Revue des Energies Renouvelables Vol. 9 N°3 (2006) 165 – 172

Contribution of multispectral satellite imagery to the bathymetric analysis of coastal sea bottom

F. Houma [1*], R. Belkessa [1] and N. Bachari [2]

[1] Laboratoire 'Environnement, Aménagement et Ecosystèmes Littoraux',
Institut des Sciences de la Mer et de l'Aménagement du Littoral,
Campus Universitaire de Delly Ibrahim, Bois des Cars, 16320 Alger, Algérie

[2] Faculté des Sciences Biologiques,
Université des Sciences et Technologie Houari Boumediene,
B.P. 32, El Alia, 16111 Alger, Algérie

(reçu le 21 Juin 2006 - accepté le 30 Septembre 2006)

Abstract - *The knowledge of the topography of the seafloor is important for several applications. Image satellites of observation of the earth are the result of the interaction of the electromagnetic radiance with the system sea - atmosphere and sensor. To understand this complex phenomena us developed an analytic model of radiatif transfer simulation in water coupled to an atmospheric model in order to simulate measure by satellite. This direct model permits to follow the solar radiance in his trajectory Sun-Atmosphere - Sea - Depth of sea- sensor. The goal of this simulation is to show for every satellite of observation (Alsat1, Spot, Landsat MSS, Landsat TM) possibilities that can offer in domain of bathymetry. The principle of measure of bathymetry necessarily takes this model of reflectance joining the intensity of radiometric signal measured by the satellite to the depth as a basis; it can call on the physical method that requires the knowledge of all parameters governing this model (optic properties of water, coefficient of reflection of the bottom, transmittance of the atmosphere,). In application, a set of relations figures are gotten to determine the bathymetry of an inshore zone of Algeria. The model provides of image mono channel where each pixel of the maritime domain is represented either by a radiometry in - situ but rather by a calculated depth. In general the use of hybrid multiple Spot band regression algorithms are superior to the exclusive use of any single band.*

Résumé - *La connaissance de la topographie du fond marin est importante pour plusieurs applications. Les techniques classiques utilisent le sondage comme un moyen de cartographie du fond marin mais cette technique est coûteuse, il est donc nécessaire de rechercher d'autres techniques plus ou moins accessibles. Les images satellites d'observation de la terre sont le résultat de l'interaction du rayonnement électromagnétique avec le système mer- atmosphère et capteur. Elles deviennent de plus en plus performantes vu leur richesse spectrale qui permet une visualisation multi couleur et leur résolution spatiale qui peut donner une vision large et fine. D'autre part, un certain nombre de propriétés de l'eau influe de façon significative sur le transfert du rayonnement électromagnétique en son milieu, nous avons pour cela développé un modèle analytique de simulation de transfert radiatif dans l'eau couplé à un modèle atmosphérique afin de simuler la mesure satellitaire. Ce modèle direct permet de suivre le rayonnement solaire dans sa trajectoire soleil -atmosphère –mer –profondeur capteur. Le but de cette simulation est de montrer pour chaque satellite d'observation (Alsat1, Spot, Landsat MSS, Landsat TM) les possibilités qui peuvent offrir dans le domaine de la bathymétrie. L'analyse des mesures simulées a permis donc de comprendre le comportement de la mesure satellitaire selon la profondeur, l'état de l'atmosphère, la nature des sols, les angles d'observation et les propriétés optiques des capteurs du système Spot et Landsat. Le principe de la mesure bathymétrique se base nécessairement sur ce modèle de réflectance reliant l'intensité du signal radiométrique mesuré par le satellite à la profondeur, il peut faire appel à la méthode physique qui nécessite la connaissance de tous les paramètres régissant ce modèle (propriétés optiques de l'eau, coefficient de réflexion du fond, transmittance de l'atmosphère,.). En application, un ensemble de relations statistiques est obtenu pour déterminer la bathymétrie d'une zone côtière de l'Algérie. Le modèle fournit des images mono-canal où chaque pixel du domaine maritime est représenté non plus par une radiométrie in-situ, mais plutôt par une profondeur calculée.*

Key words: Bathymetry - Spot XS - Physical modelling - Statistical analysis.

[*] houmabachari@yahoo.fr _ belkessararabah@yahoo.fr _ bachari10@yahoo.fr

1. INTRODUCTION

The Algerian coast is full of bay and practically the big cities are to the clinches them. Therefore these zones undergo transformations in sedimentary occupation because of the natural effects and human actions. To make a continuous surveillance in space and in time require some expensive means. Algeria has just launched an Alsat1 microsatellite it opens doors on the possibility to use pictures satellites to facilitate the surveillance [1].

The Alsat1 satellite is endowed of a multispectral radiometer composed of three similar strips to the one of SpotXS. Until now images of Alsat are not exploitable and for this reason that we used the SpotXS images to study possibilities of exploitation in the inshore environment [2].

2. MODELLING OF SATELLITE MEASURE UNDER SEA WATER

The spectral distribution of the submarine radiance varies complex way with the depth, in relation with the selective character of the attenuation. The total signal received by a sensor operating above to high altitude water can be decomposed in a first time, in two terms:

$$S_{t_\lambda} = S_{a\lambda} + S_{e_\lambda} \tag{1}$$

with $S_{s\lambda}$ is an atmospheric component and $S_{e\lambda}$ is a water component.

In a second time, it is possible to analyze the composing water measured near the surface:

$$S_{e_\lambda} = S_{s\lambda} + S_{d_\lambda} + S_{f_\lambda} \tag{2}$$

with $S_{s\lambda}$ a specular reflection at the surface, $S_{f\lambda}$ is a reflectance of the bottom in shallow waters, $S_{d\lambda}$ a component owed to the diffuse reflection by volume water [3].

$$S_{e\lambda} = G_\lambda \rho_\lambda + G_\lambda \rho_s . \omega_0 \left(\frac{1}{\rho_\lambda} - 1 - \left(\frac{1}{\rho_\lambda} - 1 \right) R_a \exp(-kz(\cos\theta_z + \cos\theta_v)) \right) + G_\lambda (1 - \rho_\lambda) R_a \exp - kz(\cos\theta_z + \cos\theta_v) \tag{3}$$

with ρ_λ a reflectance of the sea water; R_a a reflectance of the bottom; k is attenuation coefficient; z a depth; ω_0 albedo of diffusion of water molecules; θ_z a zenith angle and θ_v a viewer angle of the sensor.

A diffuse radiation by the surface of water passes through the atmosphere in a direct manner with an angle of v view and sudden some analogous attenuation have those met in the sun direction targets before being captured by the satellite. We consider T a transmission coefficient sea-sensor. The spectral radiance that reaches sensor transformed with the optic filters for every channel defined by an optic sensitivity function OH. The middle luminance of the i channel is [4]:

$$\overline{L_i} = \frac{\int_{\lambda 1}^{\lambda 2} S_{f\lambda} \, T_\lambda \, O_{i\lambda} \, d\lambda}{\int_{\lambda 1}^{\lambda 2} O_{i\lambda} \, d\lambda} \tag{4}$$

2.1 Simulation study

This developed model is put in an account numeric Simulation of the Data Satellite (SDDS). In this account numeric data to enter are distributed in three categories: astronomical data; atmospheric data and radiometric data [5].

In second place for a metric step of the specific seafloor (nature of the bottom), we calculus a luminance's for the different optic sensors (SpotXS, Landsat MSS, Landsat TM, IRS1-C, NOAA, Meteosat). Results of the simulation are presented in has following Fig. 1.

Data satellite for spot in the channel 3 doesn't vary with the depth. It implies that the effect of the bottom on measure in this channel 3 is negligible. This interpretation is valid for the two TM3 channels and TM4.

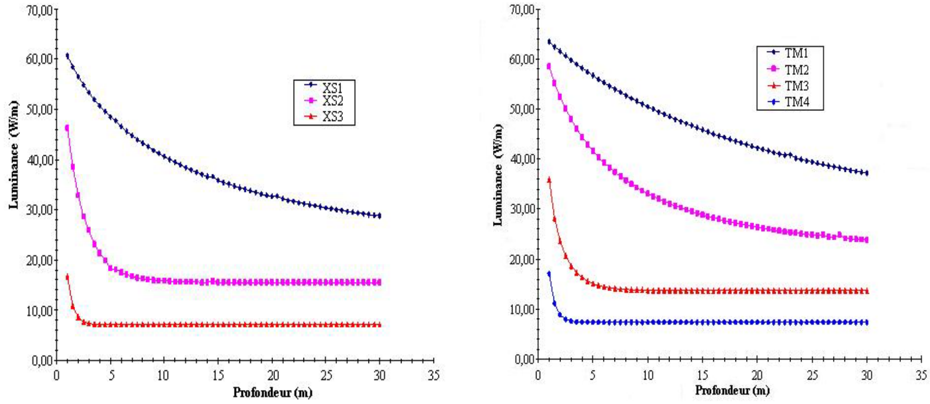

Fig. 1: A variation a luminance's of a SpotXS and Landsat TM with a depth

In the case of the channel 2 of the spot the sensitivity of this channel to effects of the bottom can reach the 10 meters. For the channel 1 of the spot the effect of the bottom can reach funds that pass the 30 meters. For the TM1 the effect of the bottom can reach funds of 40 to 50 meters.

3. MATERIALS AND METHODS

3.1 Presentation of the survey site

The bay of Algiers is situated in the central part of the Algerian coast; it is characterized by her shape semi circular of an approximate surface of the order 180 km^2. It is limited to the East by Bordj El Bahri and to the west by Rais Hamidou (Fig. 1). This region is urbanized very and the majority of units is concentrated in the industrial zones of Oued Smar, El Harrach, the harbor of Algiers, Rouiba and éeghaia. The geographical coordinates of the bay of Algiers are: (36°49', 03°14') and (36°49', 03°00'). The bay of Algiers is submitted to the urban dismissals and the influence of port activities. In the middle of the bay pours Oued El Harrach that takes the shape of a sewer in the open. To the East pours El Hamiz that present a load pollutes important little [6].

3.2 Data measured in-situ

The sampling is done with the help of the boat of *IBTASSIM oceanography* of the Science Institute of the Sea and Planning of the Coastline (ISMAL). This boat is equipped of an echo-sounder Navicom type NF 180 and of a Global Position System (G.P.S). The day of sampling the sea was quiet none agitated, the colour of the sky is blue deep and the speed of wind is the order of 2 to 4 m/s. Stations of measure are localized on the figure 1. Parameters measured for every station are:

1) Parameters measured in-situ as the temperature of the surface and the bottom, salinity of the surface and the bottom and the bathymetry.

2) Parameters determined to the laboratory as suspended material (TSS), the dissolved oxygen.

3) Calculated parameter while using the equation of state of the sea water as the density of the surface and the bottom.

3.3 Image satellite

For the same period of sampling one has a picture multispectral of the satellite Spot. The scene composed by a three image with 20 meters a spatial resolution and panchromatic image with 10 meters a spatial resolution.

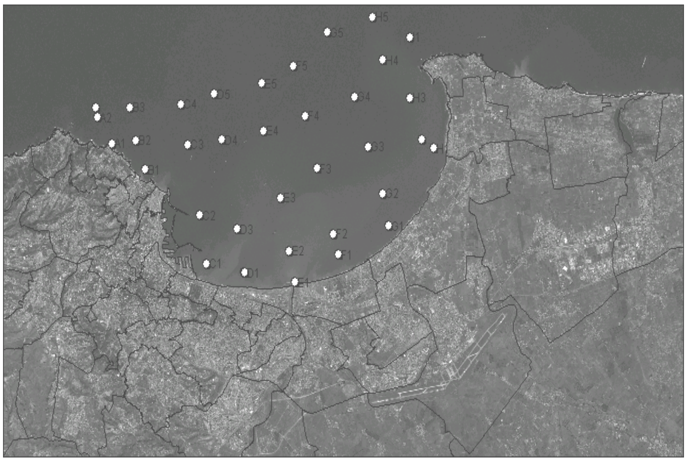

Fig 2: Bay of Algiers with the main dismissals (presented by arrows) and stations of sampling

For every station one does a reading of the numeric accounts. A brut accounts numeric is blemished of atmospheric noise. We corrected images of this effect uses the covariance matrix [7]. This technique is merely mathematical and requires no information of the middle. She is simple to apply and give results interest on all for images that covers in whole or in part the sea.

4. APPLICATION AND DISCUSSION

4.1 Principal components analysis (PCA)

The matrix of interrelationship can serve like a first reading for the research of relations between the measured parameters and data satellite. To understand better one used the analysis in Main Components (PCA) and one made the projection on the two main axes. Results are presented in the following Fig. 3:

One drew two contours indicating families greatly bound. The first family is presented by TSS, O_2, Ts. And the second family regroups Tf, Z, CN1 and CN2 corrected. Model to only one channel.

4.2 Data corrected

The CN2 quantities and CN1 are luminance's corrected of the atmospheric effects. As in this case one removed the point that present a maximum of SM. This singular point presents an anomaly that indicates the streamlined convergence of currents.

One notices the point of seen outdistances the variable Z is just to the middle in relation to the two luminance's. We removed data that correspond to depths superior to 60 ms.

Since for depths that pass the 50 meters the effect of the bottom on measure satellite is non-existent. The set of the corrected data are analyzed by an exponential regression. Results in this case are better presented and the curve of adjustment is representative of the cloud of points since the coefficient of interrelationship reaches the 88 %.

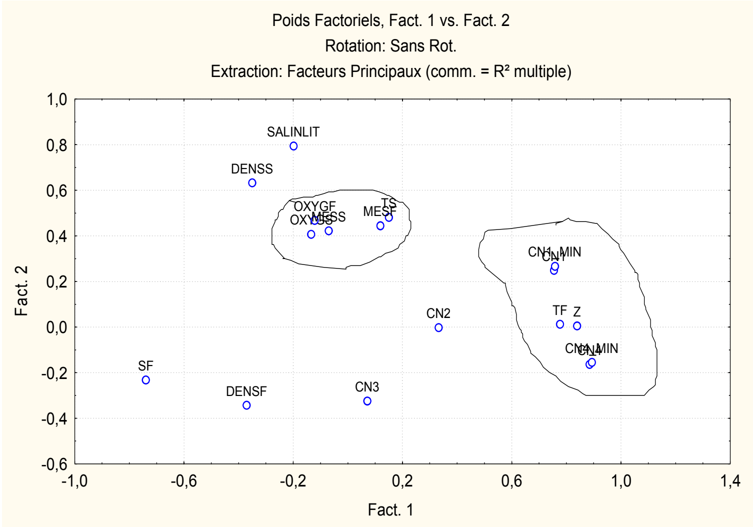

Fig. 3: A projection of parameter's in two principal components

4.3 Correlative analysis

4.3.1 Monoband model

Results of studies led on the bathymetry are bound directly to features of satellites. On curves of reflectance's we notice that more the depth is big, more the radiance is absorbed and more the level of radiometry is weak. The spectral resolution permits to observe in the lucid waters of objects until funds of 40 ms on the XS1 channel, and until funds of 15 m on the XS2 channel. The XS3 channel when to him doesn't bring any bathymetric information since the infrared is absorbed by water. The reflectance of the bottom, during his ascension toward the surface, sudden a selective attenuation. All it has for effect a bruising of the spectral answer of the bottom that returns discriminations difficult dice that the depth increases [8].

XS1 $$Z = -0{,}27823 + 2{,}68400\exp\left(-\left(XS1 - 47\right)/5{,}886\right)$$

XS2 $$Z = -0{,}2579 + 5{,}83395\exp\left(-\left(XS2 - 25\right)/4{,}24134\right)$$

4.3.2 Several channels'

For this reason one tried to achieve some multiple and polynomial interrelationships between these three variables [9]:

$$Z = -148.8 - 2.76\,XS1 + 17.93\,XS2 - 0.014\,XS1^2 + 0.57 * XS1 * XS2 - 2.04 * XS2^2 \quad (5)$$

4.3.3 Multiple parameter's

To the just the measures satellite depends the radiance thought by the seafloor and the quality of water [10]. A multiple regressive analysis between the measured numeric accounts and suspended material (TSS) gave us results following:

$$Z = -140.029 - 0.91 * TSS + 3.584 * XS1 + 2.478 * XS2 \quad (6)$$

This relation permits us the TSS passage in bathymetry and the inverse is true. For a region of which one knows the bathymetry one can determine the suspended mater therefore in abeyance and can achieve a navy pollution survey from image satellites.

4.4 Application

The developed equation permits us to achieve a direct extraction of the bathymetries while combining the two pictures satellites a hold in the channel1 and the other in the channel 2. To achieve the extraction of the bathymetry from pictures satellites one used the software *PCSATWIN* [11].

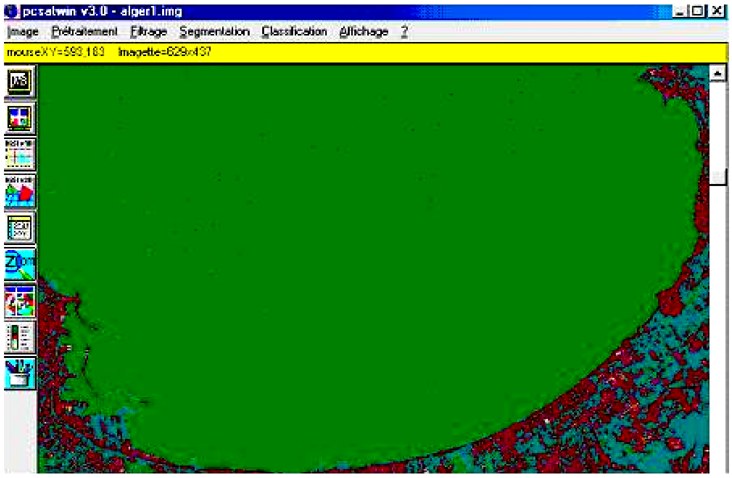

Fig. 4: Spot image of the Algiers bay on the XS1 channel

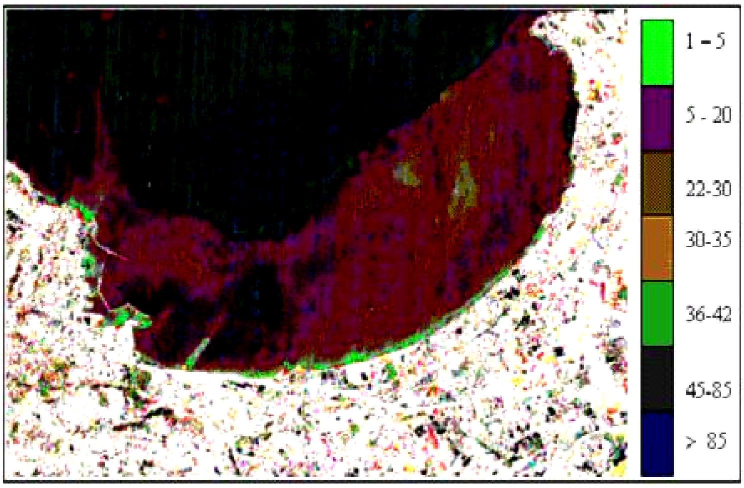

Fig. 5: Spatialization of the Algiers bay bathymetry.
SpotXS1 image transformed to bathymetric image. (Monoband model)

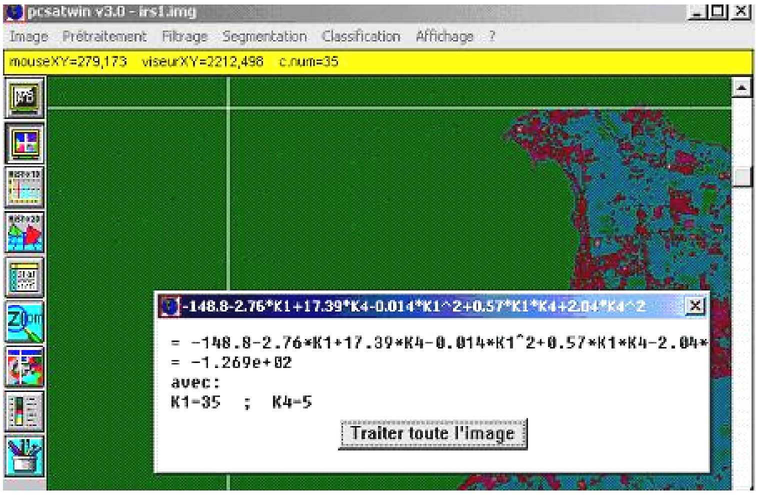

Fig. 6: Image satellite SpotXS1

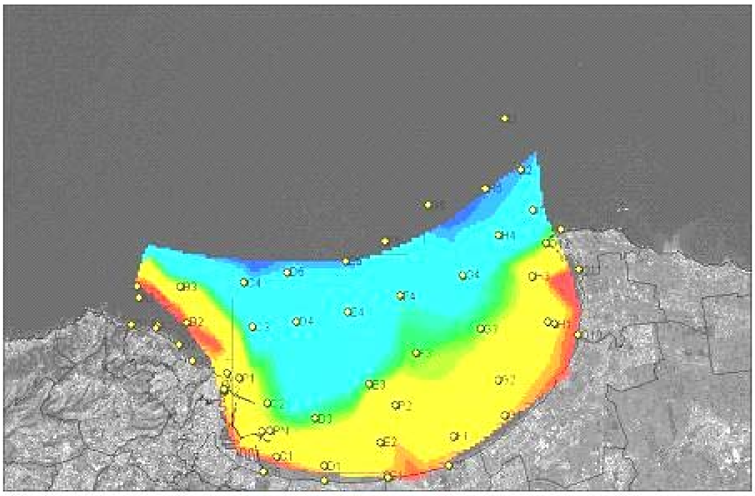

Fig. 7: Bathymetric image SpotXS1

5. CONCLUSION

In the case of sciences of the sea the number of stations cannot cover some big spaces and therefore the achieved matrix is far from being precise. On the other hand techniques of interpolation are the mathematical methods that take the numeric mathematical concepts as a basis. In this case the number of nudes is the main factor to achieve a good cartography.

Nevertheless the use of pictures satellites permits us to cover a big space, to achieve a continuous survey in space. Data acquired to soil permit to calibrate pictures and to pass some raw data in specific data. We showed that it is possible to determine the shallow water bathymetry but also that him a possibility to determine the suspended material in abeyance from pictures satellites if we know the topography of the place.

REFERENCES

[1] F. Bonn et G. Rochon, '*Précis de Télédétection – Applications Thématiques*', Volume 2, Presses de l'Université du Québec UREF, Canada, 633 p.

[2] A. Bricaud, '*Modèles de Réflectance, Diffuse de l'Océan, Applications à la Détermination Satellitaire des Concentrations des Substances Présentes dans l'Océan de la Mer*', Remote Sensing from Space Physical Aspects and Modelling, Toulouse 88, pp. 605 - 623, 1988.

[3] D. Durand, '*Suivi et Simulation de la Qualité de l'Eau en Milieu Littoral par Modélisation et Télédétection',* Thèse de Doctorat, Université de Nice, Sophia Antipolis, 197 p., 2000.

[4] J.M. Froidefond et D. Doxaran, '*Télédétection Optique Appliquée à l'Etude des Eaux Côtières*', Journal Télédétection, Vol. 4, N°2, pp. 157 - 174, 2004.

[5] L. Estep and J. Holloway, '*Estimators of Bottom Reflectance Spectra*', Int. J. Remote Sensing, Vol. 3, N°2, pp. 393 – 397, 1991.

[6] F. Houma, M. Boulahdid et A. Khouider, '*Développement d'une Méthodologie pour Caractériser et Déterminer la Pollution des Eaux de Mer par les Hydrocarbures en Utilisant des Images Satellites*', Rapport du 37e Congrès de la CIESM, Barcelone, Vol. 37, 208 p., 2004.

[7] P.M. Teillet, '*Image Correction for Radiometric Effects in Remote Sensing*', Int. J. Remote Sensing, Vol. 7, N°12, pp. 1637 – 1651, 1986.

[8] D. Spitzer and R.W. Dirks, '*Classification of Bottom Composition and Bathymetry of Shallow Waters by Passive Remote*', Sensing. Proc. Symp. Remote Sensing for Res. Develop. and Envir. Manag, Enschede, pp. 775 - 777, 1993.

[9] J.F. Tanis and W.A. Hallada, '*Evaluation of Landsat Thematic Mapper Data for Shallow Water Bathymetry*', Proceedings of the International Symposium on Remote Sensing of Environment, Vol. II, pp. 629 – 643, 1984.

[10] J.M. Jaquet, S. Tassan, V. Barale and M. Sarbaji, '*Bathymetric and Bottom Effects on CZCS Chlorophyll-like Pigment Estimation: Data from Kerkennah Shelf (Tunisia)*', Int. J. Remote Sensing, Vol. 20, N°7, pp. 1343 - 1362, 1999.

[11] N.I.B Bachari, N. Benabadji et A. Abdellaoui, '*Développement d'un Logiciel d'Analyse Spectrale et Temporelle des Images Satellitales Type Spot, Landsat et Météosat*', A.M.S.E. Periodicals, Advanced in Modeling & Analysis, Vol. 38, N°1, pp. 15 - 34, 1997.