THE CONTRIBUTION OF ERS1 AND SPOT DATA IN THE MORPHOLOGIC AND BATHYMETRIC STUDY OF THE NORTH SEA AND THE SCHELDT ESTUARY

Anne Lise COMHAIRE - André OZER - Annick JASPAR.

Université de Liège
Laboratoire de Géomorphologie et de Géologie du Quaternaire
Phone : (+ 32) 41.66.53.35 - Fax: (+32) 41.66.57.22.

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ABSTRACT
The objectives of this project are mainly to develop a methodology which uses satellite and particulary ERS1 imagery to create topographic maps of the sea bed, to understand local factors responsible for visible surface phenomena seen on radar and to use the tide level to cartography some flooded zones.

The first one is situated in North Sea between Zeebrugge (Belgium) and Walcheren peninsula (the Netherland) where we want to extract information about sea floor morphology. The image chosen are the one with the best contrast which seems to be the one sensed one or two hours before or after tide. After differents processing we did a classification which gives a very good information for the Vlakte van de Raan and the Spleet bankje where there are high currents. In the areas where the depth is higher than 15 meters it seems difficult to get information.

The second area is the Scheldt estuary where we studied the location and the extention of some islands in function of the tide. The tidal flat area of Saaftinge was examined too to follow the evolution of this zone

1. Location and interests.
As part of this research programme, we examined two zones situated to the North of Belgium, on the Belgian continental shelf submitted to regular tides and currents (Fig.1).

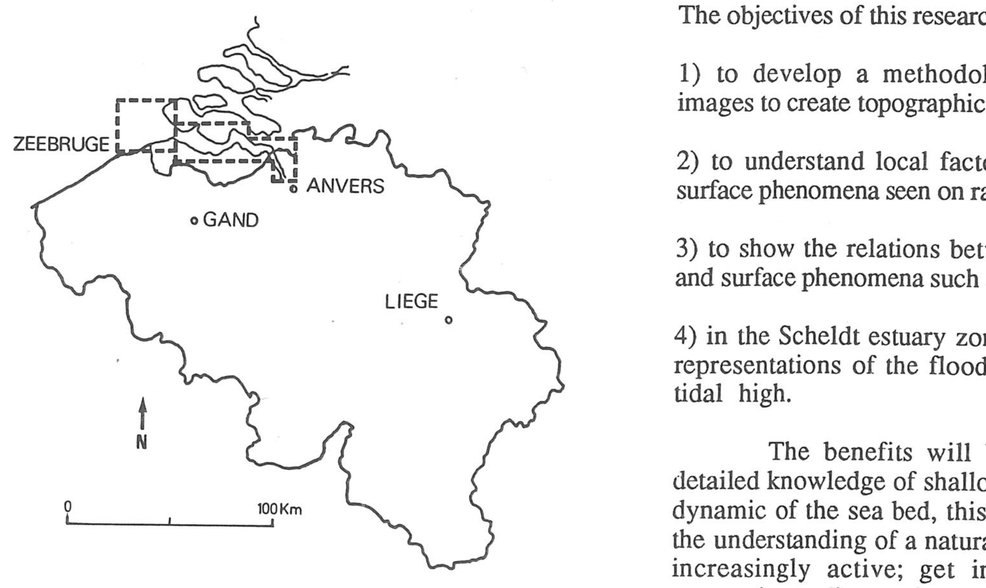

Fig. 1. Location of the areas of interest in Northern Belgium.

The first one extends (Fig 2) from the port of Zeebrugge (Belgium) to Walcheren peninsula (The Netherlands). In this zone, the depth varies from to 25 meters. Looking at the deep areas, we find the navigation channel called the Scheur channel (up to 15 meters depth) extending from the port of Zeebrugge to the Scheldt estuary and the area along the western coast of Walcheren peninsula (up to 25 m depth).

The shallows are represented by the Vlakte van de Raan, a large sand bank of triangular form with its south border parallel to the Scheur channel and its east border parallel to the Spleet bankje (shallower zone: 0,9 m) and the Zoutelande bankje (shallower zone: 0,5 m) the nearest to the coast.
These last banks are long and thin banks oriented to the NNW-SSE and located between the Vlakte van de Raan and Walcheren peninsula.

The second zone is the Scheldt estuary from the mouth of the river to the port of Antwerp. This river is a tidal river and one have to be sensible to the fact that the tide level is not the same in the whole estuary.

The depths, in this area are approximatively the same as in the first area. There is a succession of islands which are changing in location and area and this information is very important for navigation. The tidal flats and marshes areas of Saaftinge situated near to the port of Antwerp have also been observed.

The objectives of this research are:

1) to develop a methodology which uses satellite images to create topographic maps of the sea bed.

2) to understand local factors responsible for visible surface phenomena seen on radar.

3) to show the relations between sea floor topography and surface phenomena such as sea currents and waves.

4) in the Scheldt estuary zone, to realize cartographic representations of the flooded zones as a function of tidal high.

The benefits will be the following : get a detailed knowledge of shallow coastal water zones and dynamic of the sea bed, this is of particular interest in the understanding of a natural ecosystem where man is increasingly active; get information for problems concerning sedimentation and erosion of the beaches as well as access channels to ports and identify sedimentary structures and their mobility.

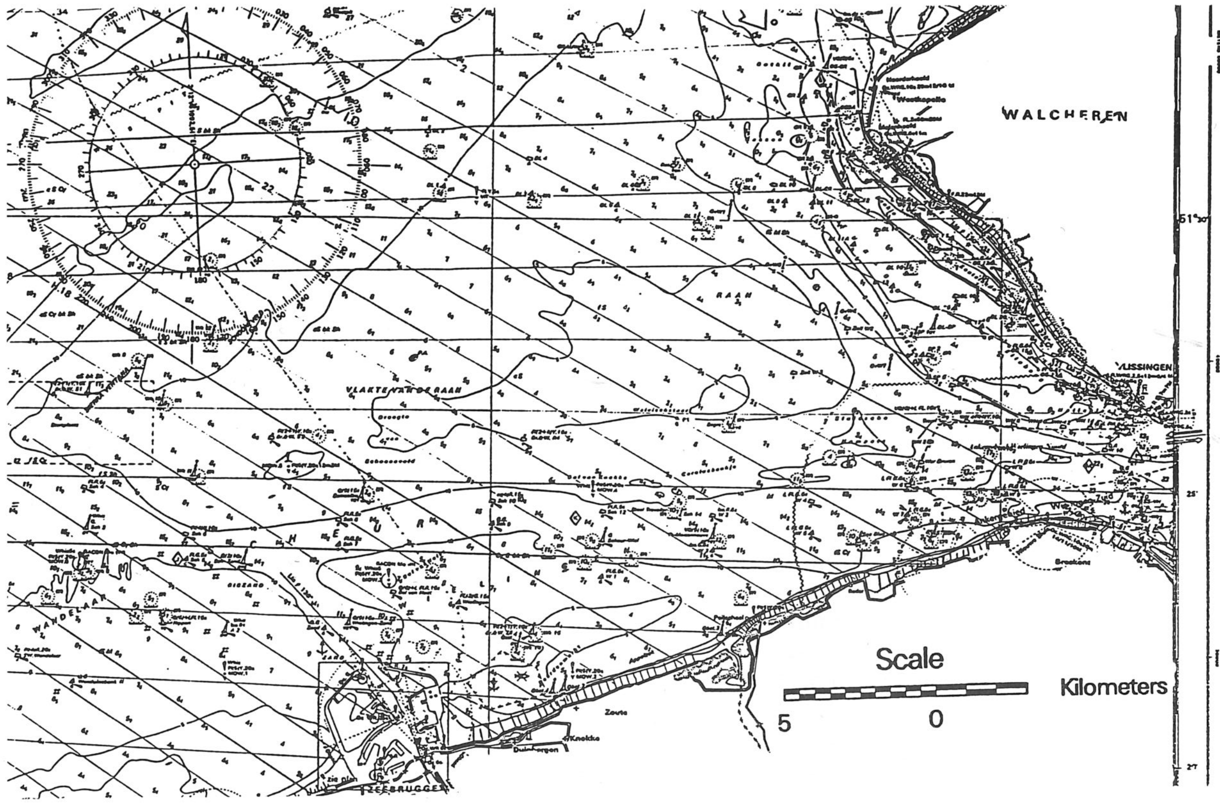

Fig. 2. Bathymetric map of the area (source: Hydrografische Dienst der Kusthavens Oostende, 1992).

2. *From Zeebrugge to Walcheren peninsula.*

2.1. Classification by multitemporal composition

Among the fifteen SAR-PRI images of the zone we get, we have chosen the three images the most interesting by their high contrasts to realize a multitemporal composition followed by a classification. The images are:

•4848 - 2565 from the 19/06/92 at 10:40:49 (1h28 after low tide at Zeebrugge).
•3996 - 1034 from the 20/04/92 at 21:48:21 (0h58 after low tide at Zeebrugge).
•11361 - 2565 from the 17/09/93 at 23:49:10 (1h27 before high tide at Zeebrugge).

The images with the best contrast appear to be those which are taken one or two hours before or after the tide just when tidal currents are at the strongest. This point seems to be fundamental for bathymetric studies by SAR images and the study will go on with a comparative study in this domain.

The image processing was approximatively the same for the different points of interest of this paper. It will be described here.

Rectification :
A Spot image was first rectified by reference to the topographic map by facility. The three radar images were rectified using first the four coordinates given in the header and further by reference to the Spot image.

Masking :
Using SPOT XS3 a mask was performed to extract only the sea and it has been applied to each ERS1 image.

Filtering:
Each image was then submitted to a median filter, just as efficient over the sea as statistical filter, to reduce irregularities.

Transformation into 8 bits images :
This is due to the weak power of our workstation which makes impossible the work on multitemporal compositions on 16 bits images.

Multitemporal composition:
It was done by superimposing the three bands.

Supervised classification:
Some visually homogeneous areas selected manually on the multitemporal composition were used to help the classsification. The result contains 5 classes.

Filtering:
A 5 x 5 majority filter, which eliminated isolated pixels from classification was applied.

Result of the classification see fig.3

Class	% of points	Depth
1	2,76	0 - 2 m
2	19,2	2 - 4 m
3	8, 12	No indication
4	16,59	4 - 6 m
5	53,33	6 - 18 m

-Class 1 includes the zones from 0 to 2 meters deep. We find a good correspondance at the Spleet Bankje. This class appears too at the south west border of the Vlakte van de Raan which is not explain.

-Class 2 includes the zones from 2 to 4 meters deep. We find it at the Spleet Bankje, the Vlakte van de Raan and the Zoutelande Bankje where we have a good correspondance.

-Class 3 is difficult to interpret since its origin is due to an artefact on the image 4848-2565 (extremely dark area but due to a decreasing of the roughness not yet explained). This is present at the river mouth (13 to 18 meters) and to the east of the port of Zeebrugge (2 to 4 meters). This fact is an illustration to show how prudence is important to interpret SAR images.

-Class 4 represents depth from 4 to 6 meters. This class is present in the western border of Vlakte van de Raan as well as to the area situated between the precedent sand bank and the Spleet bankje.

-Class 5 concerns the remaining pixels. It doesn't give any indication.

The radar has detected the three sand banks of our zone but there are parasit areas of the class 2 in the open sea and the extension of these banks is not exactly the same than on the numerical terrain model.

By now, no difference has been detected for the depth higher than 15 meters.

Another classification was done from a multitemporal composition of two SPOT band and one SAR image. The result get approximatively the same limits for the banks but in the Vlakte van de Raan we get 2 classes and the higher depth appears better. The results have to be confirmed.

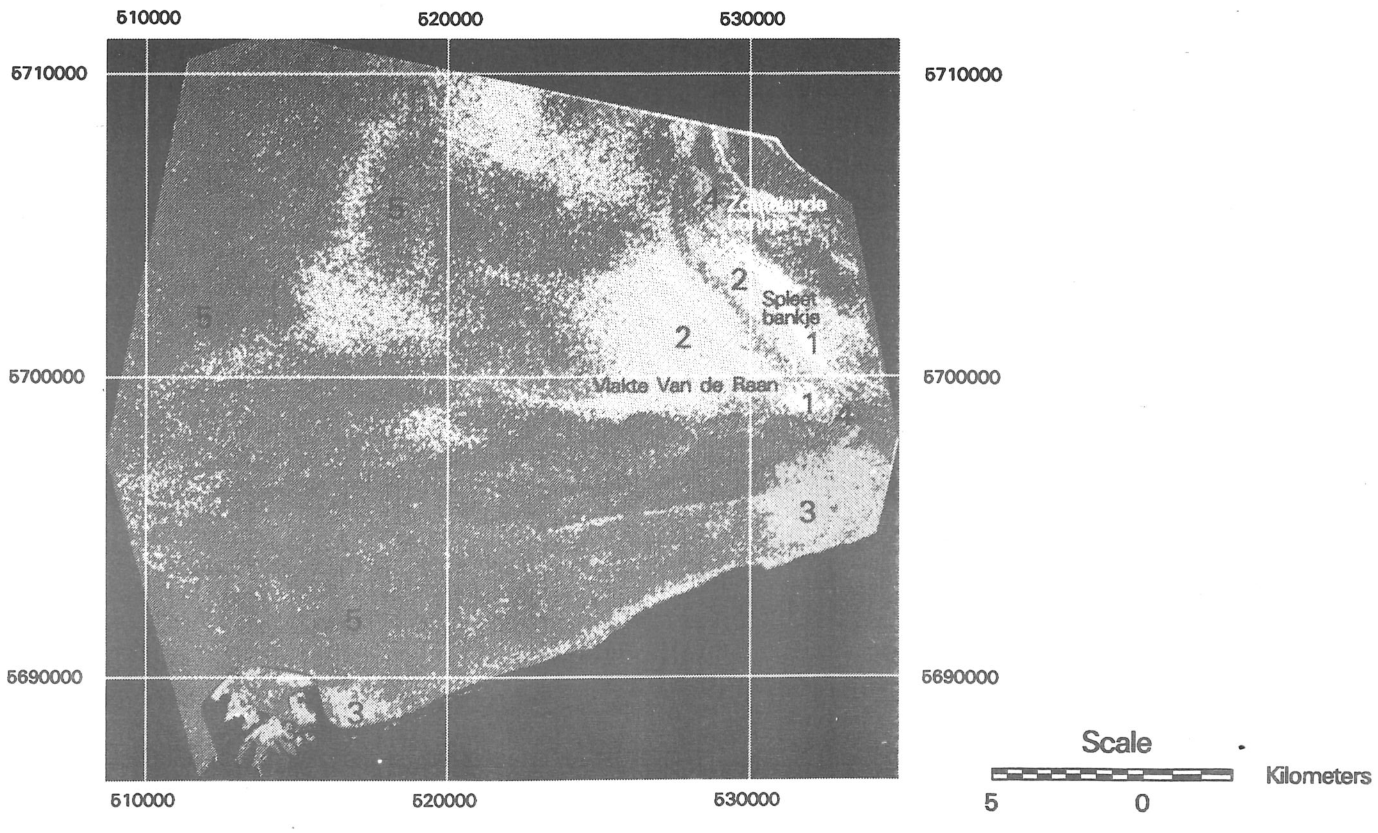

Fig. 3. Result of a classification realized by supervised classification on a multitemporal image.

2.2 Area of the Vlakte van de Raan

When we look at the limits of the Vlakte Van de Raan on ERS1 and SPOT data, we notice that on satellite imagery it has an extension to the SSW not present on the numerical terrain model (Fig 4). This information must be controlled now by "in situ" measurements.

Remark:we get different informations for the SAR images: on one image the Vlakte Van de Raan appears very contrasted, on another one, we can't see anything at this place. This is a problem of correlation between the sea surface morphology due to the meteo-marine conditions and the ERS1 SAR images.

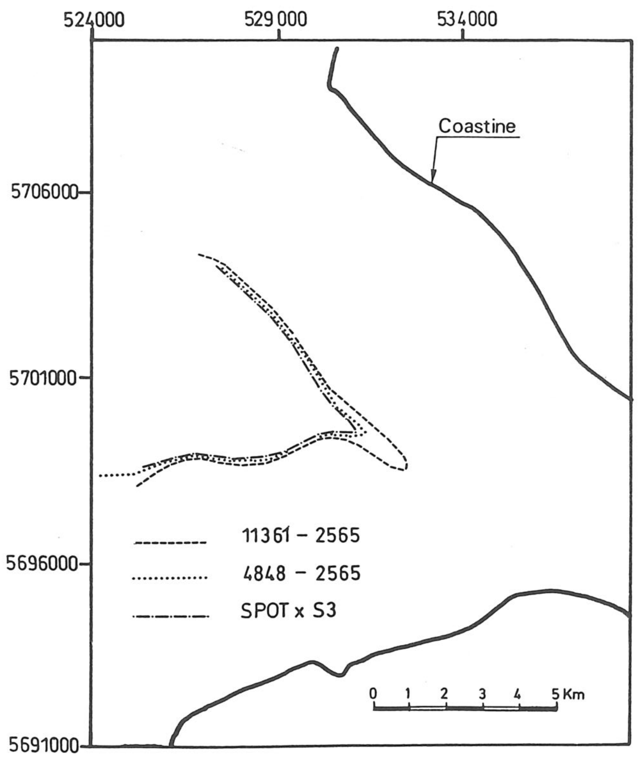

Fig. 4. Location and extension on satellite images (ERS1 and SPOT) of the Vlakte van de Raan. An extension to the SSE is visible which is not present on the map.

2.4. Conclusion

The classification done on the three ERS1 images give a general information concerning the morphology of the area but sometimes not very precise. Opposite to this, the position of the crests give a very precise information concerning the limits of the bank showing that tides and currents take a place of first importance for detecting submarine topography.

The two methods are complementary to give information concerning the sea bed and its evolution.

The morphology near Walcheren appears better than the one near Zeebrugge and Vlissingen probably because of the higher strength of the current force at these places

2.3. Area of the Spleet and the Zoutelande bankje

Some crests appears on differents ERS1 images (Fig.5). These crests where located on the map and we can see that one is situated just above the south border of the Spleet bankje and the other one is just above the south border of the Zoutelande bankje. This phenomena is due to currents which create a different roughness on the 2 sides of a sandbank. A more thorrough study on the currents direction and intensity is underway in our laboratory.

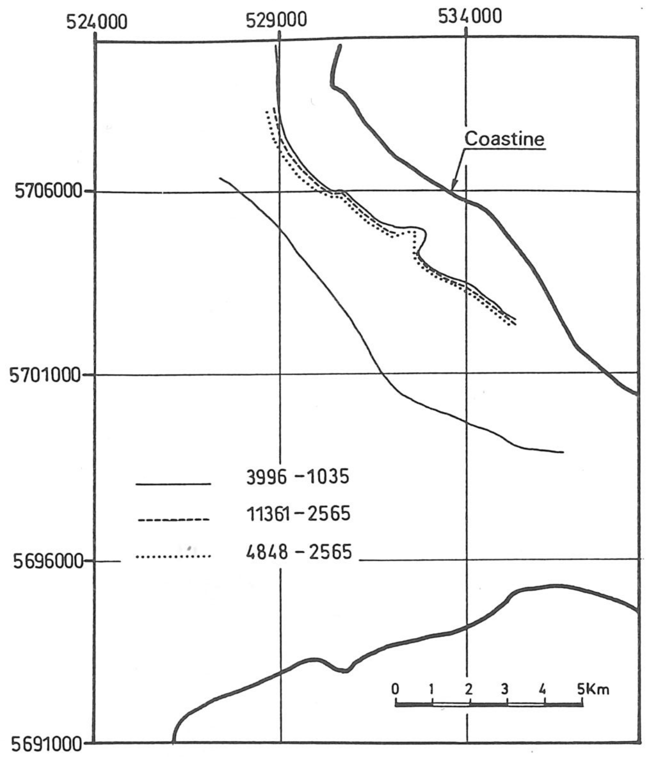

Fig. 5. Location of crests seen on radar which appears to be just above the south border of the Spleet bankje and the Zoutelande bankje .

(other images in study). In zones without tides and currents, it seems improbable that ERS1 could give sea floor information. What we can see depends very strongly of the current model of the area.

3 From Vlissingen to Antwerp

We selected the three images we get which contain this area :

•4848 - 2565 / 19.06.92 at 10:40:49
(1h05 before low tide in Antwerp-high : 1,13 m)
•11361 - 2565 / 17.09.93 at 23:49:10
(1h33 after low tide in Antwerp- high : 0,83m)
•7854 - 2565/ 15.01.93 at 15:28:29
(1h12 after low tide in Antwerp - high: 0, 38m).

The tide levels were calculated for Antwerp. We project to calculate the tide level for each station in the Scheld estuary. We had the chance to get three images near low tide, that makes them in fact more interesting for us.

3.1. Precise location and extension of islands discovered at low tides.

With the three images, we did a multitemporal composition. We could locate the actual position and extension of the islands and observe that their form has changed and that they have drifted (Fig 6).
These result must be confirm by other images because of the possible interference of the wind which can create a very important roughness when it meets an island and a very small one behind it. The effect of the wind increase then artificially the extension of the island by creating the same signature then the island behind it where in fact we have only water.
For example, the Platen van Valkenisse has moved to the NW and its shape has changed.
Monitor the evolution of these islands is by itself an interest of ERS1 SAR.

3.2. The extension of an island as a function of the tides is a relevant information for cartography.

We concentrated our mind on one island located nearly in front of Saaftinge. With the help of the different images we can map this island at different moments of the tide. This allow us to get an evolution of the emerged areas when the tide goes down. The method enables to draw some contour lines and then to realize a partial topography of these zones by an indirect method (Fig. 7).

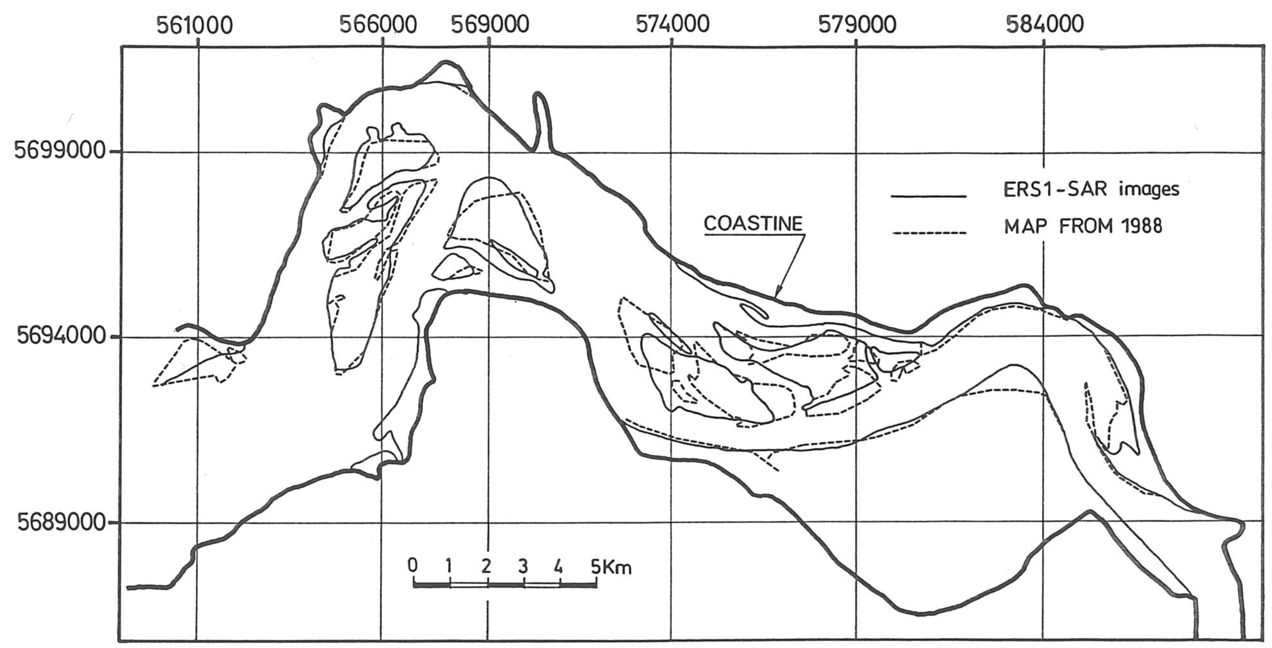

Fig. 6. Extension of the islands of the Scheldt estuary observed on multitemporal composition of three ERS1 images and comparison with the topographic map of the area of 1988. The shape and the extension of some islands seem to have change.

3.3. Visualisation of the Scheldt estuary channel on an image

Only on a part on one of the three images, can be seen the navigation channel of the Scheldt estuary. This is a future point of investigation to see if a monitoring of this channel can be done.

3.4. Tidal flat and marshe zones of Saaftinge.

On the same multitemporal composition, the tidal flat area of Saaftinge was examined (fig. 8). The superposition allow us to observe the nearly maximal extension of the tidal flat zone. When it is comparated to the actual map of the same place we observe a very good correspondance for nearly every tidal-creek. In these areas, we can find very different kinds of signatures: a very bright one when the tide is low and that the tidal zone has been dried and where we usually find ripple marks, and a very dark one when the tide has just left or is just coming, when there is a thin water film on the surface of the area. We plan to do *in situ* measurements when ERS1 will sense the zone and hope to be able to give reliable informations concerning the dominant factors which influence radar in this area.

A classification on the multitemporal composition was done showing the different phases of the retreat of the tide.

4. Conclusion

4.1. Scheldt zone

ERS1-SAR, extremely sensible to water, can use the information given by the movement of the tide, it allows to map intertidal zones, and eventually later to create a DEM of the area. Further, a monitoring of these zones by comparing two situations is possible. This area of study belongs to a recent interest of us which has been confirm by our results. Deeper investigation will follow to understand the real factors which have a primordial importance in these kind of areas. When they will be elucidated, they will be usable in other places without any need of anterior map which is not the case for the morphological map of the North sea.
Then we can say that for the study and the mapping of areas submitted to regular flood, radar give impressive results at a scale of 1:50000.

4.2. The North sea zone

The study of the currents, their orientation and their strengh, especially in North sea but also in the Scheldt estuary is of great importance to understand what we observe in the shallow zones (up to 15 meters) in the radar images.
Due to differents factors, the quality of the images is very variable. Determine the best conditions for observing a maximum of phenomena will be studied on the different images we have. Classifications will be done on the best contrasted one eventually on smaller areas then what we did yet.
In the future, we hope that this methodology will be use in regions difficult to access like in Hai Phong bay (Vietnam). A project to apply it there with ERS2 has been proposed.

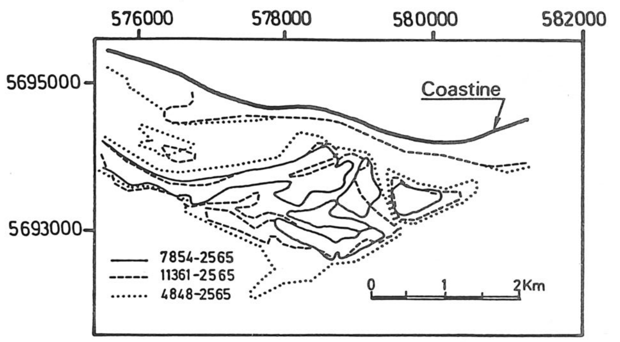

Fig. 7. Evolution of the extension of an island with the restreat of the tide by means of three ERS1-SAR images taken at differents moments.

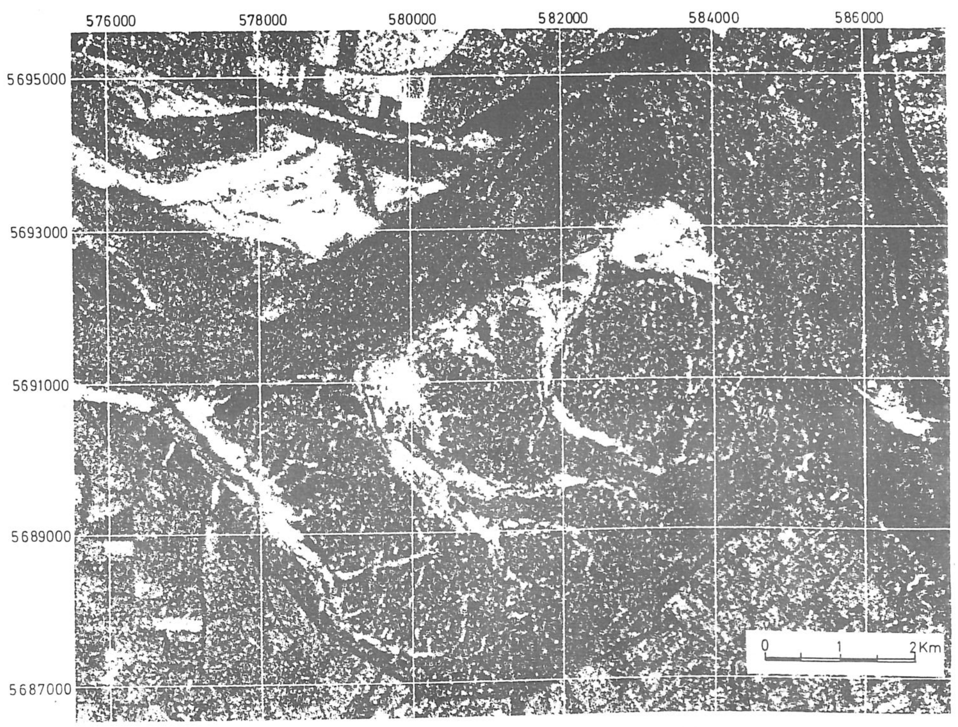

Fig. 8. Multitemporal composition of three ERS1 images taken near low tide showing nearly the maximal extension of the tidal flat area in Saaftinge (situated in the Scheldt estuary).

DETECTION OF SEA-BOTTOM TOPOGRAPHY WITH ERS-1 SAR.PRI IMAGES ON THE BELGIAN CONTINENTAL PLATFORM.

Linde Vande Velde, Carlos Vernemmen, Guy De Moor, Annick Jaspar
Departement of Geography, Research Unit Marine and Coastal Geomorphology,Krijgslaan 281/S8, 9000 Gent, Belgium.
phone: (32) 9 2644636, fax: (32) 9 2644970

ABSTRACT

Visual comparison of ERS-1 SAR.PRI sea surface images with bathymetric maps suggests a certain correspondence with the sea bottom topography in the area of the Kwintebank and Middelkerke Bank (Continental Platform of the Southern Bight). The sea bottom topography has been deduced from existing nautical maps and from graphic representations of new depth data acquired at sea during the satellite passage. The matching suggests a slight translation between map and image positions. Possible links between simultaneously acquired field data on sea water temperature at a few meters depth and on the bathymetry have been studied. In a perspective of optical image analysis such information could be useful for further sea bottom detection.

1. OBJECTIVES

This research is part of the Belgian Telsat-III program. Its final objectives are: (1) to deduce the sea bottom topography from the characteristics of ERS 1-SAR images; (2) to obtain information about sediment transportation by using sequential radar images; (3) to use these radar images for studying possible relationship between sea bottom topography and oceanographic characteristics such as temperature, salinity and chlorophyl-a content.
This paper reports on bathymetric, oceanographic and meteorological data acquisition on board of the oceanographic vessel Belgica in the research area during passages of the ERS-1-satellite in september 1993 and in november 1993. It deals as well with the results of a visual comparison of the radar images with such mapped data, especially with different types of bathymetric maps. It also reports on a matching of sea water temperature data with depth data.

2. RESEARCH AREA

The research area covers the Flemish banks, offshore the Belgian coast and, more specifically the Middelkerke Bank and the Kwintebank (total area approximately 12 x 12 km) (figure 1).
The Flemish banks are a group of parallel sandbanks stretching in a SW-NE direction, slightly oblique to the sandy macrotidal coast. The banks are separated by swales dipping to the NE. The swales generaly are not deeper than 30 m below mean spring low water level. The banks are about 20-30 km long, 10-20 m high and 1-2 km wide. In some parts of the banks the crest zone rises to less than 4 m below spring low water level. The flanks and the summits of the banks are covered with various types of bedforms especially at their northern edges, where large dunes reach heights up to 8 m and where the energy of the waves is heigher. Upslope the flanks large and small dunes gradually become parallel to the crest line of the banks (De Moor, 1985).

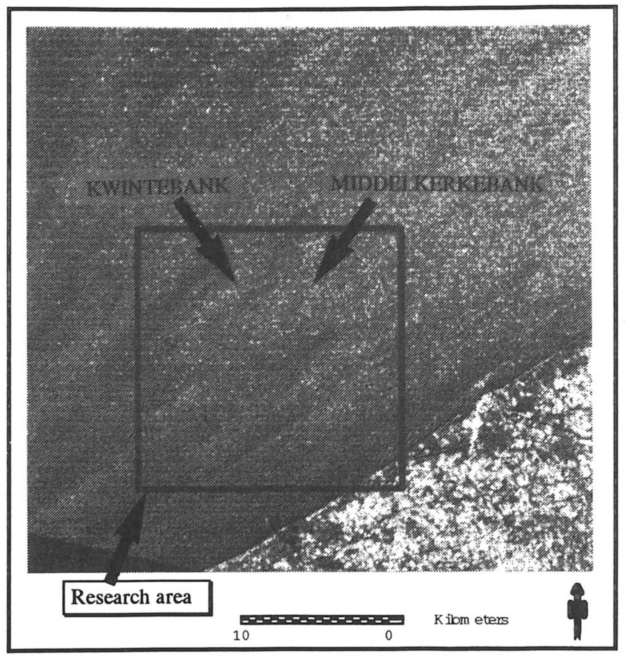

Figure 1 : Research area (150 km²)

3. DATA ACQUISTION AND PROCESSING

3.1. Oceanographic terrain data

3.1.1. Data acquisition

Table 2 shows the oceanographic data acquired at sea during the Belgica campaigns of 13-18 September 1993 and of 8-10 November 1993.

data	equipment	freq. of acquisition
position	Syledis	2 Hz
bathymetry	Echosounder	2 Hz
wave height	TSS	2 Hz
sea temperature	Sea-bird	1/12 Hz
salinity	Sea-bird	1/12 Hz
chlorophyl-a	Fluorometer	1/12 Hz
meteo-data	Friedrichs	0,03 Hz

Table 1: The recorded oceanographic data