NRA - Water Quality 53

National Centre for Instrumenatation and Marine Surveillance

Sea Empress Oil Spill - February 1996
Overview Of Surveillance Activities

Draft

Report NC/MAR/14
Issue 1.0
20th March 1996

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Introduction

This report is intended as a concise record of the surveillance activities undertaken by the NRA National Centre for Instrumentation and Marine Surveillance (NCIMS) as a result of the grounding of the Sea Empress and resulting oil spill in February 1996 .

This report is not intended to make any statements on the severity or environmental consequences of the oil spill or to propose any scientifically robust interpretation of the data resulting from the surveillance activities; such conclusions can only be drawn once data from all sources has been pooled and analysed in a scientific framework.

The system deployed by the NC IMS is described in the context of oil spill surveillance. A record of the sorties flown is presented with example imagery. In addition, a record of the publicly available satellite imagery that is available is presented, with one example.

Concepts for future treatment of this data are put forward.

Richard Saull,
Data Manager,
IMS
March 1996

The NRA System

Instruments

The NCIMS have been developing and operationally deploying a small aircraft based remote sensing system for the last 3 years. The aeroplane and survey equipment are commercially available systems that are supplied on contract. The combination of the sensors used and the ground support, in terms of data processing and treatment, are, however, unique.

The major sensor is a reflected light sensor known as the CASI (Compact Airborne Spectrographic Imager). The CASI is capable of splitting the visible and near infra-red spectrum into very precisely defined slices and recording them to digital tape. The attitude and coordinates of the platform are also recorded. The CASI is capable of collecting data with good spatial resolution and up to 19 slices (or bands) from the spectrum, or many more bands with coarser spatial resolution (typically 74 or 288 bands). These two modes of operation are termed spatial or spectral respectively. The sensitivity of the CASI's recording mechanism far exceeds that of conventional photography, and, being digital, lends itself to scientific analysis of a quantitative nature as well-as manipulation in computer systems. As a rule of thumb, the ground resolution of the CASI is equivalent in metres to the height of the platform in thousands of feet, so by flying the platform at 3,000 feet the ground resolution is approximately 3 metres for each "dot" or pixel on the computer reconstitution of the data.

In support of the CASI, a conventional colour video camera and thermal scanning system that is recorded on analogue video tape are deployed. The colour video system provides a continuous inventory of the sub platform view, but is prone to atmospheric attenuation in the blue wavelengths as altitude increases. The thermal system is an uncalibrated system that shows relative changes in emmitance of heat from the sub platform surfaces. This represents a valuable additional source of data as different surfaces that have the same colour signatures frequently have different thermal signatures, thus promoting discrimination.

The IMS have developed a unique and efficient processing chain for the CASI data that includes the calibration to spectral reflectance units and geolocation (fitting to a map) of the data. This processing system promotes the rapid delivery of results that can be interpreted in relation to the ground events.

Oil Spill Surveillance using the IMS system

The NCIMS system was present at the Braer tanker incident in the Shetland Islands in January 1993. Subsequent analysis of the resulting CASI data by the scientific community proved that the CASI could detect oil sheens, oil slicks, and in certain circumstances, oil in the water column. The weather conditions in the Shetlands promoted the rapid breakdown of the oil spilled, so the usefulness of the CASI in identifying the intermediate stages of breakdown or location of dispersant was not fully assessed.

The specification of the CASI and the data handling procedures used by the IMS have greatly improved since the Braer incident. Greater sensitivity and control of the instrument as well as the geolocation of imagery have now been achieved.

The proven abilities of the CASI and the supporting sensors make the NRA system ideal to contribute to the operational monitoring of oil slicks and the subsequent scientific analysis of the environmental effects of the oil spill. Such data is vital in better understanding the mechanics of the breakdown and distribution of oil resulting from a large oil spill. This knowledge is critical in the formation of policy recommendations for the minimisation of the damage to the environment.

Sorties Flown & Example Imagery

The aerial survey schedules of the IMS do not include surveying in the months from October to May. On hearing that the Sea Empress was aground, immediate enquiries with the contractors revealed that the CASI was in Canada being recalibrated. An accelerated recall was initiated by the contractors in case the system was needed. The system was rapidly assembled by the contractor so that it could be deployed.

Sortie one.

The first sortie was flown on the 22nd of February, on station between 14:45 GMT and 16:16 GMT. The sortie was flown under cloud at 4000 feet, yielding a ground swath of a little over 2 km, with a ground resolution of 4 m. The proposed survey schedule was re-designed in the air due to cloud height. A number of lines were flown in spatial mode (see map) with one line flown in spectral mode (line E). The survey was targeted over the area known to contain oil at that time, from Skomer Island to Caldey Island.

Image one shows the northern section of image C (see map), represented as a false colour composite image designed to best highlight suspected oil features. An initial interpretation is included on the image.

Image two shows Milford Haven (image A on the map) with the same processing as image one.

Image three shows the area between Milford Haven and St. Ann's Head (image E on the map) treated in the same way as image one.

CASI Flightlines, Milford Haven Area, 22nd February 1996.

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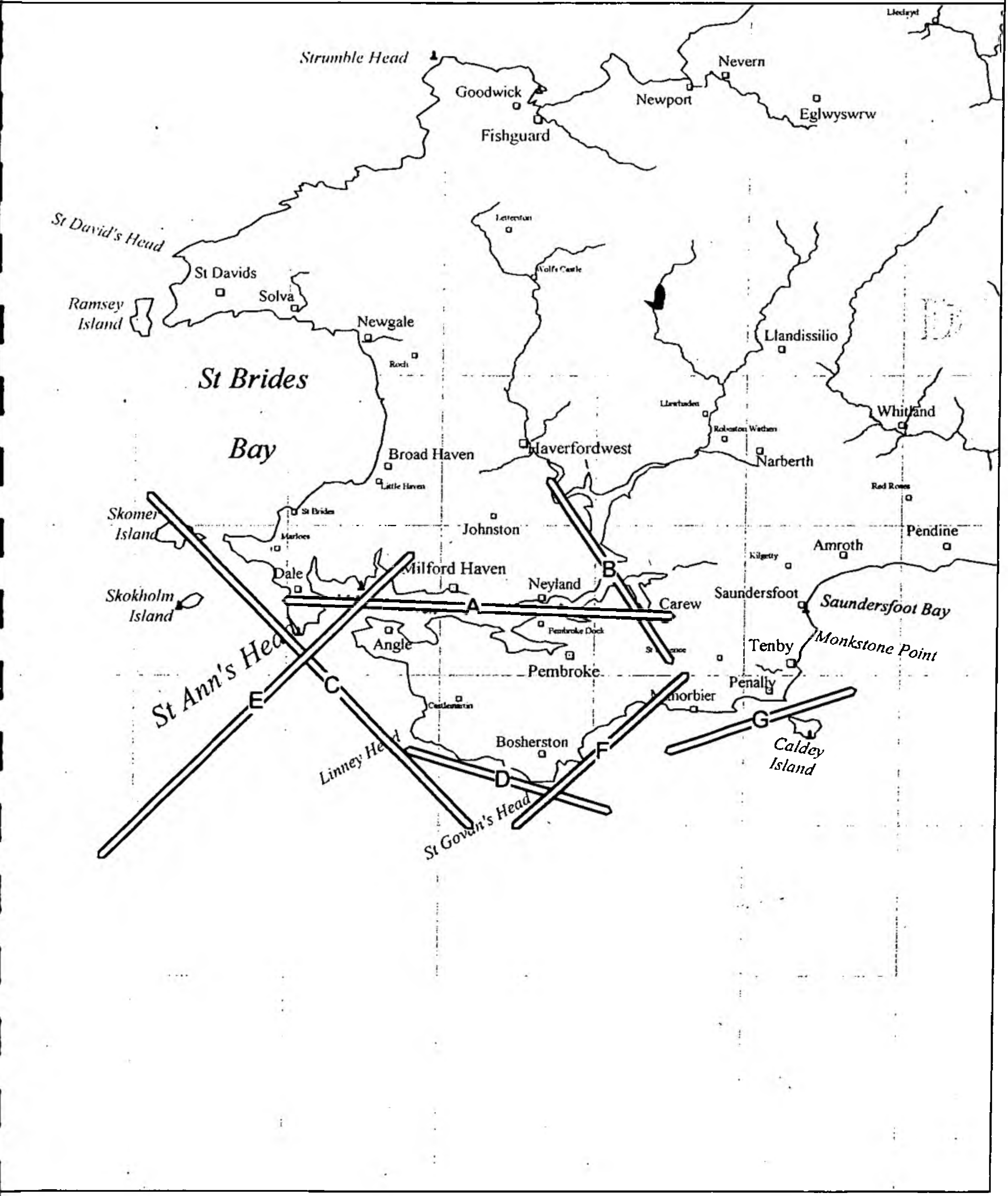
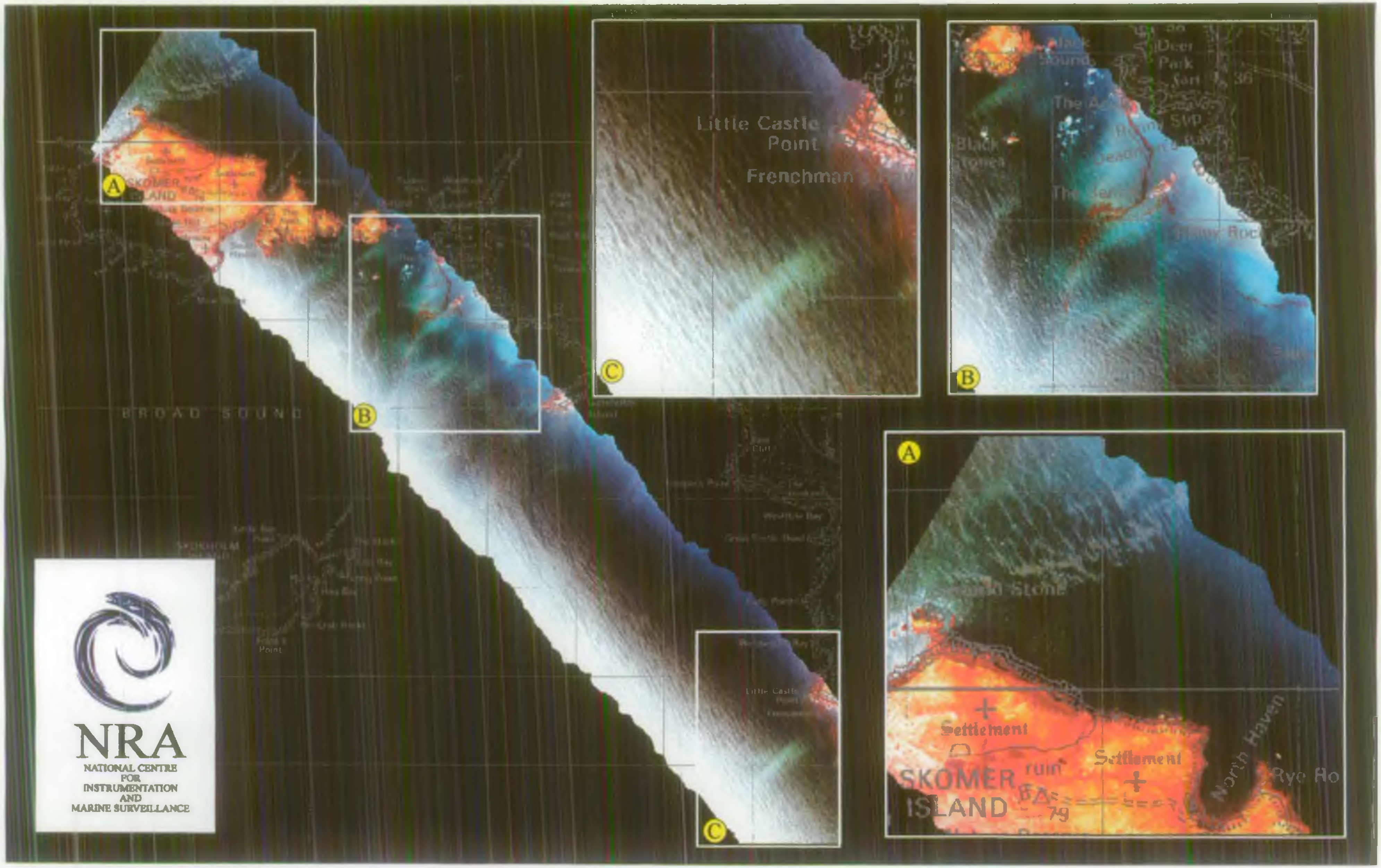




Enhanced false colour composite CASI image
Skomer to mouth of Milford Haven
22nd February 1996 15:30 GMT

Image 1

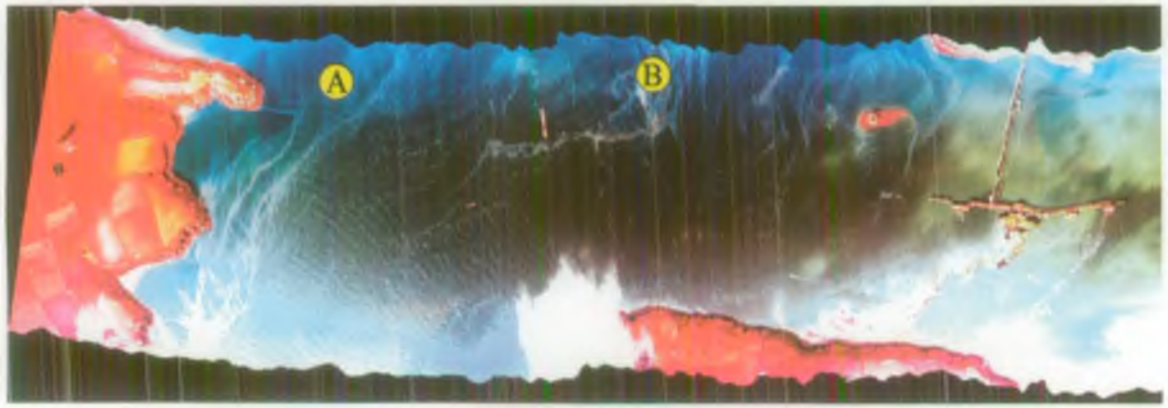
TENTATIVE INTERPRETATION

A: Oil breaking down to the north west of Skomer. Solid oil is seen as a red area with breakdown products seen as grey streaks. Oil can also be seen in North Haven and around Rye rocks.

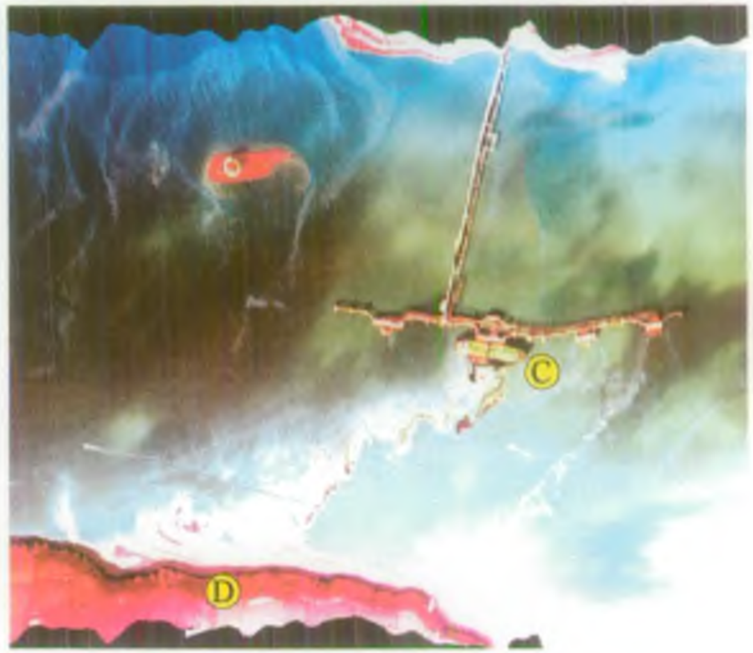
B: Organised oil in between Skomer and Gateholm seen as red, coming ashore in the area of Deadman's bay. White streaks perpendicular to the coast and in other areas of the main image are consistant with the characteristics of dispersant.

C: Streaks of slick oil (red) coming from Little Castle Point, close to the point where the Sea Empress ran aground. The left hand side of the image is affected by atmospheric attenuation, hence it is light in colour.

1



2



3

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4

CASI imagery of Milford Haven
22nd February 1995 15:00 GMT

TENTATIVE INTERPRETATION

1: Overview image of Milford haven shown as a true colour composite enhanced to show water features.
2: False colour composite of the western end of Milford Haven showing surface sheens (A) & (B).
3: Close up of the area surrounding the Sea Empress on the pier head. The image is presented as an enhanced false colour composite. (C) oil can be seen leaking from the tanker and approaching the shore (D)
4: Close up of the eastern end of Milford Haven showing oil sheen in the water (E).

Image 2

Enhanced false colour composite CASI image.
Milford Haven to St Ann's Head
22nd February 1996 15:30 GMT

TENTATIVE INTERPRETATION

(A) Stream of solid oil from St. Anns head, with smaller streaks running parallel. There is a background brown signature in this area which could be either associated with suspended sediment or oil breakdown products in the water column.

(B) Patch of dispersant? also similar to patches to the N. East of the image.

(C) & (D) Surface oil sheens.

Image 3

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Sortie two.

The second sortie was flown on the 23rd of February, on station between 14:18 GMT and 15:50 GMT . The sortie was flown under cloud at 1000 feet, yielding a swath width of approx 500m and 1 metre pixels. The purpose of this survey was to ascertain the maximum movement of the oil towards the North Devon coastline and especially the island of Lundy. CASI data taken at 1000 feet is approaching the limit of usefulness of the data as the resulting images cover thin strips of the surface (see map). An eye account of the location of the oil was passed to North Wessex operations on landing, and followed up with an initial assessment of the extent of the oil later that evening, and finally a faxed precise location map within 24 hours. Examples of the imagery around Lundy are shown as image four, and a copy of the faxed product is shown as image five.

A sortie was attempted on the 24th February, but was aborted due to a cloud base lower than 100 feet. Imagery cannot be obtained at this altitude, and the pilot aborted the mission on health and safety grounds.

CASI Flightlines Flown on February 23rd 1996.

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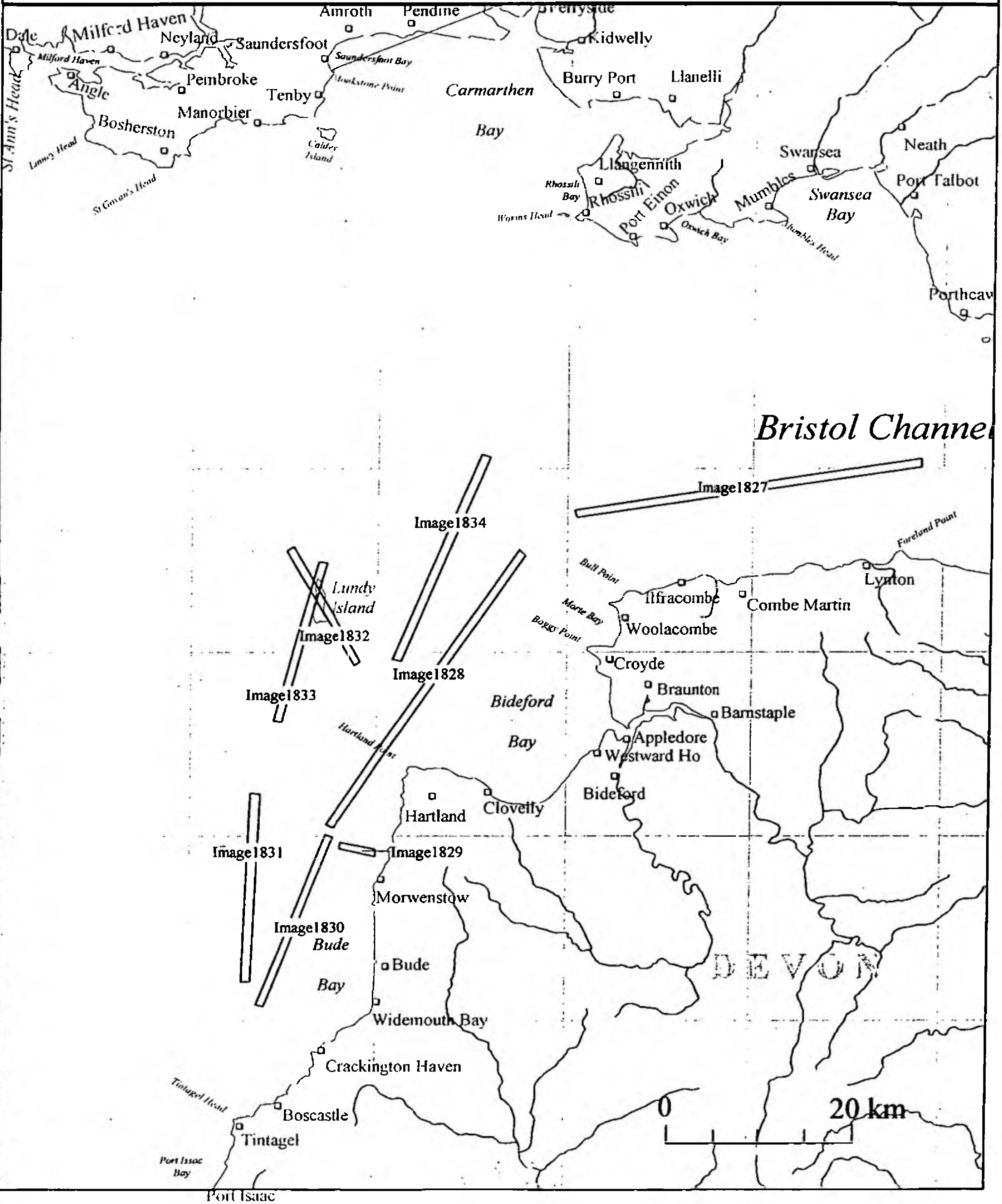

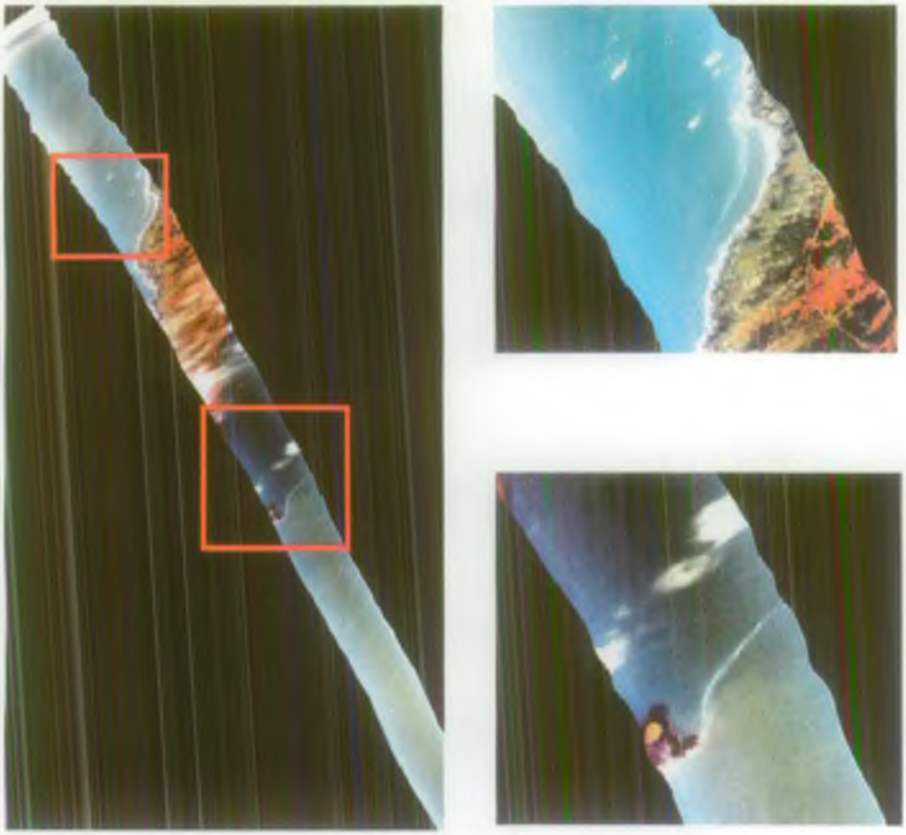

True colour composite image running north-west to south-east.
Surface sheens consistant with oil shown in enlargements.

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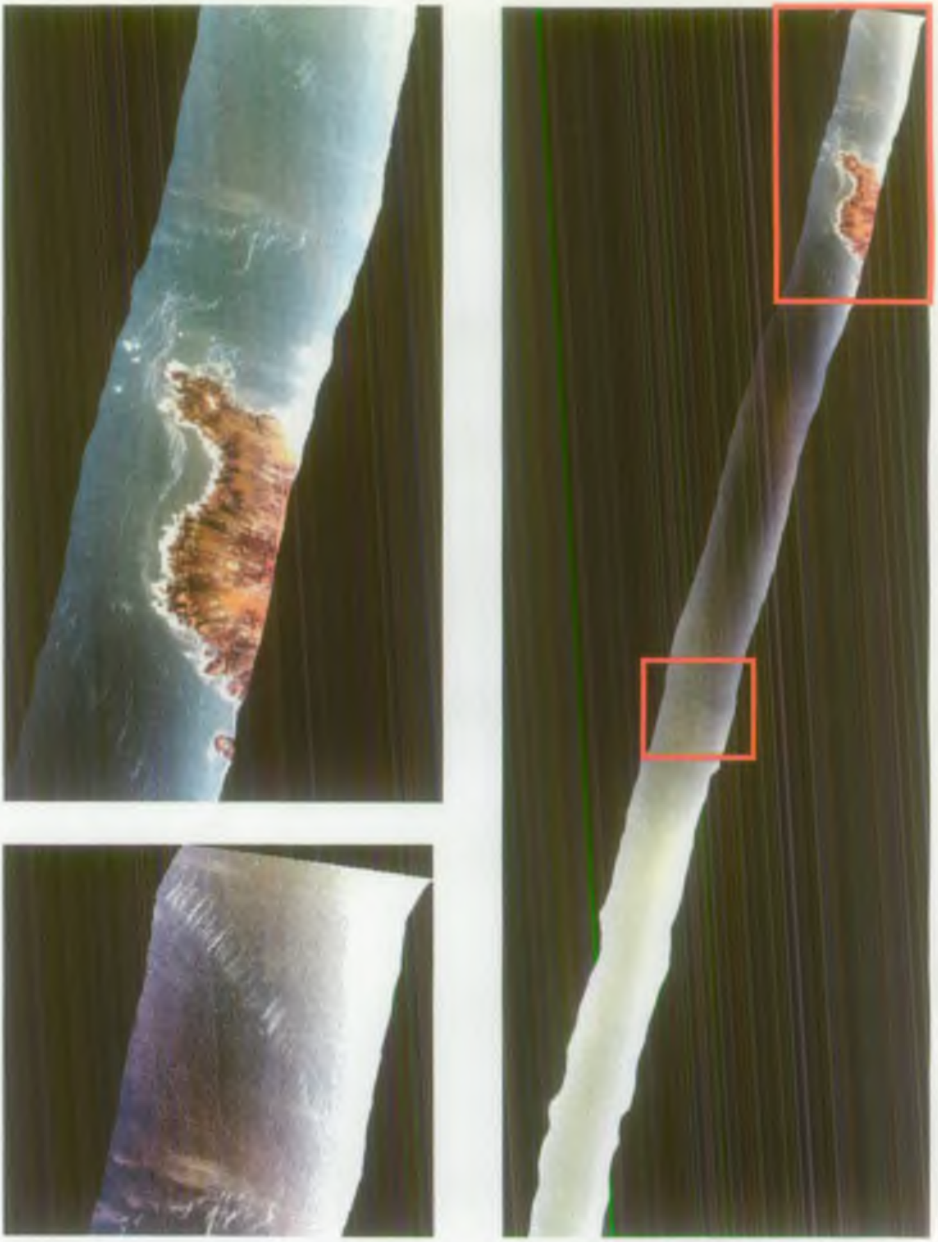
CASI colour composite imagery of Lundy
February 23rd 1996, 14:00 GMT



True colour composite image runnng north-east to south-west.
Surface sheens consistant with oil sheens shown in enlargements

Image 4

Oil Patches on Images 1832 and 1833, Lundy Island, 23rd February 1996, 14:00 GMT.

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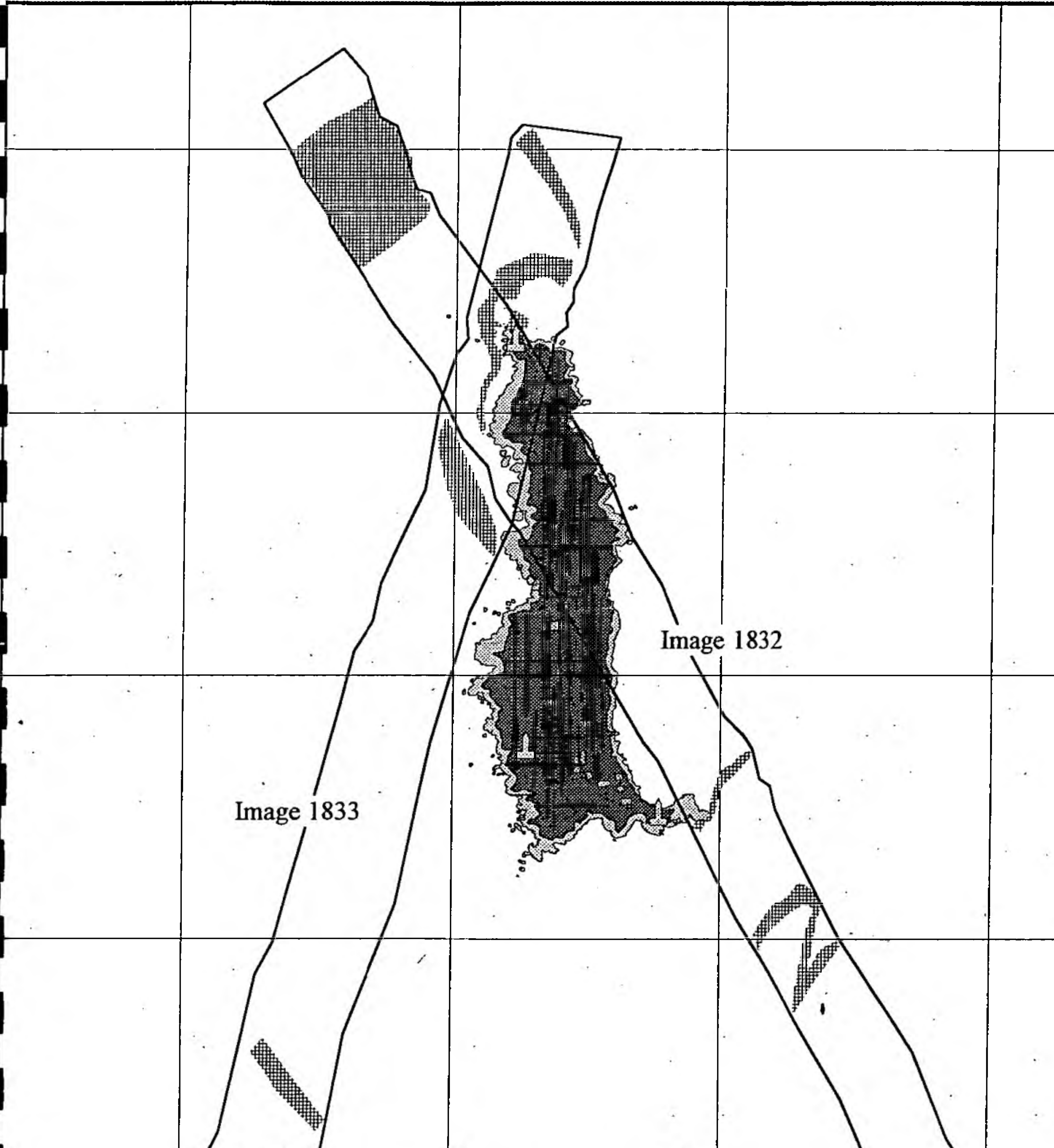

Image 5

Sortie three.

The third sortie took advantage of the clear skies on February 27th to cover the South Wales coastline from Newport to Swansea Bay (with the exception of the military exclusion areas south of Milford. The entire North Devon coastline was covered, as was the island of Lundy and surrounding sea. In addition a transect line from Hartland Point to St. David's head was flown (see map). This data therefore forms a total coastal inventory at the time. The survey was conducted at 10,000 feet, yielding a swath of 5 km and a ground resolution of 10 m. The survey was conducted between 09:56 GMT and 14:30 GMT.

The North Devon and Lundy imagery were processed rapidly to provide an assessment of any oil approaching the coastline. No oil was seen on any of the Lundy or Devon images or by eye in this part of the sortie. This was reported to the operations room in the North Wessex Region.

Image six shows a composite of all the South Wales images.

CASI Flightlines Flown on February 27th 1996.

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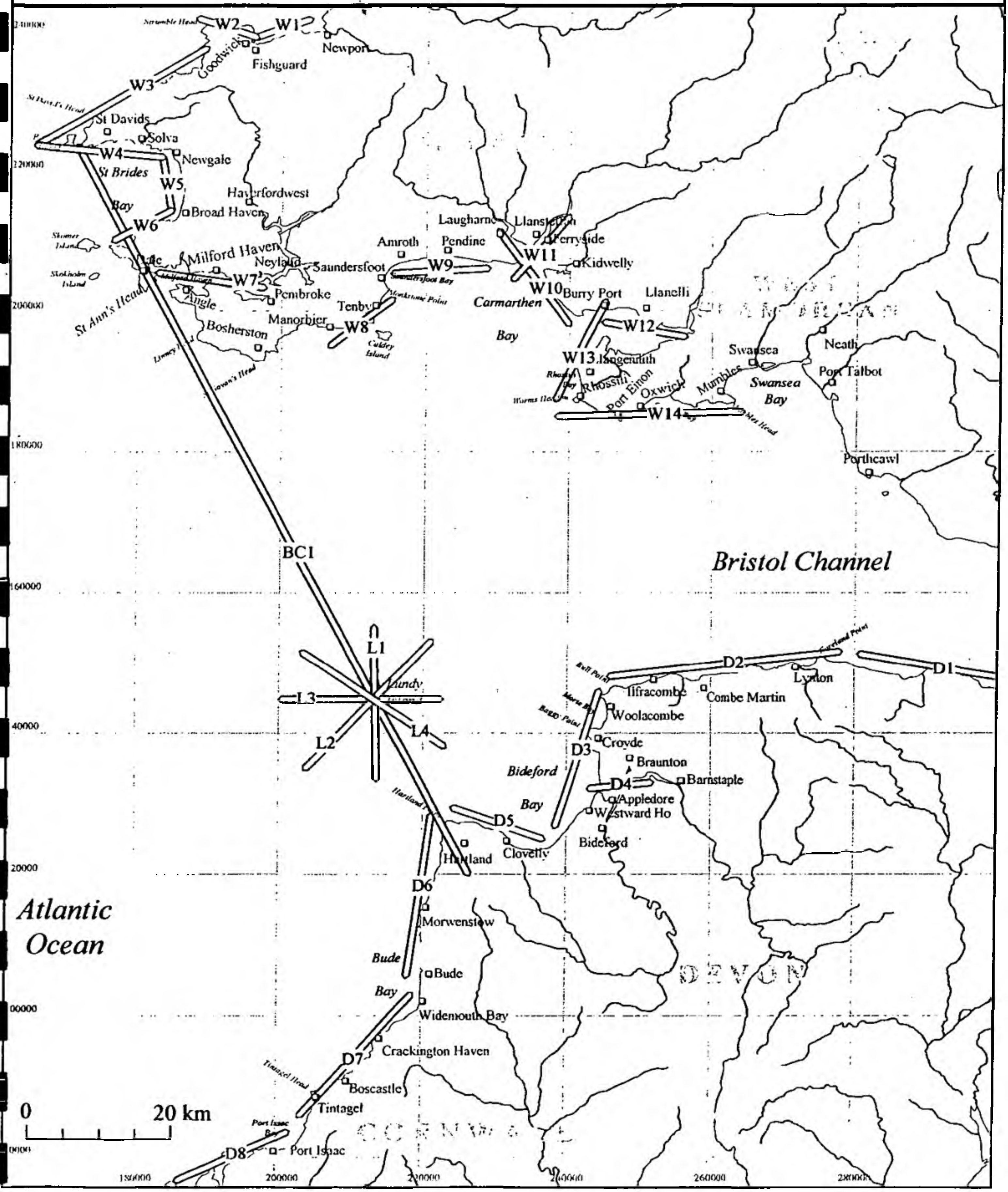

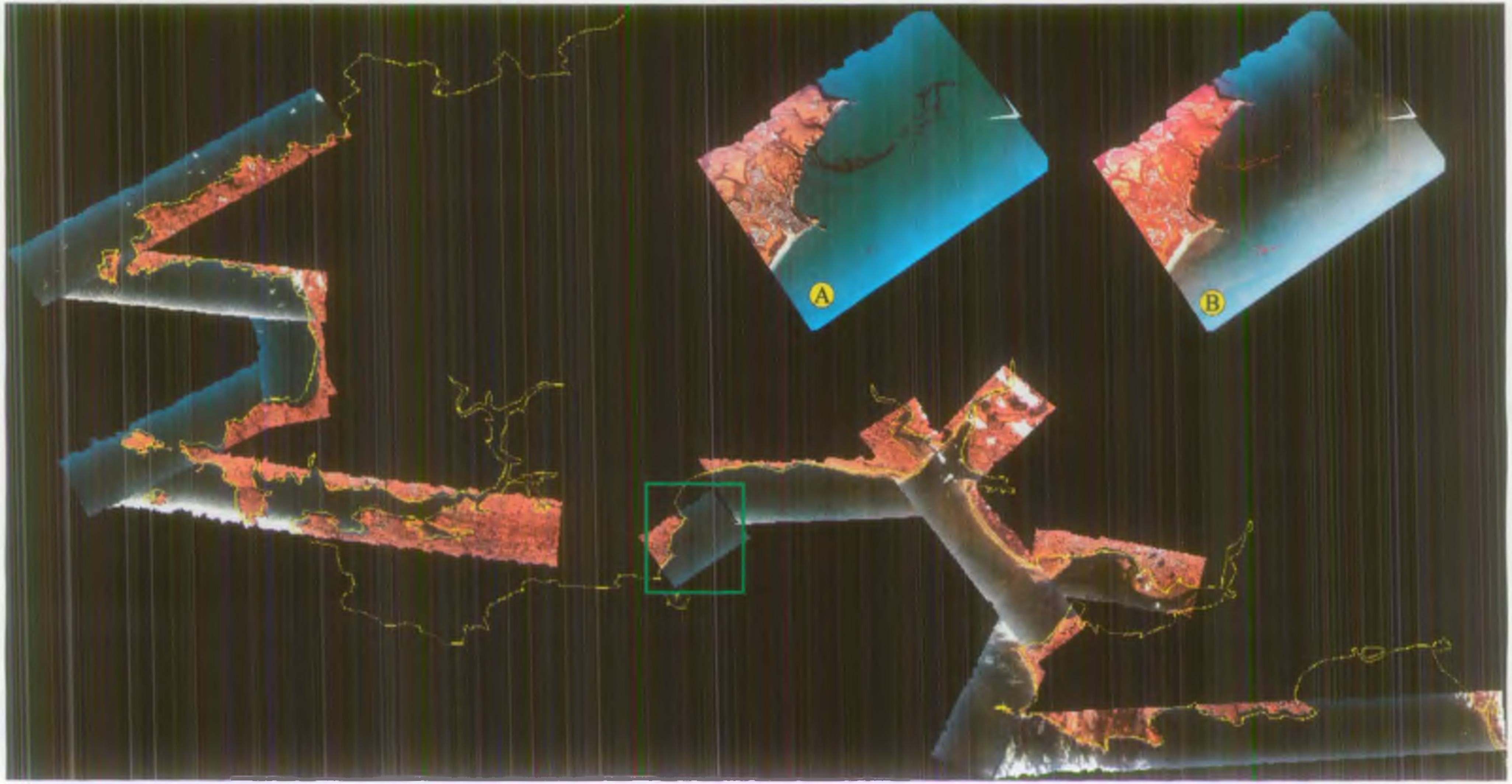

CASI composite of South Wales: 27th February 1996.

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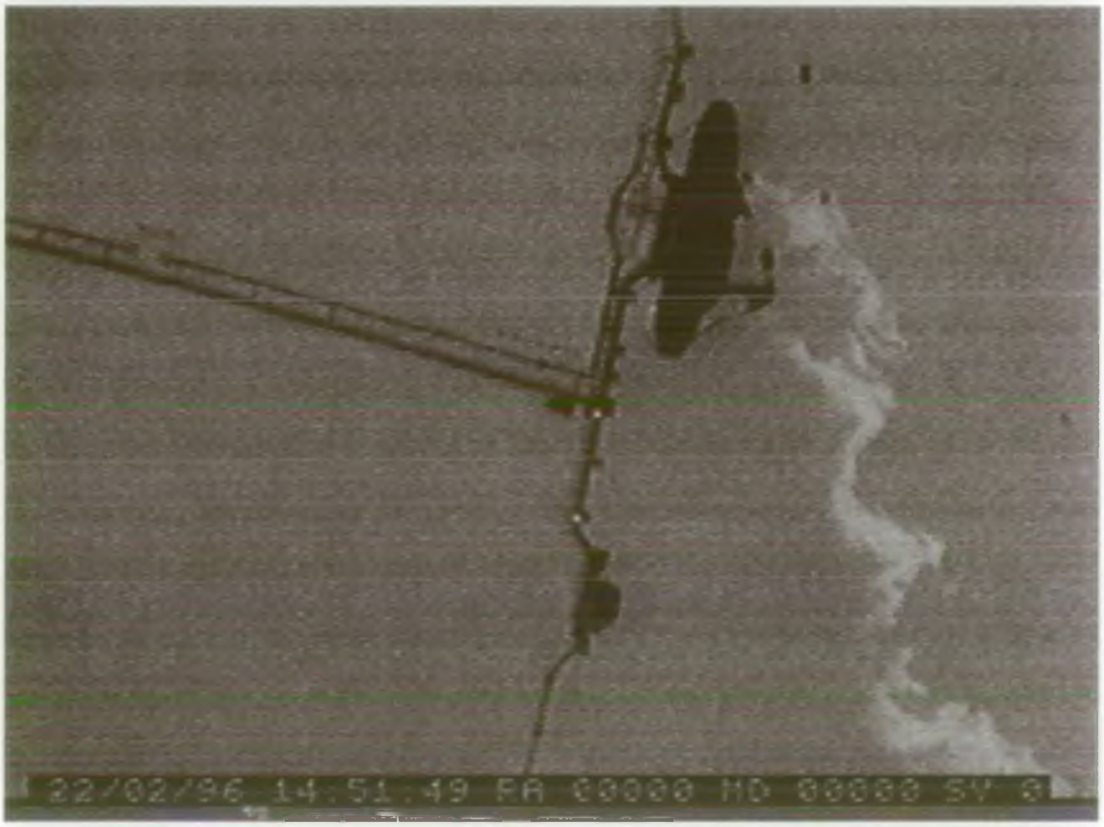
TENTATIVE INTERPRETATION

This is a composite of false colour images enhanced to show water features. Image (A) shows an enlarged image showing the detail available the area on the overview image that is enlarged is indicated by the green box. An oil slick is clearly visible. Image (B) shows the same area with further enhancement, showing the suspended sediment in the water column as well as the oil.

Image 6

Thermal and colour videos.

Results from the thermal and colour videos are available from the NCIMS in the form of summary tapes with event logs. A "frame grab" of both a colour and thermal video is included as image seven.



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Colour Video & Thermal Video of the Sea Empress, Milford Haven, 22nd Feb 1996 14:51 GMT

TENTATIVE INTERPRETATION

The colour video (top) shows oil leaking from the tanker and streaming towards the shore. The quality of the image is seriously degraded by the frame grabbing process.

The thermal video (bottom) shows a lighter tone for the oil, relating to cooler surfaces. The two camera systems do not have the same field of view, so the two frame grabbed images cannot be related exactly to each other spatially

Publicly Available Data

A number of commercial satellite systems were overhead during the initial period of the oil spill. These satellites fall into three broad categories: Meteorological, Earth Resource Scanners and Earth Resources RADAR. This document is not the place for a full description of these systems, a full description being available from the NCIMS in the report NC/Mar/003 (July 1995). A brief description of the types and their merits for oil spill monitoring is attempted below:

Meteorological

These systems provide a coarse spatial overview of areas on a regular basis. For example, the NOAA series of satellites will provide an image at least twice daily in the visible and thermal spectrum at a resolution of 1 km. Being passive sensor systems they cannot see through clouds. Cloud free NOAA imagery for the period of the spill is available, and is reputed to show thermal anomalies in the area due to differential emissions from the water surfaces. Data from these systems is low cost.

Earth Resource Scanners

These systems provide a good spatial resolution in wavebands chosen for land based applications on a very infrequent basis. For example the SPOT system provides data with a spatial resolution of 20 metres in 4 wavebands on a repeat time of typically 26 days. These systems cannot see through clouds, data is expensive and takes weeks to deliver. A series of "quick looks" for the area are being investigated currently, but initial cloud estimates are not encouraging.

Earth Resources RADAR

These systems provide guaranteed all weather coverage of the surface as they are active sensors based on RADAR technology. They measure the roughness of a surface and are ideally placed to detect changes in surface roughness of a water body, which could be produced by oil. Data is expensive, but is reliable in terms of aquisition time. Interpretation is difficult, as these sensors are quite new. There is a precedent for this type of imagery to be used in oil slick mapping. An informational leaflet from the European Space Agency is included as appendix 1. An example RADARSAT image is presented as image eight. The dark tones to the east of Caldey Island indicate a large change in surface roughness. A less pronounced reduction in tone in a tongue towards Lundy would be indicative of a lesser reduction of surface roughness, possible consistent with an oil sheen. Other images of the area are being sought by academic agencies to complement that bought by the IMS, and expert interpretation is being considered.

Other Systems

Other remote sensing systems, such as the airborne RADAR systems of the MPCU, were in use during the period immediatly following the oil spill. A comparison between systems such as these and satellite RADAR is undertaken in appendix 1. These data would be useful and complementary to the systems listed above and the NRA system in any study of the Sea Empress incident.

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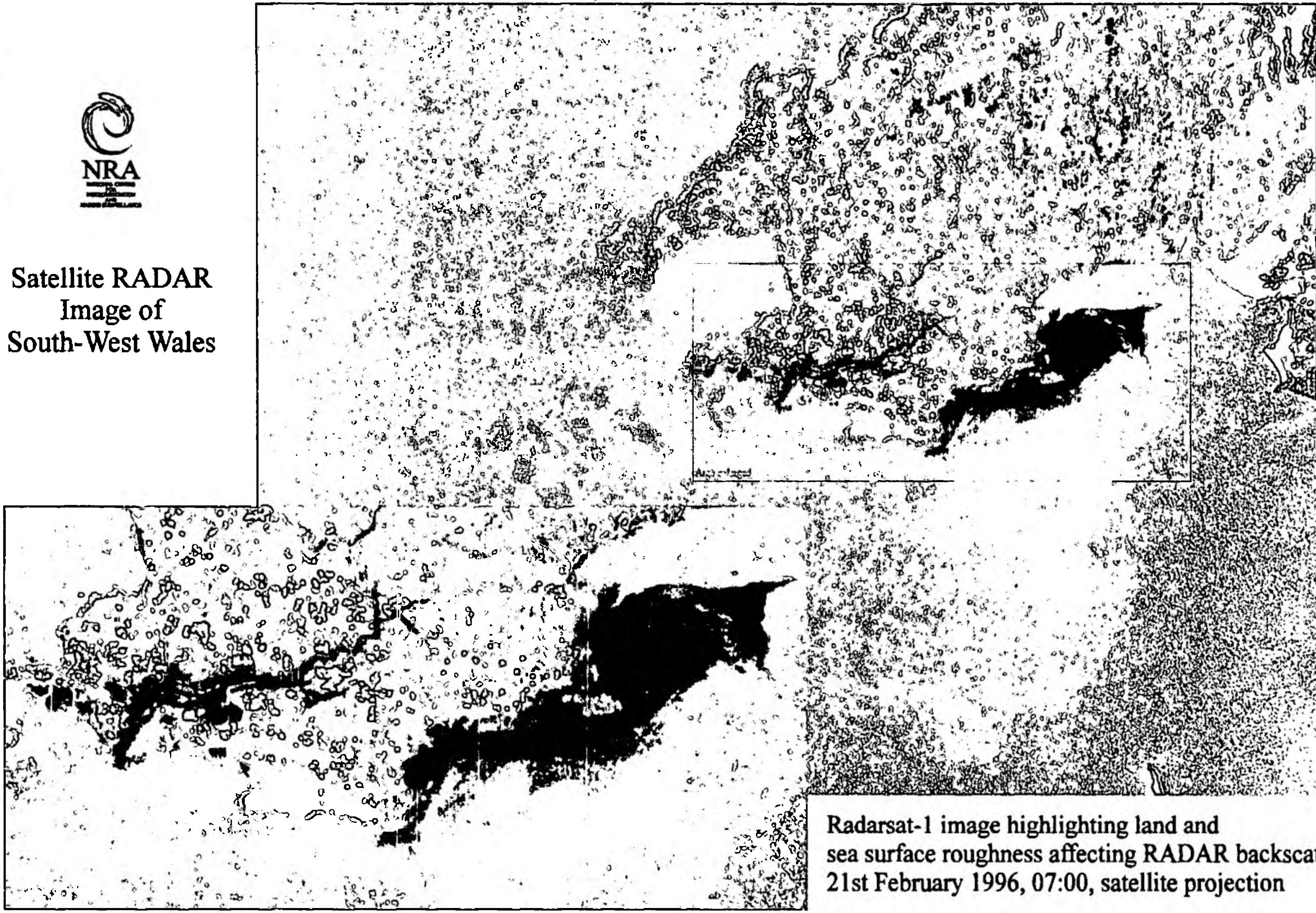
Satellite RADAR Image of South-West Wales



Radarsat-1 image highlighting land and sea surface roughness affecting RADAR backscatter. 21st February 1996, 07:00, satellite projection

Conclusions and further work

The NRA CASI and satellite RADAR systems were used successfully in operational support during the Sea Empress incident, providing valuable information to NRA staff on the ground. The logistics of system installation, survey design, execution and data processing, initially designed for country wide coastal surveys, are controlled in a manner that allows quick mobilisation for incident support. This capability is unique to the IMS system in the UK. In addition, the NRA system has collected a unique set of data of the incident. The worth of these data in scientific terms cannot be proven until it is collated with a full set of data from other remote sources, and more importantly, from ground truth data.

Further surveys at regular intervals in the next few months must be considered to address the question of the longevity of the oil in the water column.

Now that the immediate activity of the incident has begun to subside, a clear strategy regarding the scientific treatment of these data by a consortium of interested parties must be undertaken. To be effective, this will need to include academic experts, and representatives of the NCIMS, the regional NRA and other interested parties.

Now that the IMS system has proven itself in an operational "quick response" mode rather than the more strategic role it was designed for a clear strategy for system deployment in incident situations must be laid down, to minimise delays and uncertainty.

Appendix 1:

ESA pamphlet on oil monitoring from RADAR satellite systems.

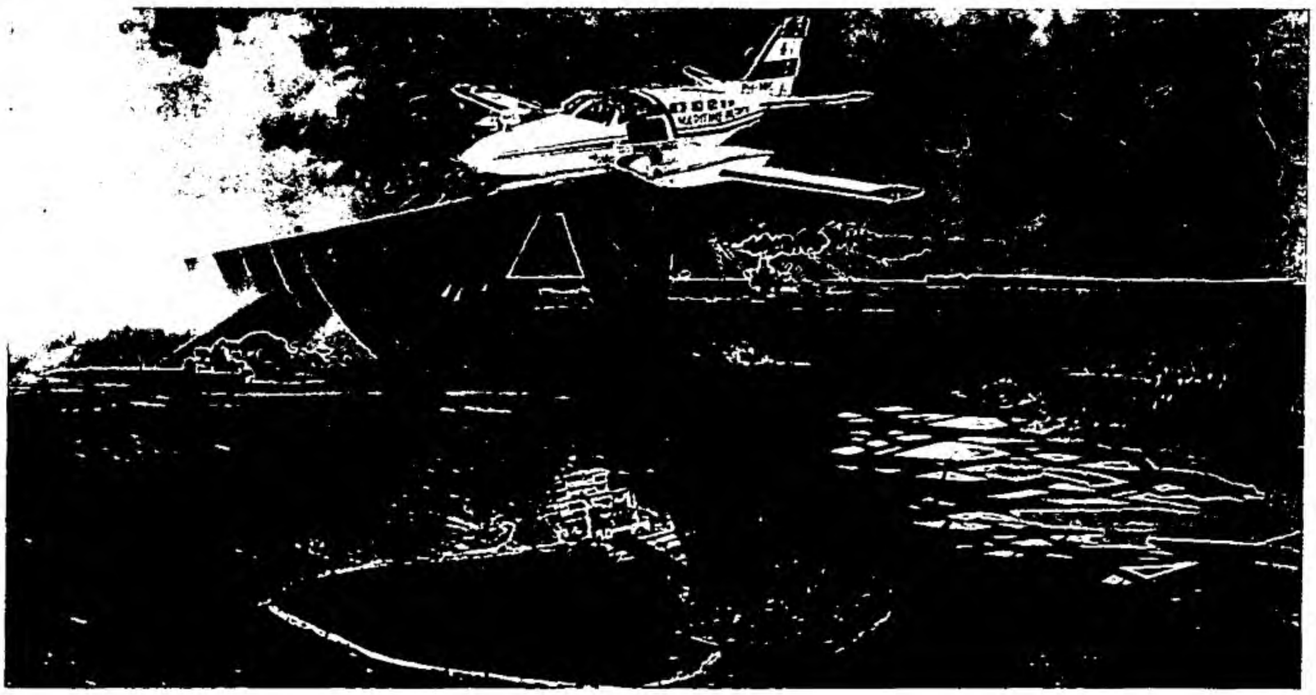
OIL SPILL MONITORING

The Situation Today

As a consequence of man's actions, oceans in general and coastal areas in particular suffer from ever-increasing exploitation and contamination. Although some water pollution is natural (plumes of suspended matter, algae blooms- both harmless and toxic, oil seepage from the sea floor, etc.), it is recognised that the great majority of stress to the marine environment is a result of man's activities.

This has led to the implementation of various national and international measures, laws and regulations, such as the total ban on oil discharges in the Mediterranean Sea. However, in spite of public awareness of these problems and the rigourous controls imposed locally on those shores dependent upon tourism, the deterioration of water quality, especially of those waters with heavy ship traffic, continues at a high rate.

Patrol ships and aircraft ensure continuous monitoring of coastal waters. Because of the high costs involved in patrolling extensive areas, these surveys require careful planning. (Courtesy of Swedish Space Corporation.)

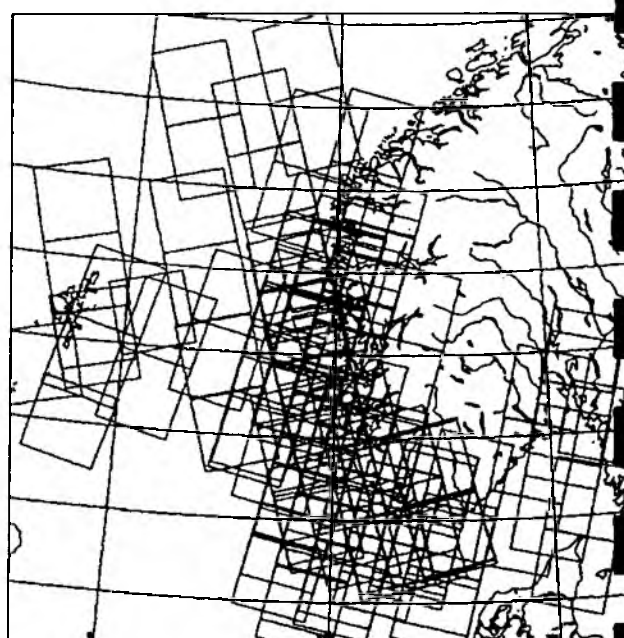


OIL SPILL MONITORING

Using Modern Technology in Operational Services

Until recently, large-scale monitoring was possible only by using aircraft; but this method was and still is very expensive. Few countries can afford routine airborne surveys so, to minimise costs, their geographic coverage is limited.

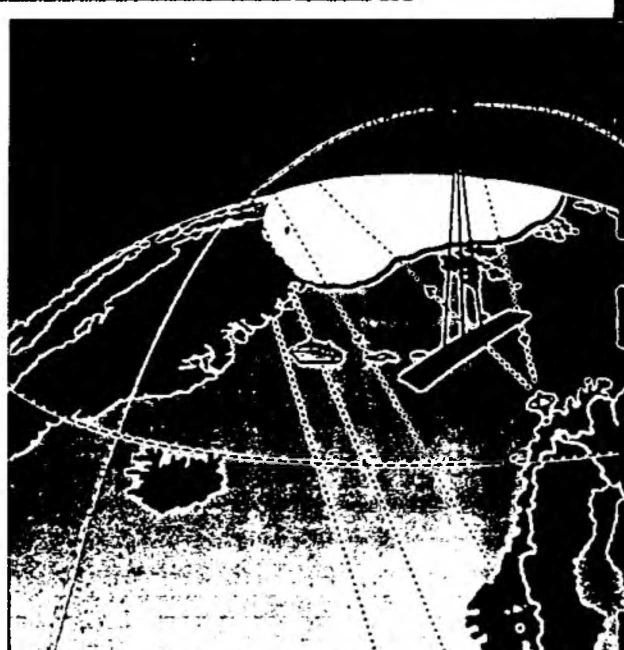
With the advent of earth observation satellites, extensive and repetitive surveys have become possible. When compared with similar airborne systems, space-based radars can provide more cost-effective monitoring.



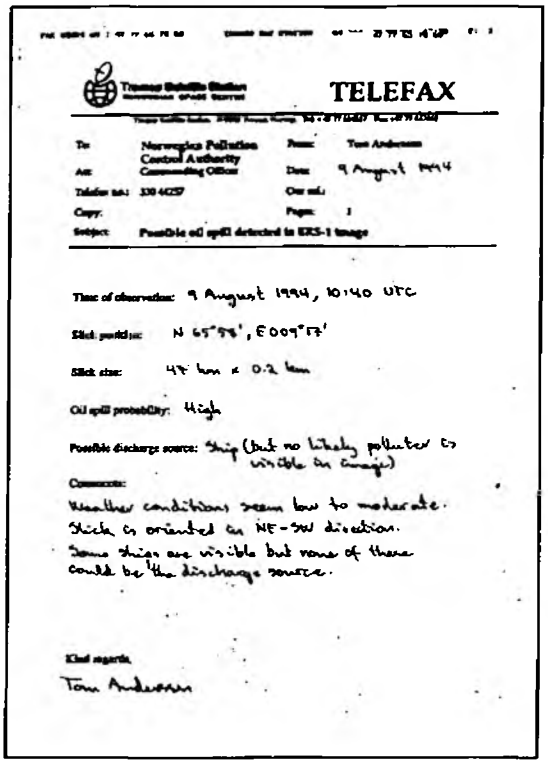
The Norwegian coasts have been monitored routinely by satellite since 1991. This observation pattern shows the ERS-1 satellite coverage of the Norwegian coast. Each square represents an area which is imaged every 35 days. Taking advantage of adjacent orbits, a specific area can be covered more than once a week, if so requested.

ERS-1 images are already used for monitoring oil spills. Maintaining surveillance of large areas with the help of satellite imagery means that not only can occasional small spills be identified (whether accidental or intentional), but also that their spreading and displacement can be monitored.

Such information is fundamental for coordinated intervention and clean-up operations. This information may also be used as evidence for insurance claims and legal actions.



The Tromsø Satellite Station receives and processes SAR data. When an oil slick is detected, a facsimile message is sent to the Norwegian Pollution Control Authority in Oslo. A "quick-look" image can also be transmitted either via "land-line" or telecommunications satellite link. (Courtesy of Norwegian Space Center.)



TELEFAX

To: Norwegian Pollution Control Authority

Att: Commanding Officer

Date: 9 August 1994

Pages: 1

Subject: Possible oil spill detected in ERS-1 image

Time of observation: 9 August 1994, 10:40 UTC

Slick position: N 65°58', E009°17'

Slick size: 47 km x 0.2 km

Oil spill probability: High

Possible discharge source: Ship (but no likely polluter is visible in image)

Comments:
Weather conditions seem low to moderate.
Slick is oriented in NE-SW direction.
Some ships are visible but none of these could be the discharge source.

Kind regards,

Tom Andersen

A typical facsimile message sent from the Tromsø Satellite Station to the Norwegian Pollution Control Authority. The position of the slick and other useful observations are stated.

A 12.4 km long oil slick and ships with their wakes (arrows) are imaged in the Oslo Fjord on 5 August 1991. This is one of the various oil slicks detected using ERS-1 satellite imagery. Upon receiving this satellite information, the Pollution Control Authority in Norway directed one of their aircraft to the area. Detailed on-site inspection revealed the origin and quantity of oil released.

An Example in Norway

Combining airborne observations with ERS-1 imagery has already shown good results in some countries. Norway, for instance, has set up a data processing and distribution system capable of acquiring and then quickly analysing data on the spot. This processed information is then transmitted to a specialised centre for further evaluation and analysis.

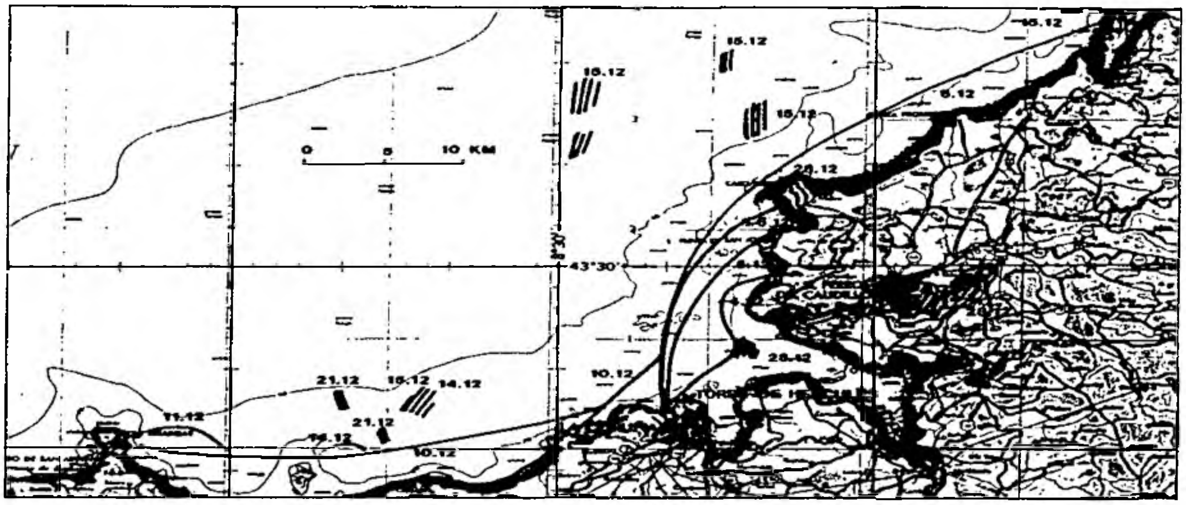
When a slick is detected in or near Norwegian waters, the responsible authority, in this case the State Pollution Authority, is alerted. Immediately, a plane is directed to the area indicated. The crew observes and estimates the extent of the spill and attempts to determine its origin. Most slicks are caused by discharges from tank cleaning operations on ships. Other discharges may originate from either oil rigs or fish processing plants. Once the source and extent of an oil slick are determined, the required actions are promptly taken.

An Example in Spain

The oil tanker disaster near La Coruna in December 1992, in which 80,000 tons of oil were released into the sea, represents a very significant case.

Detailed and daily reports from surveillance aircraft were vital in coordinating the clean-up operations. The radar data and images from ERS-1 provided wider, though less frequent, synoptic views of the area, thus offering complementary information.

By superimposing satellite images onto maps, precise information on the location and extent of oil slicks is easily seen. For longer-term monitoring, the complementary use of satellite data and aircraft checkpoints represents a cost-effective solution in meeting the requirements of governmental authorities, industries and environmental organisations.



December 1992 oil spill near La Coruna, Spain. Daily, detailed reports were collected from patrolling aircraft beginning on the day the accident occurred. Reports through 28 December are summarised.

Technical Note

The ERS satellites observe the Earth with microwave radar swaths 100 km wide. Nominal image resolution is 25x25 m. For oil spill detection, "low" resolution images of 100x100 m are used; this reduces the data content of each image from 64 Mbytes to 2 Mbytes or less. Oil spill detection is possible under wind speed conditions ranging from 6 to around 23 knots (3-12 m/sec). Within this range, the wave damping action of an oil film is most effective. The microwave backscatter is greatly reduced in these areas as compared to the surrounding oil-free waters. However, to distinguish natural from man-made slicks requires special expertise.

Contact Addresses:

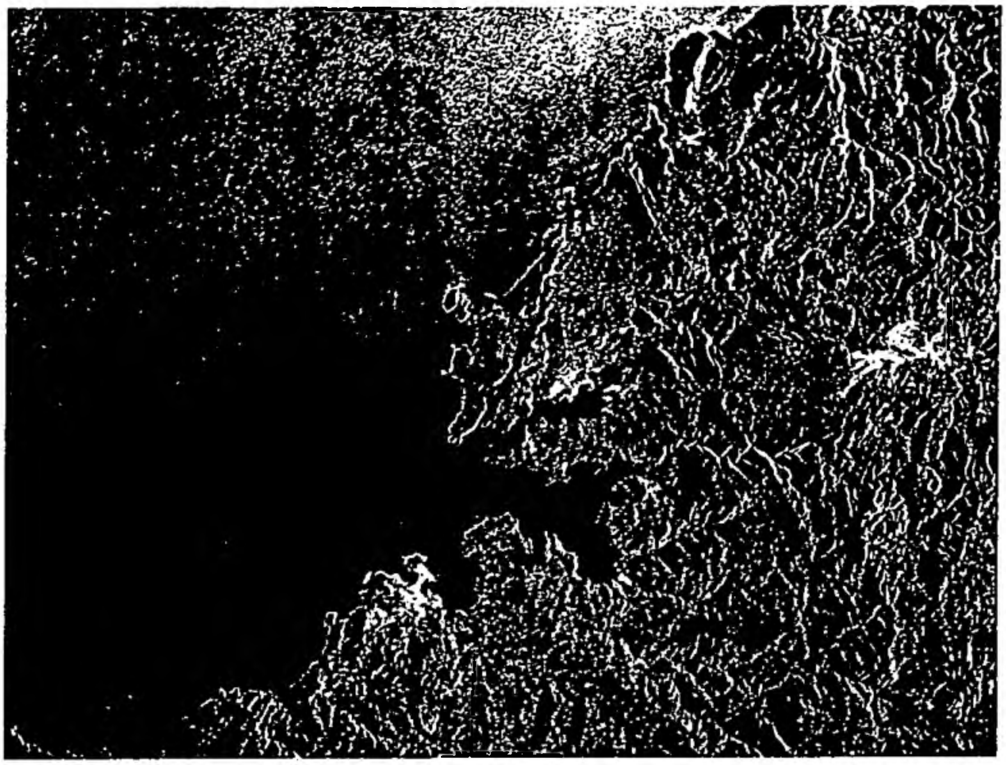
Tromsø Satellite Station
Norwegian Space Centre
Prestvannveien 38
N-9005 Tromsø (Norway)
Tel: (+47) 77 68 48 17
Fax: (+47) 77 65 78 68

ESRIN
Via Galileo Galilei
I-00044 Frascati (Italy)

- ERS Data Utilisation Section
  Tel: (+39) 6 941 80 419 or 371
  Fax: (+39) 6 941 80 520
- ERS Help Desk
  Tel: (+39) 6 941 80 600 or 711
  Fax: (+39) 6 941 80 510

esa

On 3 December 1992, the tanker *Aegean Sea* ran aground and exploded near La Coruna, Spain. Some 80,000 tons of crude oil were spilled and covered more than 200 km of coastline of great touristic importance.

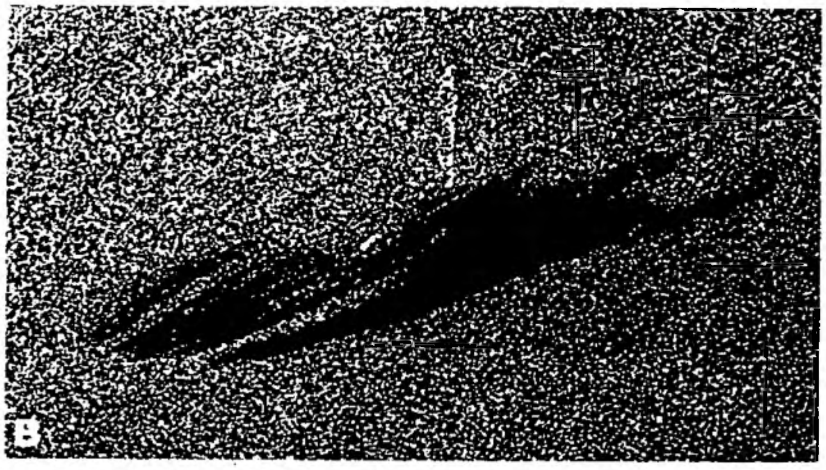


The satellite image of 13 December 1992 shows the extent of this ecological disaster.

The satellite image of 1 January 1993 shows that the pollutant is still present; this indicates a need for long-term monitoring of such events (from both aircraft and satellite).

An oil slick off the Netherlands coast as observed by airborne SAR and ERS-1 SAR. Satellite data are used by the Dutch Coastguard in their North Sea surveillance activities.

These images were taken almost simultaneously, within one minute of each other, by a radar-equipped surveillance aircraft and by ERS-1 on 4 June 1993. The shape of the slick appears identical in **A** (image from aircraft) and **B** (full-resolution close-up image from ERS-1).



But ERS-1 also provides a wider view **(C)** which enabled measurement of this spill's extent. This information permitted the aircraft crew to evaluate further the phenomenon in terms of thickness and quantity.