Belgian science policy office (BELSPO)

AQUATIC ENVIRONMENT

BELGIAN EARTH OBSERVATION

Projects financed by the Belgian research programme for Earth observation Telsat 4 (1996-2000)

Introduction

Coastal regions are of exceptional ecological value, in part because their biological diversity is much greater than areas located further inland. But they are also hugely important from a purely economic perspective.

Over half of the world's human population live in coastal areas (less than 50km from the sea). Many people depend on the sea for their livelihood: fishery, port activities, tourism, etc. Eighty percent of all human activities take place in coastal zones, inevitably causing some harm to the marine environment, through oil spills, sewage disposal, sand mining, and so on. Overfishing fosters coastal erosion, which causes economic losses, e.g. by sedimentation, which in turn necessitates expensive dredging operations.

Today, conservation of the sea and coastline is receiving increasing attention. For example, a joint programme of IUCN (International Union for Conservation of Nature) and UNEP (United Nations Environmental Programme), under the aegis of the Barcelona Convention, is helping the countries around the Mediterranean to create protected marine areas and adopt a common approach for managing their coastlines. The OSPAR Convention for the Protection of the Marine Environment of the North-East Atlantic entered into force in 1998, which moreover was the International Year of the Ocean (IYO).

Both optical and radar satellite data can be of great help for sustainable management of oceans and coastal environments.
In coastal areas, satellite data are used to locate navigable channels and perform bathymetric measurements, identify schools of fish, detect oil spills, but also to monitor coastlines, water quality, sedimentation, and fragile marine ecosystems such as reefs and mangroves. Radar images are particularly useful for detecting oil spills, sand banks, etc.
Further out on the open sea, satellite data are used to map currents, measure and monitor water surface temperature, and help determine the most suitable shipping routes. Radar data can also be used to validate and improve forecasting models for waves and storms.

THE MULTICOULORED NORTH SEA

THE SEA ISN'T ALWAYS BLUE

The colour of the sea depends on its composition and the way the components of seawater absorb and/or scatter light. For example, the colour of the ocean is affected by sediments in suspension (sand, mud, clay), phytoplankton, dissolved organic matter from plant decomposition, etc. This research project is based on this relationship… but it moves in the opposite direction. The objective is to develop methods to convert satellite measurements into maps of chlorophyll (an indicator of phytoplankton) and suspended sediments.

Why look at the sea's colour ?

Nitrates and phosphates from human activity (such as the agricultural use of fertilisers) reach the sea via the rivers. These biological nutrients can significantly modify the coastal ecosystem and cause a proliferation of undesirable species of phytoplankton (microscopic marine plants). Scientists call this phenomenon “eutrophication”. According to international agreements such as the Oslo and Paris Conventions, now OSPAR Convention, or the prevention of marine pollution, the states responsible for eutrophication problems must take measures to reduce such pollution, for example by limiting the use of fertilisers and constructing waste water treatment plants. There is also an international obligation to monitor the evolution of this problem.

False colour SeaWIFS image obtained by combining measurements at blue, green and red wavelengths (© SeaWIFs project, NASA and Orbimage)

A visible consequence of eutrophication – “dirty” foam of biological origin on the beach

Methodology and Results

HOW IS SATELLITE DATA PROCESSED ?

Information on the chlorophyll content of seawater and on the concentration of suspended sediments is obtained after a complex processing chain. Briefly, the satellite measures the intensity of light coming from the sea. This light is scanned at a number of distinct visible (blue to red) and infrared wavelengths. Then the signal is "atmospherically corrected": it is decomposed into the component coming from the atmosphere, which is regarded as "noise", and the component coming from sea water, the signal of interest, which may form only between 5% and 40% of the total signal. Finally, this sea water component is fed into MU-COLOR, a computer model of ocean colour developed at MUMM, which converts the optical information into maps of concentrations of the desired water quality parameters : the chlorophyll and suspended sediment content of sea water.

The SeaWiFS sensor measures the intensity of light at a number of distinct wavelengths. These images show measurements made for blue (left) and red (right) wavelengths. The images are shown with a grey scale for intensity: the stronger the signal, the whiter the image.

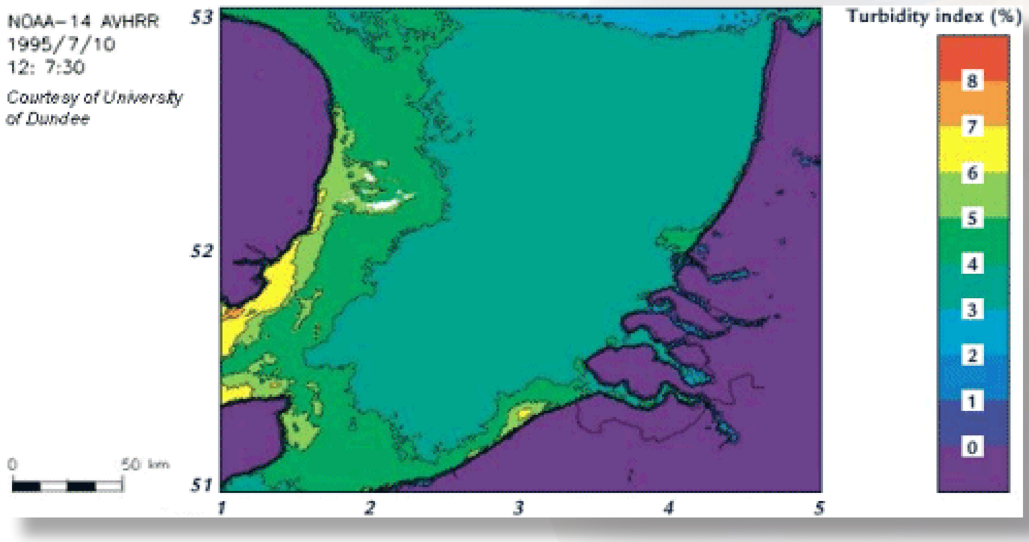
False colour SeaWIFS image obtained by combining measurements at blue, green and red wavelengths

Methodology and Results

SO, WHERE SHOULD WE DREDGE ?

Maps of suspended sediments from both AVHRR and SeaWiFS show distinct patterns of high concentrations related to resuspension of bottom sediments in shallow areas such as the Flemish Banks and at the mouth of the Scheldt Estuary. The image shows a map of suspended sediment concentration obtained from the AVHRR sensor. Concentrations are colour-coded ranging from blue (low concentration) to red (high concentration). On this map, a region of high suspended sediments can be clearly seen a few kilometres offshore of Oostende (approximately 3°E).

The satellite-derived maps are confirmed as realistic by measurements taken in situ. Public and private sector end users involved in the dredging and dumping of sediments need such maps for information about sedimentation rate.



Map of suspended sediment concentration obtained from the AVHRR sensor. Concentrations are colour-coded ranging from blue (low concentration) to red (high concentration). On this image, a region of high suspended sediments can be clearly seen a few kilometres offshore of Oostende (approximately 3°E)

A SNAPSHOT OF CHLOROPHYLL ? MAYBE LATER

Chlorophyll mapping by satellite has not yet been achieved because the signal is fairly weak and requires sensors with good coverage of the red part of the spectrum. However, chlorophyll mapping will come within reach in the next few years with the new generation of optical sensors. When available, such maps will enable the marine management section of MUMM to more accurately determine the extent and impact of coastal eutrophication, and hence will provide a sounder scientific basis for environmental legislation.

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Info

Abstract

Because of human activity (such as the agricultural use of fertilisers), nitrates and phosphates leach into rivers and ultimately arrive in the sea. These nutrients can significantly modify the coastal ecosystem by causing a proliferation of undesirable phytoplankton (microscopic algae). Scientists call this phenomenon "eutrophication".

According to the international agreements such as the OSPAR convention for the prevention of marine pollution, the countries responsible for eutrophication must take measures to curb this problem, for example by limiting the use of fertilisers and constructing waste water treatment plants. There is also an international obligation to monitor the evolution of this problem.

The quality of Belgian coastal waters is monitored regularly using samples taken by the Research Vessel Belgica. However, the spatial and temporal coverage of seaborne measurements is too limited to adequately monitor the rapid four-dimensional variation of water quality parameters, and they are also very expensive.

Under cloud-free conditions, satellite observations can complement these measurements by providing daily snapshots of the entire region for two key parameters that determine eutrophication: chlorophyll and suspended particulate matter.

Observation area

The region of interest for the Belgian MULTICOLOR project is the Southern North Sea between 51° N and 53° N with focus on the Belgian Economic Exclusion Zone. The dashed region encloses the Belgian Economic Exclusion Zone and the dark points represent locations where measurements are regularly made from the Research Vessel Belgica.

Projects financed by the Belgian research programme for Earth observation Telsat 4 (1996-2000)
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Infos

Satellite data

Traditionally, this kind of research has been carried out by seaborne measurement campaigns. Such campaigns are expensive and miss much of the real picture, since measurements can be taken at only one location at a time. Satellites can complement such campaigns by providing images of the entire region at a single time, and can fill in the gaps between seaborne campaigns with additional imagery.

Dredging operations are necessary to keep the approach to ports deep enough for shipping, but their cost is high. Research into the study of sediment movements near the coast can help optimise such operations. Such research, carried out using computer simulations and seaborne measurements, is facilitated by satellite imagery of suspended sediments.

Satellite data for this project comes from the NOAA-AVHRR series of satellites (from which suspended sediments and sea surface temperature can be deduced) and from the SeaStar-SeaWiFS sensor (suspended sediments and chlorophyll). The SeaWiFS sensor measures the intensity of light at a number of distinct wavelengths. These images show measurements made for blue (left) and red (right) wavelengths. The images are shown with a grey scale for intensity: the stronger the signal, the whiter the image. This image shows a false colour SeaWIFS image obtained by combining measurements at blue, green and red wavelengths.

This basis is being extended to a large range of current and future optical remote sensors (MOS, LANDSAT, SPOT, MODIS, MERIS) using a generic methodology.

Some fine tuning

Auxiliary data for atmospheric and whitecap corrections comes from meteorological observations, and calibration/validation data is obtained by measurements made at sea using the Research Vessel Belgica. Measurement of water colour is made at sea using a hand-held spectroradiometer. Such measurements are used to validate the mathematical model describing ocean colour as a function of chlorophyll and suspended sediment content.

Equipment for taking water samples at sea

Measurement of water colour is made at sea using a hand-held spectroradiometer

SEDIMENT TRANSPORT

WHERE TO DREDGE ?

Hai Phong Bay in Vietnam is subject to very special sedimentation patterns influenced by the Red River's (Sông Hong) delta, the estuaries of other northern Vietnamese rivers, the tides, and monsoons. The rivers dump thousands of tons of sediments into the Bay each month, albeit primarily in the rainy season. The sediment plumes are clearly visible on the LANDSAT TM, SPOT XS and SPOT P optical satellite images shown here.

Dredging

SPOT panchromatic image (21/10/92) covering the study area

Indeed, the torrential rains that characterise the summer monsoon season lead to massive runoff down increasingly deforested slopes. The result is catastrophic erosion and watercourses with particularly high sediment loads. When the river water comes in contact with seawater in the estuary these sediments precipitate out to form a mud plug that clogs the shipping channels and thus hampers access to Hai Phong's economically important port. To correct this situation, frequent dredging is required to allow the ships to pass.

In this study we are developing an optical satellite imagery processing method to study sediment transport so as to optimise costly and fastidious field data acquisition programmes. The sediment transport and coastal dynamics studies are part of the preliminary studies for port and marine facility engineering works as well as locating the areas to dredge. These studies are also being carried out to update old bathymetric maps (depth charts) and to check local maps' reliability.

Radarsat image (18/12/96) covering the study area
© Canadian Space Agency / Agence spatiale canadienne.
Received by CCRS. Processed and distributed by
RADARSAT International

Methodology and Results

BEFORE GETTING INTO THE NITTY-GRITTY...

A series of steps is necessary to carry out such research, in the following order:

- Creation of a mask to eliminate continental pixels
- Contrast enhancement
- Classification of the marine pixels
- Superimposition on a bathymetric map and the DTM (Digital Terrain Model) derived from the bathymetric map

Erosion seen by the uprooting of palm trees
over only three years.

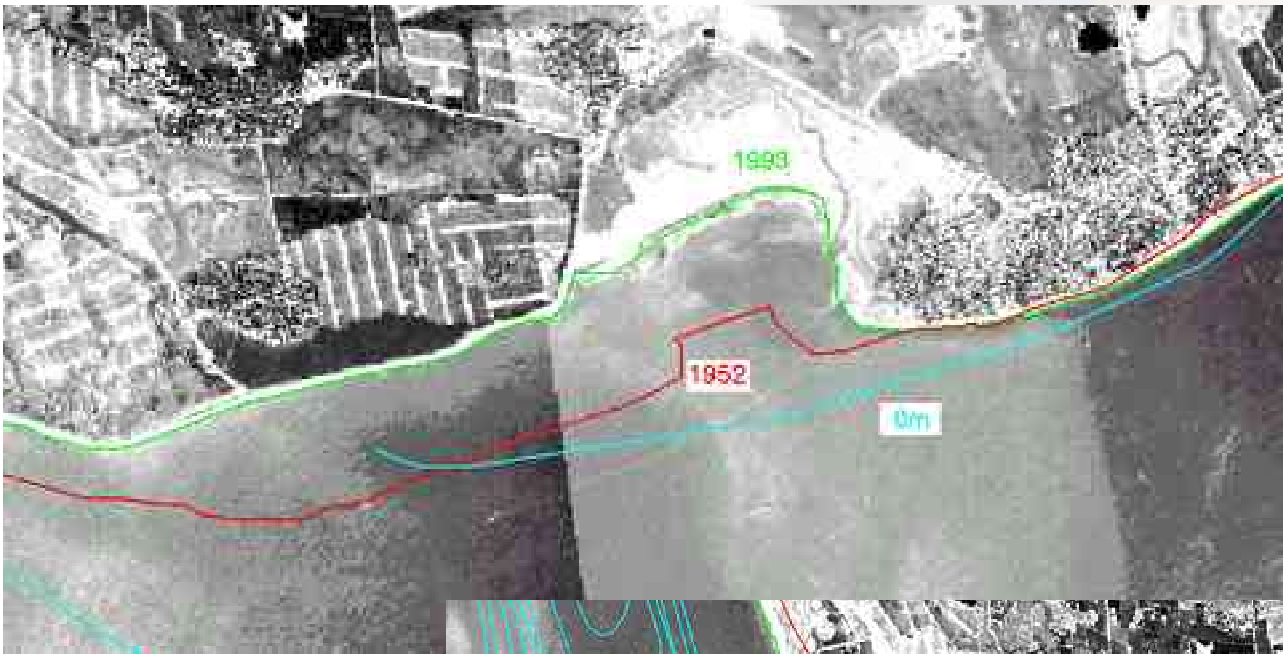
Erosion seen by the exposure of old constructions.

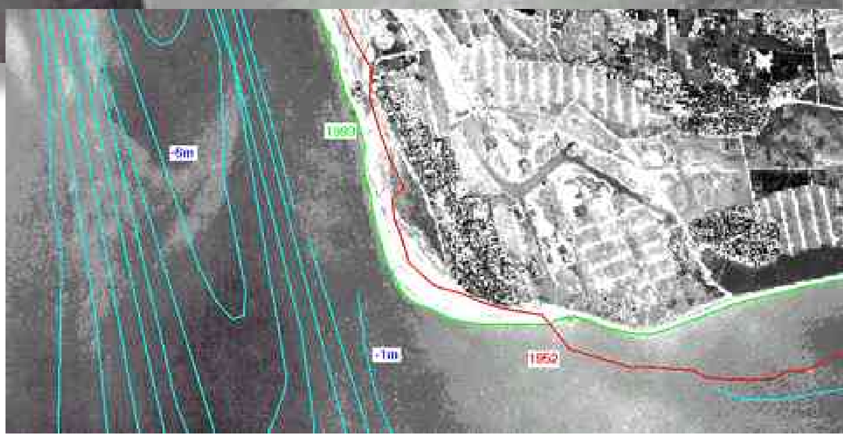
Methodology and Results

THE COASTLINE'S DYNAMICS

Some parts of the coastline in Hai Phong Bay have receded 100 to 400 metres over forty years due to severe erosion (this assessment comes from comparison of 1952 aerial photos and 1993 satellite images). Comparing the bathymetric map with the satellite images also shows that the coastline retreated up to 700 metres in some spots between 1939 and 1993. In contrast, a recent analysis has proven that this erosion is not generalised. Thus, a more than 60m advance of the coast along the estuary's banks was detected by comparing RADARSAT satellite images from 1996 with the SPOT satellite images from 1993. Advances in the coastline can also be detected if the 1952 aerial photos are compared with the 1993 satellite images.

Coastal erosion between 1952 and 1993. Comparison between 1952 aerial photographs and 1993 satellite images. Some parts of the coastline have receded 100 to 400 meters in forty years because of strong erosion.





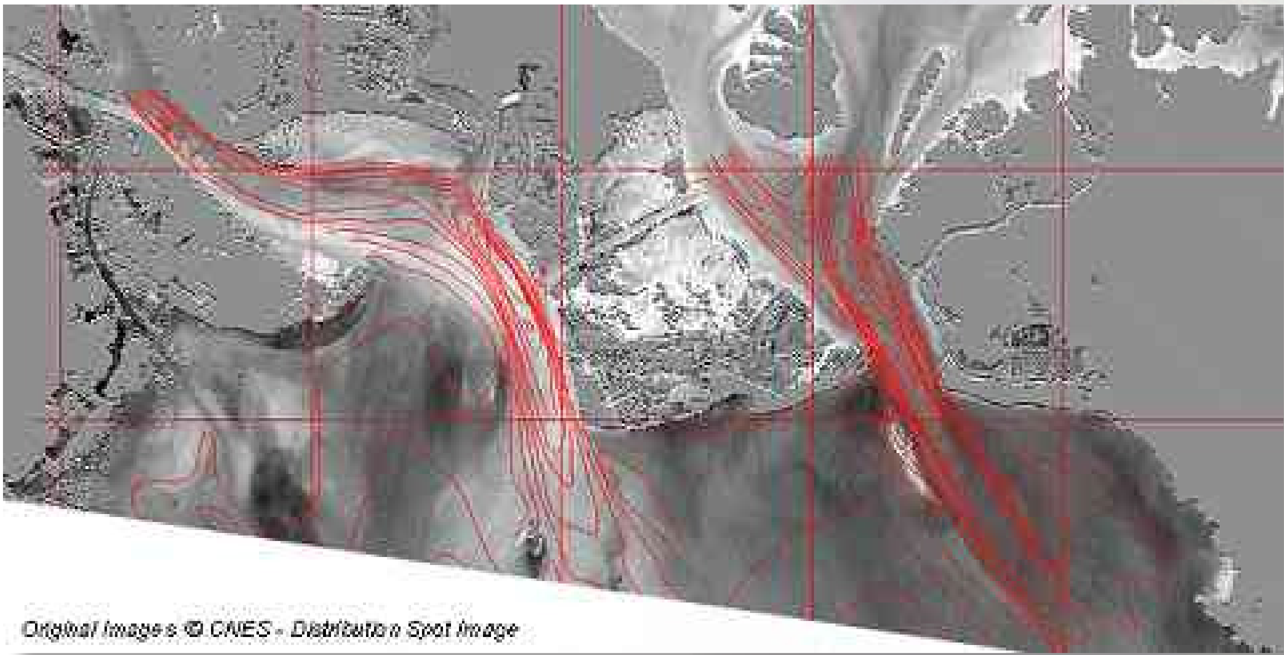
Retreat and erosion of the coastline between 1952 and 1993

Methodology and Results

SEDIMENT TRANSPORT

Plumes of coulours

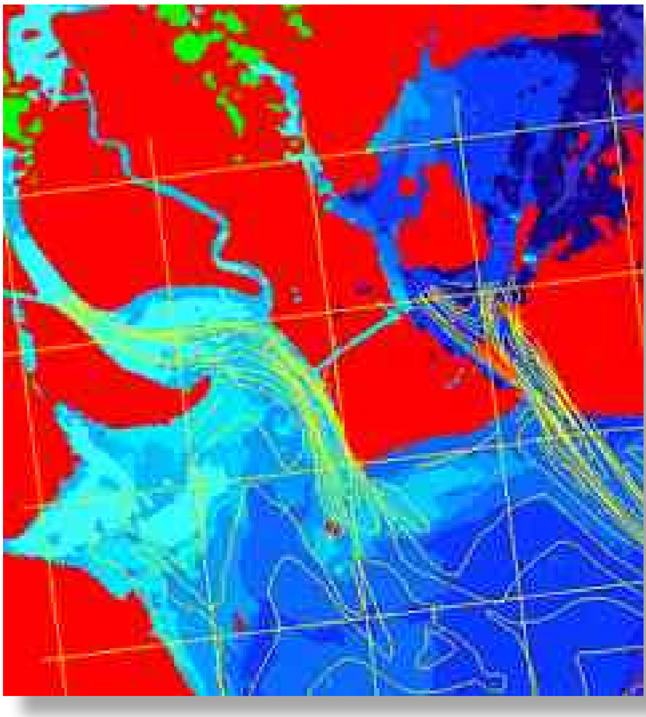
To visualise the sediment build-ups more easily, one can single out the red channel (of the SPOT XS2 or LANDSAT TM3 sensor) from an image in which sediment transport is difficult to see (during the dry season) and compare it with the same channel's signals in an image in which massive transport was seen during the monsoons.



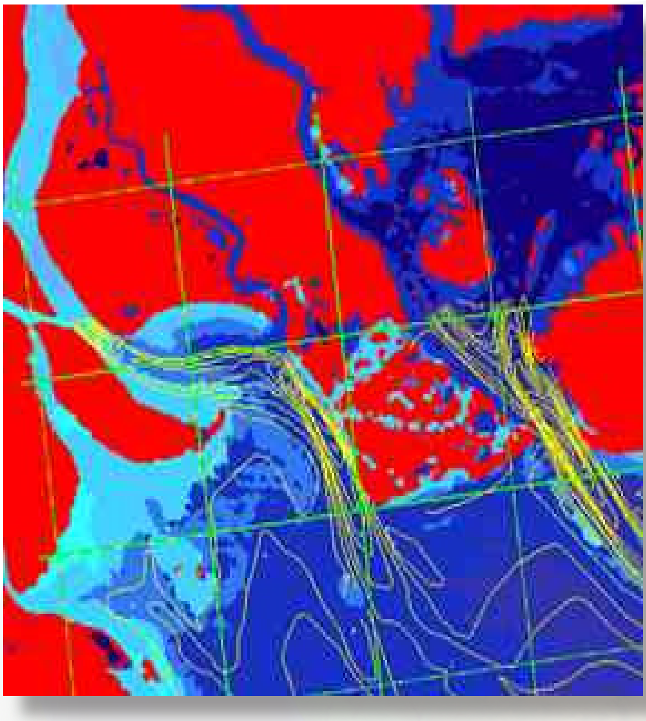
SPOT XS band 2 differential images of the study area (31/08/92 and 24/12/94) to improve visualization of sediment transport

Methodology and Results

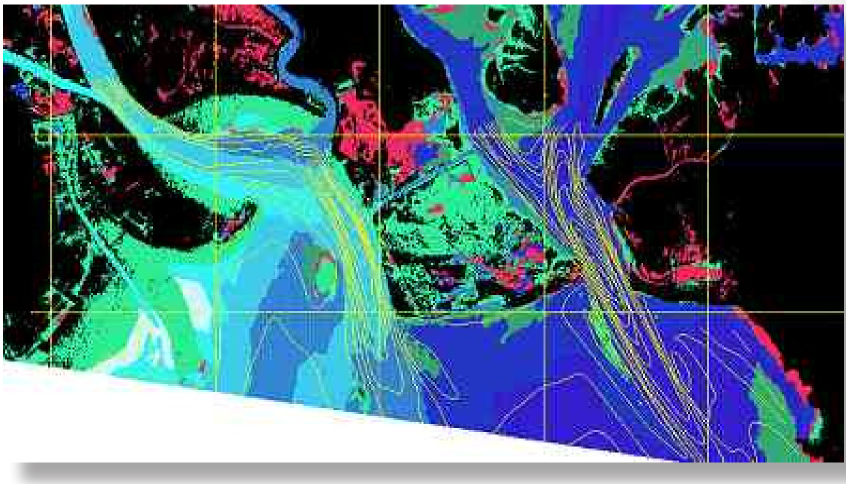
Thus, sediment plumes are visible in the estuaries in the western part of the bay in all of the rainy-season satellite images. The colours of the marine pixels in the satellite image correspond to the sediments' concentrations.



Landsat TM (16/06/89) classification.
The sediment plumes can be seen in the estuaries in the western part of the bay.



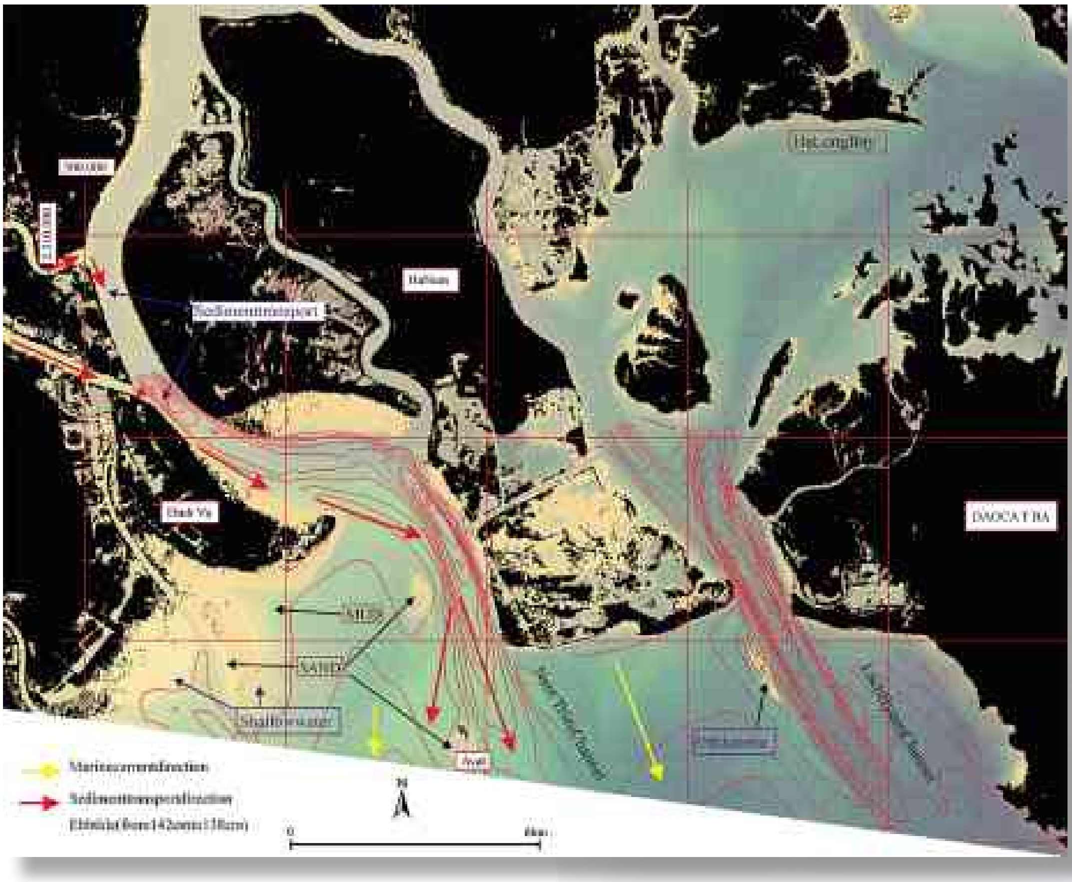
Landsat TM (01/12/92) classification.
The sediment plumes are not very visible in the dry-season images.



Spot XS (31/08/92) classification. The sediment plumes can be seen in the estuaries in the western part of the bay.

Methodology and Results

The distribution of colours indicates the southward direction sediment transport.



Direction of sediment transport derived from the satellite images

In contrast, the sediment plumes are not very visible in the dry-season images. The spectral values are correlated with the water depth in the bay and approach canals. The spectral values in Nam Trieu Canal and the shallow parts of the bay are influenced by the types of sediment (sand and clay) that are deposited.

CONCLUSION

The accuracy of the maps obtained from satellite imagery may appear relatively poor at first glance. However, they are accurate enough to give recent, relevant information for civil engineering reconnaissance work and, what is more, within strict time and budgetary limitations. The study of the coastline's dynamics can provide a foundation for conducting socio-economic impact studies, for example, assessing the impact of a beach's retreat on local economic activities (rice farming, fish farming, saltflat operation, tourism, etc.).

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Info

Abstract

Wooded areas are extremely important in uplands, for they hold down the fertile topsoil. Uplands throughout the world are subjected to high erosion because of clearing. As a result, huge amounts of arable topsoil are being carried away by rivers and streams to end up in the rivers' estuaries and fill in shipping channels.

This is a major problem in Vietnam, where getting into Hai Phong harbour has become very tricky because of sedimentation at the mouth of the Red River (Sông Hong). During the monsoon season the harbour must be dredged repeatedly to enable ships to sail in and out.

Locating the areas for dredging quickly and effectively is very important for dredging firms.

Satellite images not only locate the sediment plumes and thus facilitate the firms' preparations and siting of port facilities, but may also be used to update old bathymetric maps (depth charts).

Satellite images can also be used to monitor coastlines that are receding due to erosion. This is important for sustainable tourism planning.

Satellite Data

SPOT P
SPOT XS
Landsat TM
Radarsat

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