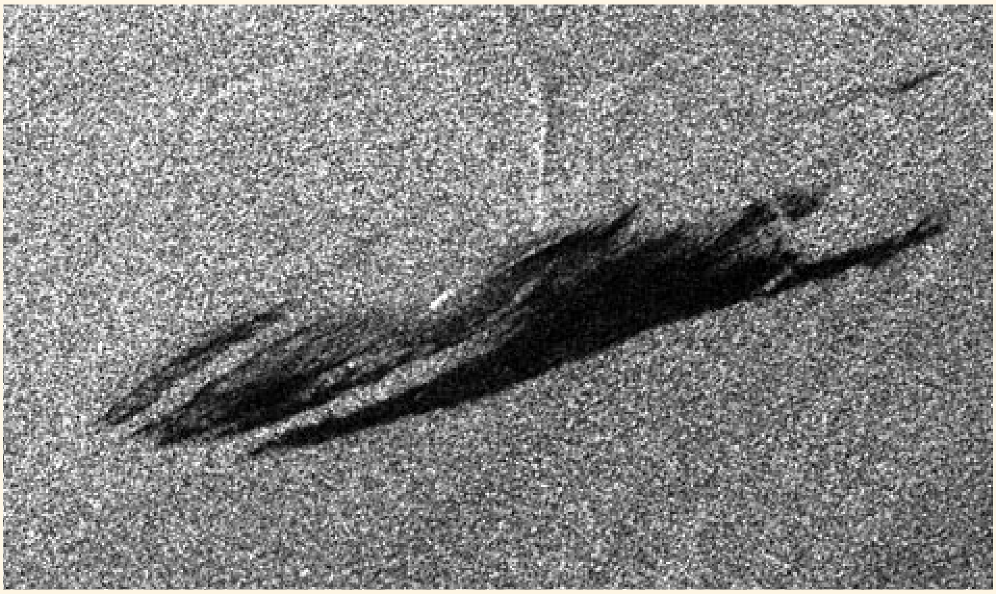
With the advent of the European Remote Sensing Satellite (ERS) missions in particular, the Earth is orbited once every 100 minutes at an altitude of 780 km. The "nominal" spatial resolution of the ERS data is 25 m x 25 m, but for oil-spill detection "low-resolution" images of 100 m x 100 m are more than sufficient, reducing the data content of each image to about 2 Mbytes. This type of image can easily be made accessible via the Internet.

Experiments have been carried out to assess qualitatively and quantitatively the potential of ERS SAR data for oil-spill detection. It can be stated as a result that the detection capability of the space-borne SAR is comparable to that of the SLAR systems used in today's maritime airborne surveillance programmes.

The presence of an oil film on the sea surface damps out the small waves due to the increased viscosity of the top layer and drastically reduces the measured backscattered energy, resulting in darker areas in SAR imagery. Use of the ERS SAR low- resolution images has demonstrated the satellites' ability to detect even very thin pollution layers for low wind speeds of 3-4 m/s and thick oil emulsions for wind speeds up to 12 m/s. Slicks as small as 0.1 km^2 in area can be detected. Pollutants that can be identified by ERS SAR include crude-oil emulsions, run-off water from acidic pitch deposits on land, drilling fluids from offshore oil rigs, waste from fish-production plants, and fish fat remaining on the sea surface from trawler catches.

An oil slick off the Dutch coast as observed simultaneously by a SLAR-equipped surveillance aircraft (top), and by the ERS-1 SAR (bottom). The shape of the slick appears identical in the two images





However, SAR (and airborne SLAR) scenes require careful interpretation because:

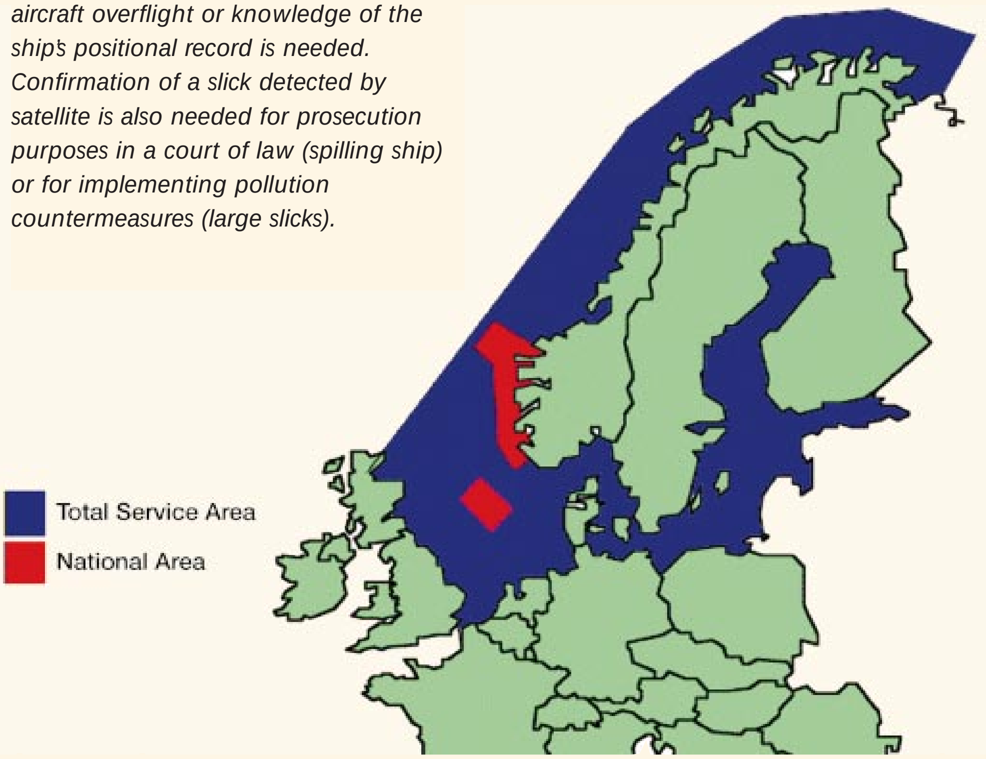
- with low wind speeds, dark areas might not be oil slicks but merely local wind effects or natural oil films, causing false alarms unless experienced image interpreters or well-tuned classification algorithms and wind information are employed
- with very high wind speeds, the pollutant may mix rapidly with the sea water, leaving no surface effect to be detected.

On a SAR image, a polluting ship can be spotted but not identified, for which an aircraft overflight or knowledge of the ship's positional record is needed. Confirmation of a slick detected by satellite is also needed for prosecution purposes in a court of law (spilling ship) or for implementing pollution countermeasures (large slicks).

Examples of Space-Based Applications

An operational spill-monitoring service in Norway*

Since the launch of ERS-1 in 1991, a service affording near-real-time access to ERS SAR data has been offered by the Tromsø Satellite Station in northern Norway, as part of the Norwegian Space Centre's national ERS-l programme. Based on this activity, a near-real-time oil-spill monitoring service has been established for the Norwegian Pollution Control Authority (SFT), a governmental expert agency belonging to the Norwegian Ministry of the Environment.



The Norwegian oil-spill-service coverage area (blue) and national high-priority area (red). ERS SAR data for the blue and red areas are analysed in near-real-time

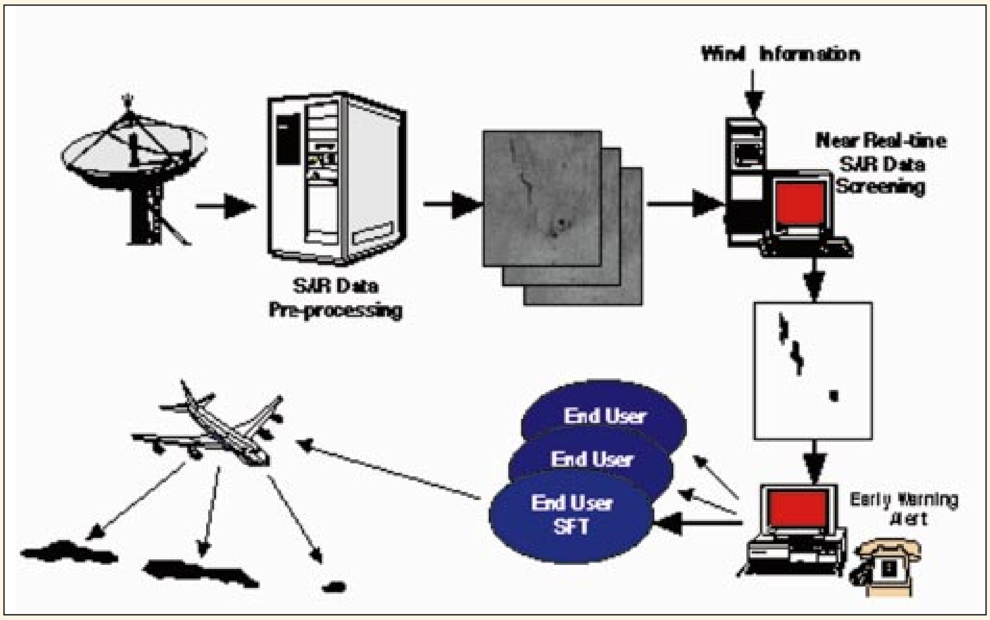
* The development of the service provided by the Tromsø Satellite Station has been supported by a number of institutions, including the Norwegian Space Centre (NSC), the Norwegian Pollution Control Authority (SFT), the Norwegian Defence Research Establishment (NDRE), the US Marine Spills Response Corporation (MSRC), the oil companies Statoil and ESSO, and ESA. Recipients of near-real-time data include the Dutch North Sea Directorate (NSD), SFT, and pollution-control authorities in Sweden, Finland, the United Kingdom, Poland and Estonia.

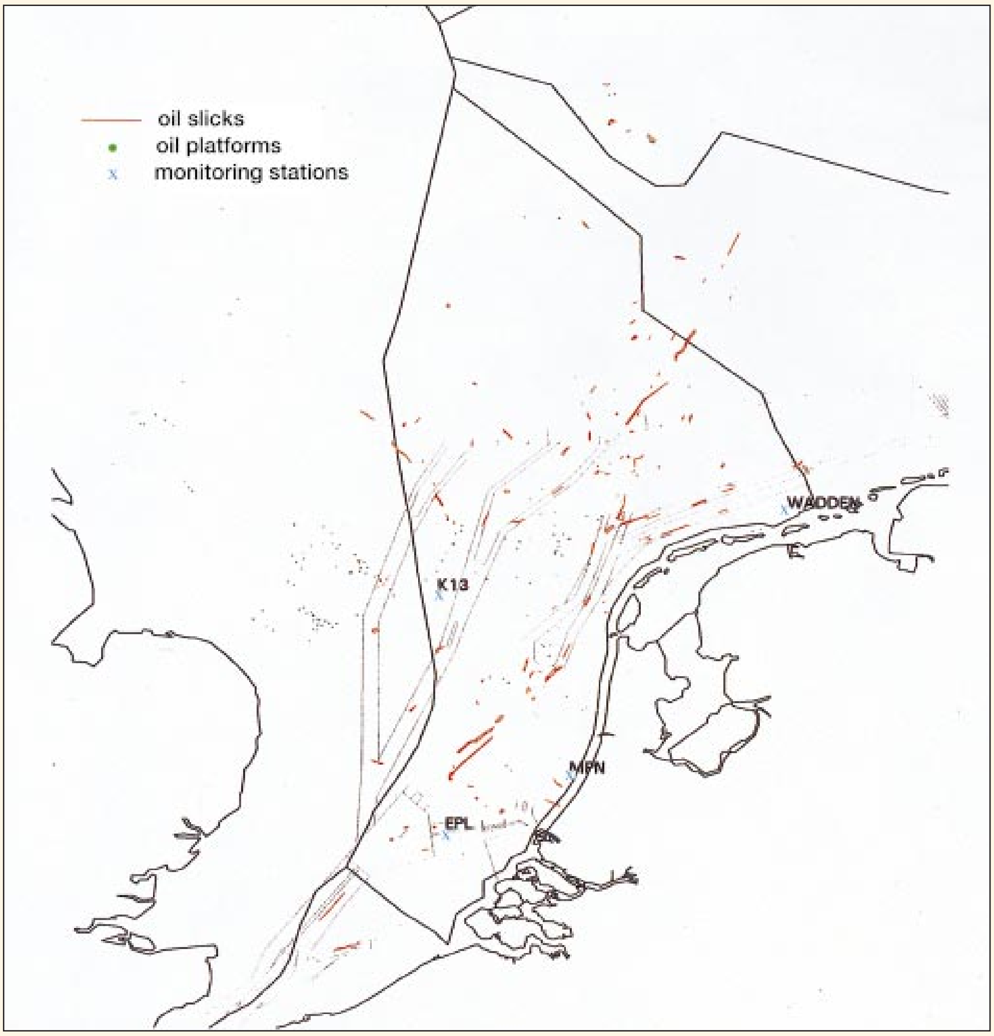
The Tromsø Satellite Station service includes the near-real-time analysis of ERS SAR data collected over Norwegian waters and the provision to the Pollution Control Authority of relevant oil-spill location information within one hour after satellite overpasses. A 100 km x 100 km SAR image is generated at the station in 6-8 minutes. An average of 300 such ERS scenes from the service area are analysed per month by the highly trained operators. The reporting is based on human, computer-supported analysis and interpretation. Reliability is further improved through the use of additional meteorological, geographical and historical information.

The Pollution Control Authority's surveillance-aircraft operations are planned and co-ordinated based on the timings of the ERS overpasses. The Station operators are in direct contact with the aircraft crew, which allows flight-path deviations to be made to verify satellite-detected slicks.

The extent of the area monitored, in combination with the near-real-time delivery of information, are just two of the advantages of the service being provided. ERS SAR data collected over the neighbouring waters of other Northern European countries are also analysed at the Tromsø Station and the relevant national authorities are notified either directly or via the Norwegian Pollution Control Authority of any oil spills detected.

The concept of the Norwegian oil-spill detection service, from reception and analysis of the data at the Tromsø Satellite Station, through early-warning alerts, and aircraft operations by the Norwegian Pollution Control Authority (SFT)





All slicks detected by ERS-1 in the Dutch North Sea during the second half of 1993 (in red). Green points mark the positions of the oil platforms, whilst blue crosses show the positions of the monitoring stations. A clear correlation is apparent between the positions and directions of the slicks and the locations of the shipping lanes

The Dutch experience

Since the nineteen sixties, the extraction of oil and gas has become an important North Sea industry. Over 450 fixed production platforms have been installed, which are connected to production wells, to distribution points and to the shore. More than 650 pipelines have already been laid, ranging in length from 100 m to 1500 km.

The Dutch part of the North Sea is patrolled daily by an aircraft operated by the North Sea Directorate (NSD) of the Rijkswaterstaat, with the aim of detecting oil spills and discharges from ships and platforms. About 1200 flight hours are typically scheduled per year, and inspections can be performed at short notice, but are also carried out randomly. Restrictions are imposed, however, by the number of possible flights, the area that can be covered, and the prevailing weather conditions.

NSD currently receives low-resolution ERS images on an operational basis from the Tromsø Satellite Station two or three times per week, with a delay of just one to one and a half hours after data reception at the Station. Such information is fundamental for coordinated intervention by modifying the flight plans of the remote-sensing aircraft to verify features detected in ERS data.