USING SAREX AND ERASME IMAGERY FOR COASTAL STUDIES IN FRENCH GUIANA: EXAMPLE OF THE KAW SWAMP

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I. INTRODUCTION

1. The coastal dynamics

Morphological changes of the French Guiana's coastline are striking and specific, directly linked with the Amazon discharge and the seasonal variability of the offshore surface currents (M.T.PROST & C. COLIN, 1993).

One part of the supply moves in suspension offshore; the other part (some 0,1 billion m3/y) moves in the form of huge migrating *shoreface-attached mudbanks* separated one from the other by erosional *wave-dominated interbank zones*. The estimated volumes of fine grained amazonian sediment transported vary seasonally from lows of 2 x 10^6 metric tons/ month, (August to September), to 25 x 10^6 metric tons/month, (April to May; NEDECO, 1968). Local concentrations of suspended muds become so high in the accretion areas that waves are damped (WELLS & COLEMAN, 1981; RINE & GINSBURG, 1985).

The intertidal mudflats are backed by prograding *Avicennia* mangrove; within the erosional interbank zones medium to coarse sand deposited from local rivers frequently occur downdrift of their mouths.

These zones are transitional because mudbanks (and interbank zones) migrate alongshore westwardly. The migrating average rate is approximately 1 km/y; this migration mostly takes place between December and February (boreal winter). During this period trade-wind speeds are higher, sea is rough; the North Brazil Surface Current (NBC) is strong, flows closer along the coast (C. COLIN & B. BOURLES, 1990; M.T.PROST & C. COLIN, 1993) and concentrations of suspended matter within the coastal waters are high. On the contrary, the displacement of mudbanks is weaker during the calmer period (July/October, boreal summer), when wind speeds and the wave amplitudes are lower, and when the NBC veers to the South-East feeding the North Equatorial Counter Current (NECC).

On account of this complex dynamics the coastline is continually changing.

2. Remote sensing approach

The possibilities offered by the Remote Sensing imagery to define the morphological units of the coastal area, to monitoring and to quantify the complex shoreline/foreshore changes opened up a new field to the coastal research in French Guiana since 1988.

2.1. Optical imagery

A multitemporal analysis of optical views, (LANDSAT MSS, 1976-SPOT-1, 1986-LANDSAT TM, 1988), carried out by the ORSTOM Center of Cayenne in the framework of the "Coastal Environment Programme", quantify precisely, for the first time, the average yearly accretion and erosion rates of the shoreline (200 m/year) within several key-areas (M. LOINTIER & al, 1990).

Nevertheless the usual climatic conditions of these latitudes (heavy rainfall, cloudiness, high atmospheric humidity...) are a serious problem in monitoring the coastal changes by optical views.

SAREX 92 : SOUTH AMERICAN RADAR EXPERIMENT : FINAL RESULT WORKSHOP (1993 ; Paris, France)

2.2. The SAREX imagery.

Radar imagery provides accurate data under any atmospheric condition and is a performant tool to study swampy areas of French Guiana which are very difficult of acess.

This contribution is part of the Pilot Project PPF12, (ERS-1 and SAREX microwaves remote sensing) fir the study of the French Guiana coastal zone. This programme is supported by the European Space Agency (ESA), the Ministry of Research and Technology (Paris) and the CNES (Centre National d'Etudes Spatiales, France).

We use the SAREX views obtained by the CCRS Airborne SAR from Kaw. SAREX data are from April 9, in band X, band C, polarisation HH and VV.

2.3. The ERASME profiles

Two profiles were acquired with the airborne-helicopter scatterometer ERASME in vertical mode. Designed and built by CRPE (Centre de Recherches en Physique de l'Environnement), the ERASME is an FM/CW, bi-frequency (5,35GHz - 9,65GHz), bi-polarisation (HH-VV), multilook angle radar.

3. Ground data

Detailed ground observations (field survey, cores, low altitude flights, aerial photointerpretation...) were performed by interdisciplinary teams during the SAREX and the PPF12 ERS-1 campaigns.

II - THE STUDY AREA

The Kaw Swamp - situated between the estuary of the Mahury (West), the low Approuague (Est), the Guiana Shield (South) and the Atlantic ocean (North) - covers more than 100 km^2 of the Holocene coastal plain *(fig. 1)*.

1. Setting

The Kaw Swamps are a wide lowland area developed within the fine sediments of the holocene Demerara Formation. The fine-grained phases of coastal sedimentation are separated one from the other by cheniers systems.

The area studied is drained by the Kaw River and by the Crique Angelique. The Kaw River drains the southern part of the Kaw mountains and the Inery hills. Downstream the village of Kaw the river was deflected northwestward by the coastal transport. The Crique Angelique is presently a slough-like stream that drains the north of the Kaw's mountains, crosses the plain from the south to the north and ends in the subcoastal swampy area *(fig. 2)*. Although the heavy average rainfall of their watersheds (almost 4000 mm/y) both are small waterways, the lowlands beeing an important fresh-water stockage area.

The study area consists of a 7 km-long cross-section between the coastline (Pointe Acoupa) and the watershed of the creek Angelique *(fig. 3)*. Because of uniform geomorphological conditions, the results derived from this cross-section are representative for the whole coast between Cayenne and the Approuague River.

2. The Kaw's river mouth and the northern swamp

The seafront has a mesotidal regime: tides are semidiurnal with a mean range of 2.2 m and a spring tide range of 3.2 m. It is occupied at present by a underconsolidated intertidal mudflat whose the high foreshore provides a substrate for the *Avicennia* colonisation and progradation.

This area was an erosional interbank zone during the second part of the 80's. The retreat of the coastline caused the decay and death of the adult, waterfront mangrove and produced a break in the low estuary in 1989.Therefore an island was formed at the site of the ex-Pointe Acoupa. Owing to the new progradation a young mangrove is growing on the seaward side of the island.

Behind the *Avicennia* waterfront mangrove and the *Rhizophora mangle* subcoastal population, appears a *morphological discontinuity line*, more or less parallel to the present coastline. Situated at an altitude of 3 to 4 m high (according to the IGN map, Plaine de Kaw,4714 Y, 1990) this line is formed by a dense community of palms trees *Euterpe oleracea* ("palmier pinot"), sometimes mixed with shrubby vegetation dominated by *Chrysobalanus icaco* ("prunier") and

The first echo corresponds to the top of the trees, then the signal increases up to the maximum of density of vegetation and decreases up to the low and dense vegetation. An answer from the ground is visible if the vegetation is not to much dense, which is the case in the mangrove areas (*figure 5)* and is mainly related to the soil moisture.

Therefore, the variations of radar signal are related to the vertical structure of vegetation.

The main characteristic heights of vegetation have been retrieved from radar data along a track crossing the mangrove area. We compared distances from the radar to vegetation layers with distance from the ground. We have plotted on ***figure 6*** the evolution of these parameters along a transect of the helicopter (axe East West over the Kaw island). The road of the helicopter began over the shore and cross the mangrove or the island, the Kaw's river and a second area covered with mangrove. We can observe an increase of heights as expected when the radar moves away from the shore.

These results correspond to the first step of the data processing. A second step will be devoted to use a simple semi empirical model of backscattering from the vegetation in order to retrieve trees parameters.

CONCLUSION

The radar imagery (SAREX, ERASME and ERS-1) is of first interest in the equatorial environnement of French Guiana. In our study the band X of SAREX imagery assure accurate data, really necessary to follow the complexe, short-term morphosedimentary changes of the shoreline, to identify the geomorphological units of the coastal plain and to study wide swampy areas very difficult to acess.

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Machaerium lunatum ("amourette") (J.J. Degranville, 1986)

The Kaw's riverbanks are occupied by a ripicole vegetation with adult mangrove forest (*Avicennia nitida, Rhyzophora mangle)*, mixed with halophite vegetation *(Achrosticum aureum...)*, palms trees (*Euterpe oleracea)* and shrubby vegetation (*Machaerium lunatum, Montrichardia arborescens)*.... The surficial clays are more consolidated with a "pégasse" layer (acid peat).

3. The central swamp

The central swamp is drained by the slough-like Crique Angelique that flows from the north to the south (between the discontinuity northern line and the southern chenier's system, the last with an altitude of 2 m). The herbaceous, dense and rich vegetation is dominated by *Montrichardia arborescens*, the *Blechnum serrulatum* fern and shrubs of *Chrysobalanus icaco* (J.J. Degranville, 1986).

4. The cheniers' clusters

Two systems of cheniers covered by a mixed forest (*Mauritia flexuosa* palm trees and species of hydromorphic forest) extend within the contact of the central and the southern swamp. The first is formed by large sandy ridges (1200 m wider), incurved upstream, clearly cutted by the drainage; the second is more regular, formed by narrow ridges, covered by the same type of vegetation and rehanced by several drains and little lakes.

These cheniers' clusters are situated in the lowest part of the deep peat-bog swamp, the "Savanne Angelique" (since 5 m water depth.; J.J. Degranville, 1986), the stock area of the Crique Angelique's waters and the rainfall contribution. The vegetation is formed by Cyperaceae *(Eleocharis sp., Rhynchospora sp.), Thelypteris interrupta* fern, and by lines of *Mauritia flexuosa* palm trees. Peat is 1 to 3 m deep.

5. The southern swamp

Is the most confined part of the swamp, dominated by the shield border, the *mountains of Kaw* (± 300 m high) covered by a high and rich rain forest. The Crique Angelique, flowing to the north, has a narrow, funnel-like valley, opening to the Savanne Angelique. This area is covered both by the rain forest and by a swamp forest with palms trees (*Pterocarpus officinalis, Virola surinamensis, Mauritia flexuosa, Euterpe oleracea...*) developped in sandy silt-clayed sediments (J.J. Degranville, 1986).

III - RESULTS

1. Sarex imagery

We SAREX imagery of Kaw in band X, that presents a better resolution for the interpretation than the band C

The imagery shows, along the shoreline, the situation and extension of the underconsolidated mudflat, that appears very clearly in black by "mirror effect" of the radar. The previous erosional coastline is also very clearly express in white, backward the intertidal flat. We can distinguish either the tidal creeks and their extension within the seaward mangrove.

Towards the interior, SAREX imagery offers the possibility of distinguishing sections formed by the senescent mangrove (within the island), the young mangrove (opposite to the island, in the left bank of the Kaw's estuary), the adult mangrove and the backward mangrove (this one within the contact with *Euterpe oleracea* palms and *Montrichardia arborescens*). All these contacts are expressed in several grey tones and different textures.

A good correlation is observed between the field survey, the low-altitude flights observations and the radar imagery concerning the swampy vegetation areas, the drainage and the cheniers' systems.

2. The scatterometer ERASME

ERASME was used in a nadir looking mode. In addition to radar measurements, a video camera was attached on the antenna support in order to retreive the radar track and to link radar data with ground data.

The principe of the measurement is given in ***figure 4*** where it can be seen that the vertical structure of the trees can be retrieved. The right side of the figure gives the backscattered power as a function of the distance from the radar. The left side describes the structure of vegetation over the observed area with the same vertical scale.

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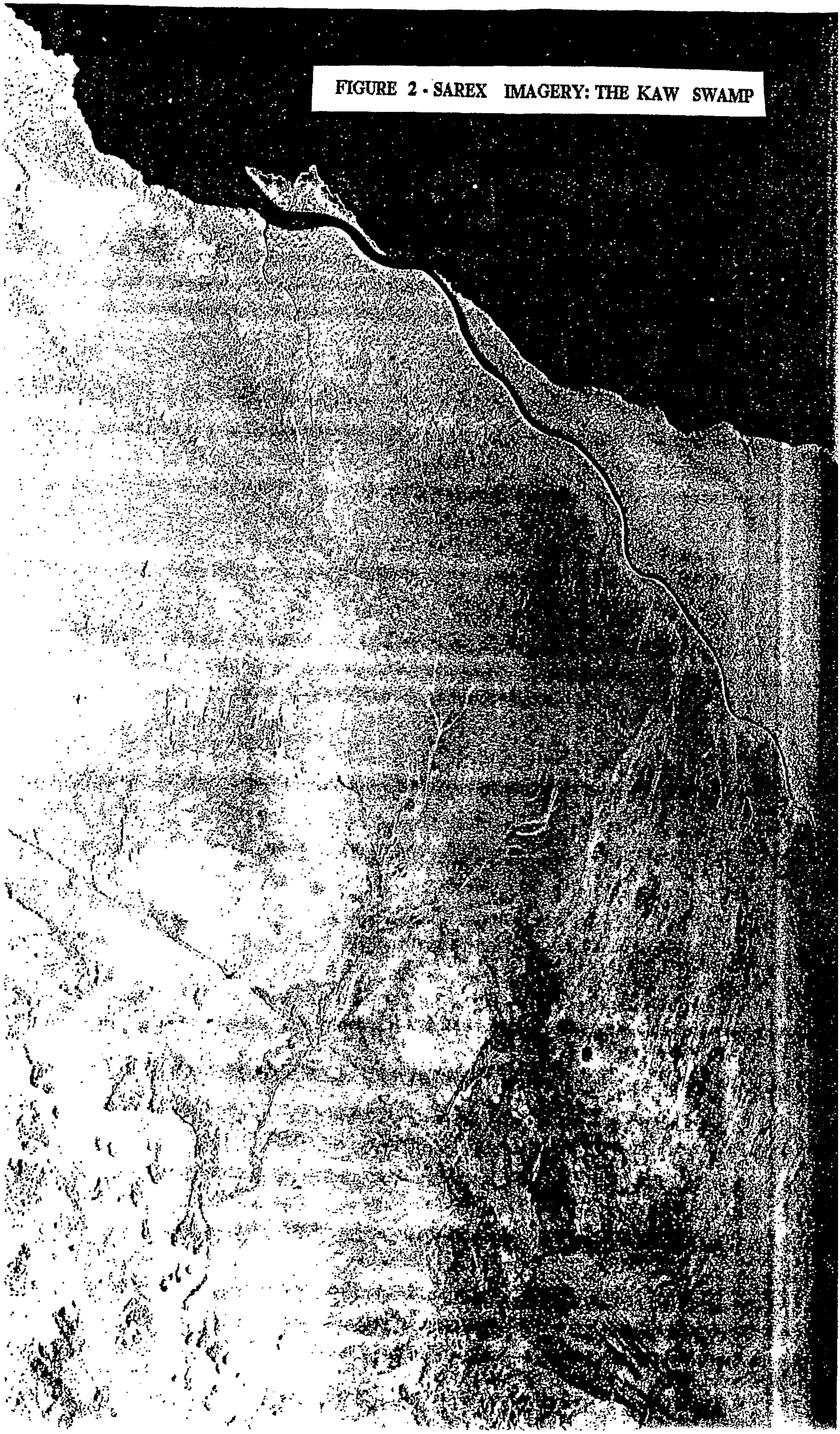


FIGURE 2 - SAREX IMAGERY: THE KAW SWAMP

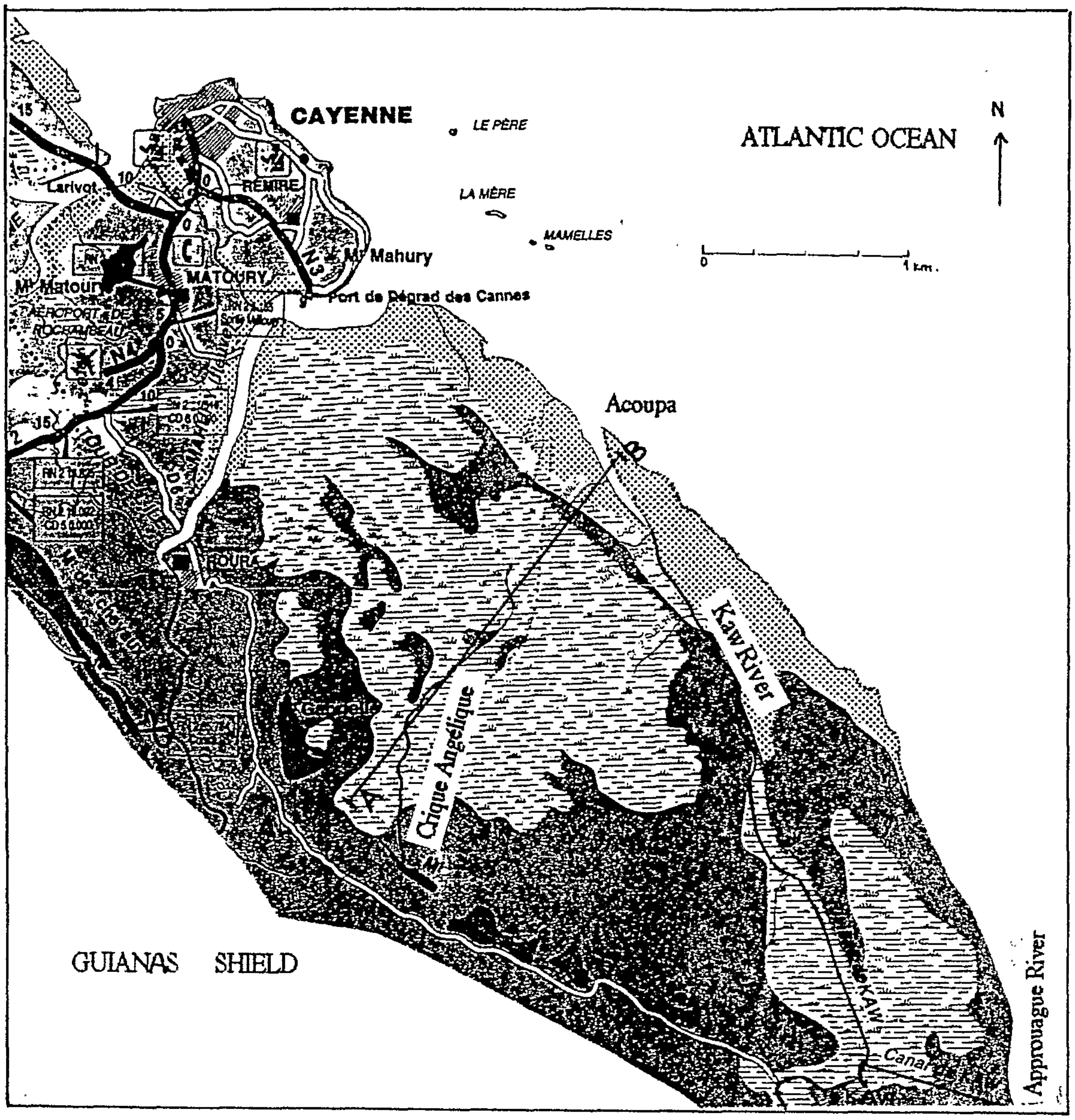
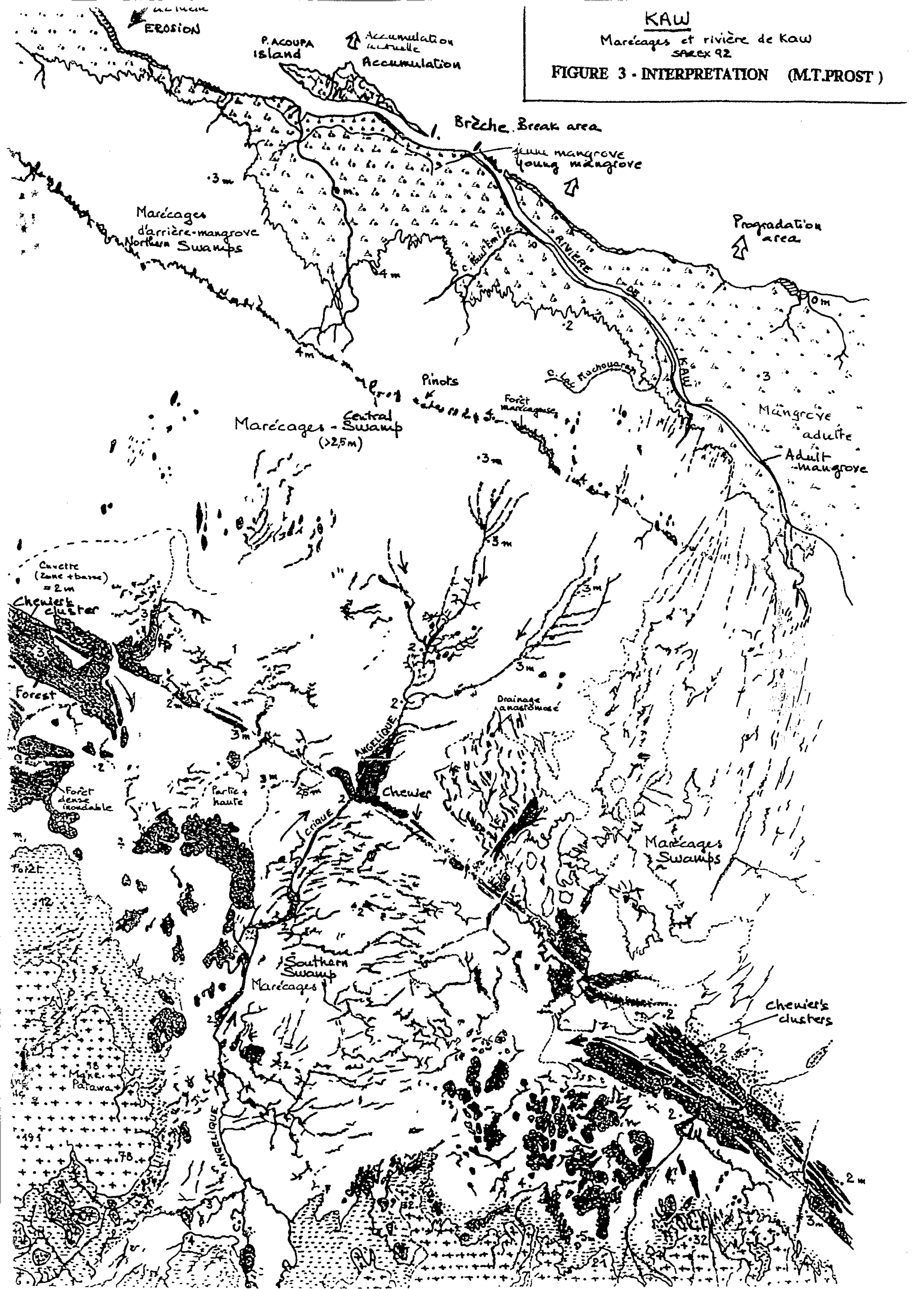


FIGURE 1 - THE STUDY AREA

Modified from: Carte routière de la Guyane. Direction Depart. de l'Equipement. 1988.
The coastline is from 1988, before the formation of the island Acoupa.

A —— B Crossing-section



KAW
Marécages et rivière de Kaw
SAREX 92
FIGURE 3 - INTERPRETATION (M.T.PROST)

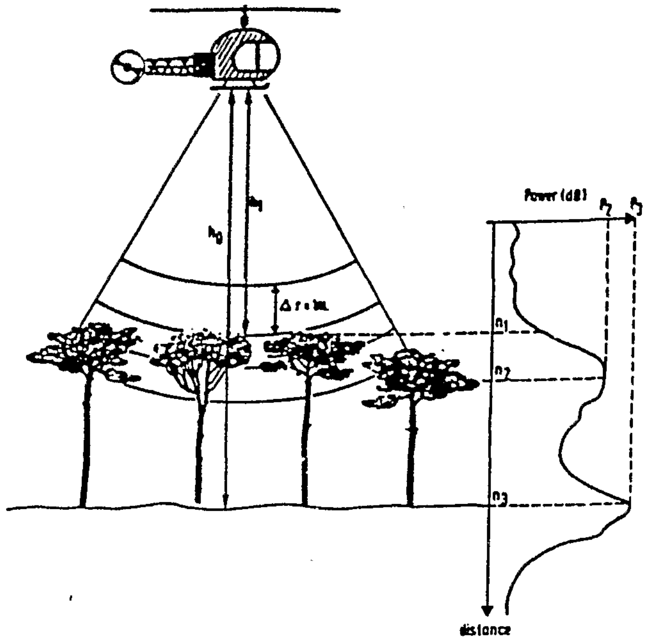
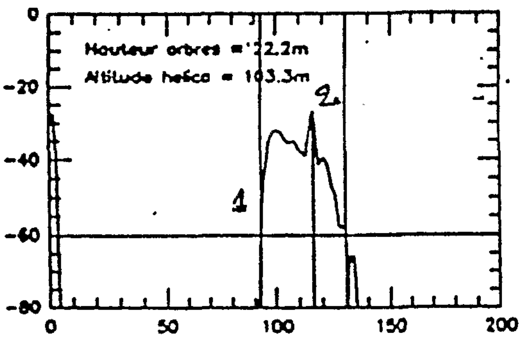


FIGURE 4- Experiment geometry. The ERASME scatterometer is mounted on a small helicopter and is looking toward the nadir in an altimeter like configuration. The radar range resolution is Dr=1m. The first vegetation echoe occurs in the radar bin n1 corresponding to a distance h1 from the helicopter. The flight altitude is h0 corresponding to the radar bin n3.

FIGURE 5- In case of mangrove, the echoes occuring from top of vegetation (1) and ground (2) are clearly visibles.



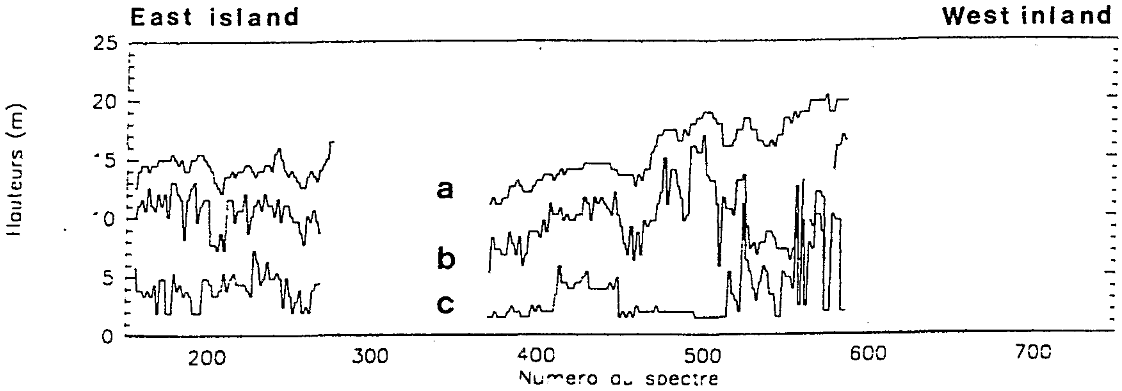


FIGURE 6- Variations of the vegetation characteristics heights along a radar track across the Kaw Island (sea profile in Figure)

a) The height of the vegetation:
   - between spectre 150 and 270 , mangrove on island
   - between spectre 270 and 370, the Kaw river
   - between spectre 370 and 460, joung mangrove inland
   - between spectre 460 and 590, old mangrove inland

b) the height of the maximun of density of vegetation

c) the height of low and dense vegetation.