Micro satellites for coastal resources management The ALSAT-1 case.

Dr/ Mokhtar Guerfi
Institut des Sciences de la Mer et de l'Aménagement du Littoral – ISMAL-
B.P 19 Dély Brahim, Alger, Algérie.

Résume:

Remote sensing techniques are becoming cost-effective. Continual progress is made in computer technology, in information networks including improvements in sensing systems for satellites. Satellite imagery can be used for observing marine features such as:

– large-scale circulation,
– currents,
– River outflow and water quality.

This can be visualized by highlighting variations in water **colour** and/or **temperature**.

These observations can be used for activities such as: environmental monitoring of sensitive coastal zones, hazards assessment, and management of fishing fleets.

Small satellites are enabling developing countries to have access to space technology. AlSat-1 (Algerian Satellite), an enhanced micro satellite is Algeria's first national satellite. It has been designed and constructed by SSTL (Surrey Space Technology Laboratory) at the Surrey Space Centre (UK). ALSAT-1 is part of an international collaboration of Earth observation satellites specifically designed for disaster monitoring, called Disaster Monitoring Constellation – DMC-.Alsat-1 is equipped with two banks of cameras giving a total of 600km field of view at 32 meters ground sampling distance in three spectral bands: Red, Green and Near Infra-Red. Alsat-1 products were used in different parts of the Algeria 1200 km coastline. The results are very interesting and encouraging. The paper will present an overview of these results.

الملخّــص:

يعالج هذا البحث مدى التطور الذي تعرفه التقنيات الفضائية في الجزائر وخاصة منها تقنيات الاستعمار عن بعد.

وقد استخدمت بعض صور أول قمر اصطناعي جزائري "آل سات 1 " للتطرق إلى الخبرة والقدرات الوطنية في ميدان التقاط صور الأقمار الاصطناعية ومعالجتها وتحليلها كي تستخدم في البحوث العلمية أو في مجالات تهيئة الإقليم وخاصّة منه المناطق الساحلية، إضافة إلى تسيير الثروات الطبيعية.

1. Introduction

Algeria is a territory of more than 2 million square kilometres, unequally populated and unequally developed. There is a huge concentration of population and activity along the 1200km Mediterranean coastal strip. 65% of the population live within 4% of the territory, and this number would rise by 2020 (3). This causes an imbalance for the coastal areas whose natural resources are threatened. Episodic events, such as earthquakes, floods and landslide pose serious threats to human life and property, particularly in the central and most populated part of the country, the coastal zone. The urban and industrial development of coast has also resulted in the degradation of the coastal ecosystems and diminishing the living resources.

Since the independence of the country, territorial planning is a major governmental concern. In implementing its Algeria's 21st agenda, the government developed a strategic plan, the "*National Territorial Planning and Sustainable Development Policy*" with the main objective of "Harmonious development of all national territory, contributing to national unity and meeting national sovereignty and security requirements". Some of the instruments of this policy are, the National territorial planning scheme (SNAT) and the **Master plan for coastal areas** (la loi littorale, Law N°02-02 of February, 2002), for the protection and valorisation of the coastal zone. Many projects and actions were initiated by the Algerian government and with international collaboration.

Spatial information technologies such as remote sensing (RS), geographic information systems (GIS) has a large part and play a key role in implementing this policy, in land resources survey (Cadastre littoral), environmental monitoring, and natural hazard forecasting and prediction.

Even for the developing countries, the easy access to satellite imagery has made remote sensing a common management tool in all areas of environmental understanding, monitoring and forecasting. In the coastal and marine environment remote sensing data can be used to monitor and evaluate natural and man made phenomena impact. It can be used to monitor and evaluate shoreline changes, studying sediment transport, monitor urban sprawl, map and inventory wetlands, and delineate wildlife habitat. Large scale events such as ocean circulation, current systems, upwelling and eddy formation can be better understood by using satellite imagery.

Using low cost small satellite projects, Algeria initiated a national space programme, ALSAT (Algerian Satellite) to meet national mapping and earth observation needs, to catalyze scientific research and have access to high-technology. This programme is conducted by the Algerian Space Agency –ASAL- and constitutes the Algerian contribution to the international space effort.

AlSat-1 has been designed and constructed by SSTL (Surrey Space Technology Laboratory) at the Surrey Space Centre (UK), and launched in November 2002, from Plesetsk cosmodrome in Russia. Alsat-2 is also designed and constructed by SSTL at the Surrey Space Centre (UK); Alsat-2 has an improved spatial resolution of 2.5 meters.

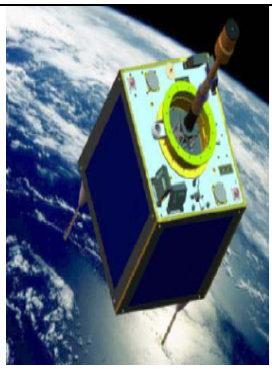
It will be launched at the beginning of 2007. Alsat-1and 2 are operated by The *Centre National des Techniques Spatiales* –CNTS- based in Arzew, Algeria. Alsat-3 will be a telecommunication satellite and will be the first microsatellite designed and constructed in the new CNTS in Oran, Algeria.

2. The ALSAT remote sensing programme

The national remote sensing programme is part of the national space programme, called the ***ALSAT programme***. It is conducted under the authority of the Algerian Space Agency (ASAL) and is made of a family of small satellites. One of the objectives of the Algerian remote sensing program is to fulfill the increasing demand on geospatial information for resources managers, planners and decision makers at the national and local level. This demand is generated by the activities of the *National territory planning Scheme* – SNAT-, including coastal planning and marine resources management. The low cost of data and their accessibility via direct reception (6) played a key role in the government decision to proceed with a national remote sensing program based on small satellites.

2.1. ALSAT-1 Mission and characteristics

AlSat-1 is an enhanced earth observation microsatellite. It is dedicated to national remote sensing purposes and is part of an international collaboration of Earth observation satellites specifically designed for disaster monitoring, *called Disaster Monitoring Constellation* – DMC-.



ALSAT-1
a cube of 60 x 60 x 60 cm

Size	**60 x 60 x 600cm**	Spectral Bands	
Mass	90 kg	Green	0, 523 – 0,605 µm
Lifetime	5 years	Red	0, 629 – 0,690 µm
Launch of date	November, 28th 2002	Near Infrared	0, 774 – 0, 900 µm
Orbit	680 km (sun-synchronous)	ALSAT-1 is operated by **CNTS** (Centre National des Techniques Spatiales, Arzew, Algeria)	
Inclination	98.1°		
Resolution	32m		

Table N°1. ALSAT-1 CHARACTERISTICS

Alsat-1 has three major characteristics, which distinguish it from the other microsatellites (5):

– **Wide swath width:** The maincharacteristic of Alsat-1 is to achieve a daily revisit in conjunction with the other satellite of the DMC constellation. A large Field of View was implemented. 10 images are enough to cover the whole Algeria territory of more than two million square kilometres.

– **Windowing:** This function allows imaging various types of areas around the world. This characteristic was exploited to take images of an exceptional size. We can see an example of an image (fig. 1) taken with bank1 (half Alsat-1 capacity) on the entire Nile River in one pass (from the Nasser lake to the mouth of the Nile on the Mediterranean Sea): a total image size of 160 x1088 km.

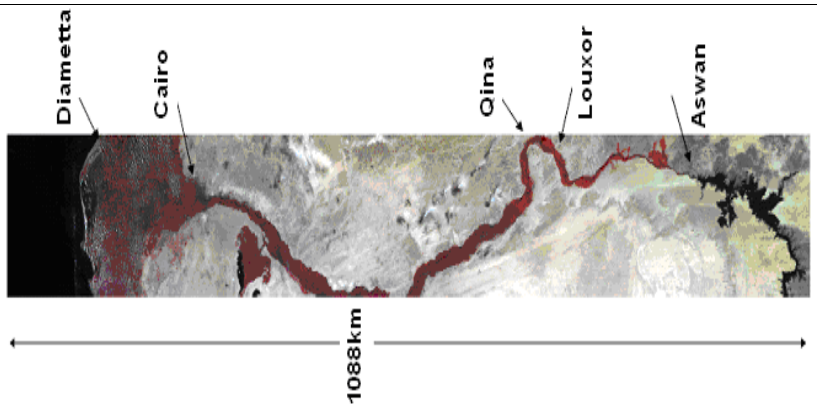


Figure N°1. ALSAT-1 image of the Nile River (from the Nasser Lake to the Mouth of t he Nile on the Mediterranean sea. A total image size of 160 x 1088km.

– **Short Revisit time:** The exceptional swath width of Alsat-1 allows obtaining a particularly short pseudo revisit period. This possibility was also exploited during the fire monitoring campaign during summer 2003 to quickly react at the start of a fire.

3. AlSat-1 for the coastal zone management

3.1. Status of the coastal Areas

The coastal zone in Algeria is ecologically rich and is also varied, with rock shores, Sandy beaches and Wetlands. This coastal zone is about 1200 km length and more than 35 km wide. This area is under great pressure, because the high concentration of population and activities (43% of the population and most economic activities are located in less than 50 kilometres from the coast (3). This concentration results in a population density almost 25 times the national average. Coastal areas have a number of sensitive ecosystems such as dunes, lagoons and sea grass beds. Many reports indicate that:

- Urban sprawl and illegal construction in coastal areas is widespread.
- Several areas are subject to serious coastal erosion.
- Pollution of coastal waters with municipal and industrial waste is widespread.
- Eutrophication is reported in coastal lagoons.
- Protection of marine and coastal biodiversity is limited.
- Wetlands are under constant threat.

3.2. The operational strategy of coastal zone management

In the framework of the "*National Territorial Planning and Sustainable Development Policy*" Algeria has a developed specific legislation which is in connection with the protection and the valorisation of the coastal zone (the Law n°02-02 of February, 2002), along with about 15 additional laws and decrees relating to the management of the coastal zones. This Law provides the framework for the integrated coastal zone management. The government considers integrated coastal zone management (ICZM) as a high priority and has recently embarked on an ambitious program to implement the new coastal law in all coastal willayas (provinces). The law also establishes the National Coastal Conservancy. There is also a Development and Management Scheme for the Coast (SDAL), an instrument to locate new development away from coastal areas. A Coastal Area Management Program (CAMP) is underway in 4 central willayas with the support of the Mediterranean Action Plan (MAP).

3.3. Remote sensing and Geospatial data role to support this strategy

All the actions or projects are supported by data collection activities and the development of accurate and up-to-date databases on all aspects of the coastal zone (habitats, protected areas, water quality, etc.) to develop management plan and carry out periodic assessment of the health of the system.

Remote sensing and GIS are extremely valuable in development of databases and to analyse them in the integrated manner and derive management action plans. satellite based information has been used for generating inventory on coastal habitats, landforms, coastal land use and shoreline condition, condition assessment of protected areas, exploration of marine fisheries, mitigation of coastal disasters and understanding of sediment dynamics.

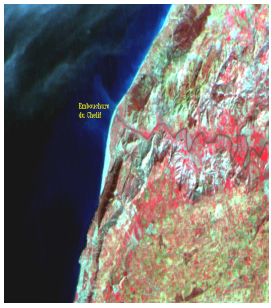
There were projects dedicated exclusively to GIS and remote sensing, such as "**Le cadastre du littoral", or ALGSATRS** carried out by ERS/RAC of UNEP MAP (data collection). It relates to MED POL Phase III for water quality data, for application of aerial and satellite images for costal erosion, chlorophyll assessment, etc.

After the launch of AlSat-1 (November 2002), several pilot projects for evaluating ALSAT-1 performance in different fields of application were carried out in collaboration with the Algerian space agency – ASAL - ISMAL (marine science institute) conducted projects in Coastal zone management using Alsat-1 imagery.

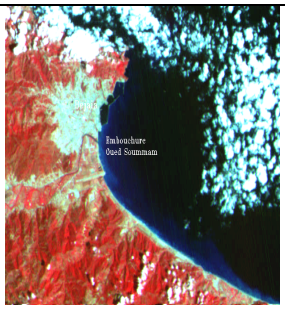
3.4. Alsat-1 imagery for inventorying the Land Based Sources of Marine Pollution

The major sources of coastal and marine pollution are originating from the land, either from urban or rural activities, such as discharge of industrial and municipal sewage, land use, tourism, etc. Pollution is discharged either directly into to the sea, or enters the coastal waters through rivers. Turbidity, temperature and colour are indicators of water quality.

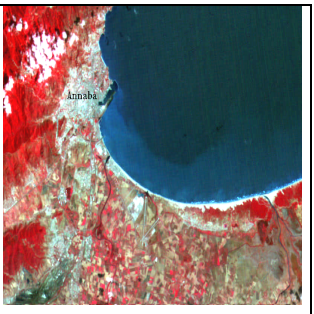
The river system (Fig.2-4)) carry to the coast chemical substances. In order to mitigate and control the impact of pollution on coastal and marine resources, it is essential that the type and load of pollutants be identified. This involves determination of the sources and their location, and the volume and concentration of the pollutants. In August 2004, a series of Alsat-1 images were captured along the 1200 km Algerian coastal areas to identify the major source of pollution (figure 2) for inventory.



Mouth of Oued Ech-Chlef
Alsat-1 image of August, 9th 2004



Mouth of Oued Soummam
Alsat-1 image of August, 6th 2004

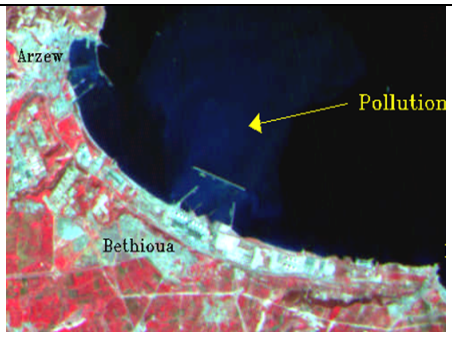


Mouth of Oued Seybousse
Alsat-1 image of August, 6th 2004

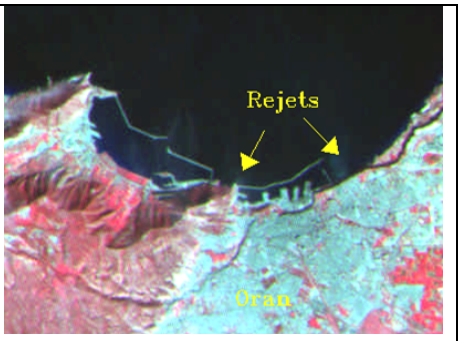
Figure N°2. Images along the Algerian coastal zone, showing the most import river system and source of marine pollution

3.5. Analysing the urban and industrial pollution

Sewage is one of the most significant pollutants affecting the coastal environments of the Algerian coastal zone. The inadequate number of sewage treatment plants in operation, combined with poor operating conditions of available treatment plants, and the disposal practices of discharging mostly untreated wastewater are likely to have an adverse effect on the quality of coastal waters. The population of coastal dwellers in most of the countries in the region continues to grow steadily, thus increasing the amounts of poorly treated or untreated sewage waste waters being discharged into the coastal waters (figure 3)



Industrial Pollution in Arzew port
Alsat-1 image of February, 2004

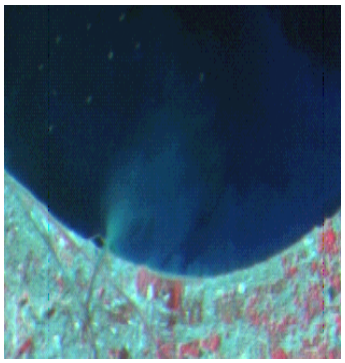


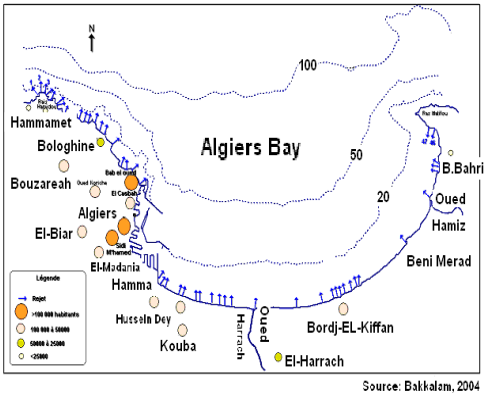
Urban sewage in Oran
Alsat-1 image of August, 9th 2004

Figure N°3. Municipal sewage and industrial waste are major types of pollution observed on the Algerian coastal zone. An additional source of sewage is from the increasing number of ships and recreational vessels within the region.

Pollution due to inadequate sewage disposal causes nutrient enrichment around population centres, and high nutrient levels and

even eutrophication near treatment facilities and sewage outfalls. Increased nutrient concentrations promote increased algal and bacterial growth (Fig.4).





Mouth of Oued El-Harrach
Alsat-1 image may 24th, 2003

Figure N°4. Population distribution and point source pollution in Algiers Bay

3.6. Marine water quality

The discharge of nutrients into coastal waters is a major cause of eutrophication, and it is actually an increasing environmental concern particularly in the Algiers Bay (Fig.4). Oued El-Harrach, a major river system in the Central, most populated and heavily industrialized part of the coastal zone, is always in a state of very high insalubrity and is a source of permanent contamination of the marine environment. The pollution of Oued El-Harrach is from urban and industrial origin; and it presents a very low oxygen concentration, a very great concentration of DBO and DCO, giving strongly polluted water causing the eutrophication of this environment. The Oued El-Harrach waters carry all types of pollution (physical, chemical and biological).

Eutrophication may cause algal blooms, changes in the aquatic community structure, decreased biological diversity, fish kills and oxygen depletion events. The presence of nutrients in the water column enhances the growth of plants, and in some cases may cause algae to overgrow the corals or seagrasses that were previously present. Habitat degradation will, in turn, cause decreased fisheries production and loss of recreational and tourism potential.

This is clearly shown in the figure below (figure 5), a sequence of image captured by MODIS (Moderate Resolution Imaging Spectroradiometer) on the Terra and Aqua platforms on August 10 to 13, 2003. After a very large thunderstorm that caused a flood and carried with it a high nutrient load from the dust, dirt, and debris that it received from the surrounding land. Opportunistic phytoplankton immediately utilized this transient nutrient supply to create the rapid population growth characteristic of a bloom. As the water was carried out to sea, the bloom went with it, slowly dissipating as the water dispersed and as the phytoplankton exhausted the nutrients in the pulse of stormwater.

Algiers Bay and Oued El-Harrach
MODIS image of August, 11th 2003

Algiers Bay and Oued El-Harrach
MODIS image of August, 12th 2003

Algiers Bay and Oued El-Harrach
MODIS image of August, 13th 2003

Figure N°5. Sequence of MODIS images showing the development of a phytoplankton bloom in the Algiers Bay.

Zemmouri Bay
ALSAT-1image May 24th, 2003

Figure N°5. Sediments transport. Alsat-1 image captured on May 24th, 2003. Three days after the earthquake that caused a huge humanitarian damage.

Suspended sediments were carried to the sea after rain storm which occurred three days after the strong earthquake in Zemmouri Bay are easily observed on this ALSAT-1 image.

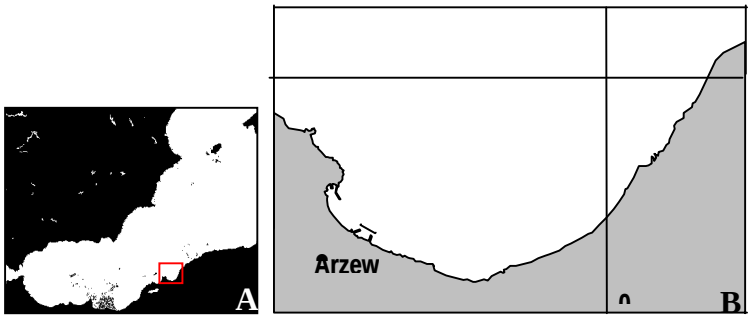
This coastal zone faces also heavy erosion due to man made causes, particularly sand mining.

3.7. Large scale events- water masses circulation-

Large scale events such as ocean circulation, current systems, upwelling and eddy formation can be better understood by using satellite imagery. Learning how these events work could provide managers insight into how to better manage ocean resources. Other oceanic properties satellite imagery can measure include chlorophyll concentrations, water temperature, wave heights, sea surface winds, and sea ice.

Along the central and western parts of the Algerian coast, the circulation is driven by the Atlantic water entering the Mediterranean Sea. This is known as the Algerian current. This current creates coastal dynamics that ensures renewal of water in bays and gulfs. As far as the land areas are concerned, it depends on the quantity and quality of the dumping, which in turn is directly related to natural conditions.

The Algerian current has been regularly studies in the past, at a macro scale (Mediterranean basin); Data sets on physical, chemical and hydraulic properties have been collected by different means. With the availability of the Alsat-1 images a one year study was carried out to understand the water mass circulation and the associated structures at a micro scale, in Arzew Gulf (Mega & al.). A series of Alsat-1 images presenting these structures were colleted, processed and analysed (figure 7).



FigureN°6. The Gulf of Arzew, Geographic situation
(A : Alboran Sea, B : Arzew Gulf).

The Arzew Gulf (Fig.6) is located in the East part of the Alboran Sea (South-West of the Western Mediterranean). It is affected by coastal properties that can enrich or pollute gulf waters. In this area, the continental shelf is 21km wide with the depth of only 2Okm, 1km off the shore, 50 isobaths is between off the shore. Having a rather remarkable bathymetry, the bay can reach the 500 meters depth at the exit, towards the broad one (vers le large).

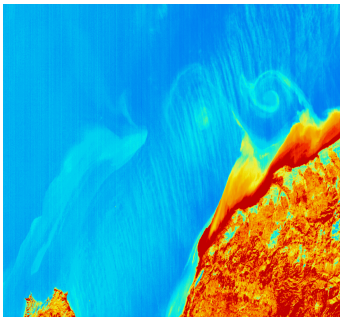
The Almeria-Oran jet is the structure that has a direct influence on circulation of the water masses in the Gulf of Arzew. A climatologic study of the circulation made by Claude MILLOT on the sea of Alboran indicates that this jet, (from the Cape de Gata in the south of Spain towards the east between Oran and Arzew), is accentuated in June and July by a difference in temperature of water of the Western swirl and that of surrounding water which can reach 4°C in the Western sea of Alboran in August and September, Atlantic water is still clearly differentiated from Mediterranean water even if the variations in temperature decrease. In October, the gradients appear to be reinforced, in particular along the front Almeria – Oran

Algerian current instabilities along the Algerian coast and coastal counter currents in the gulfs and bays create complex vertical motions and nutrients enrichment of the surface waters.

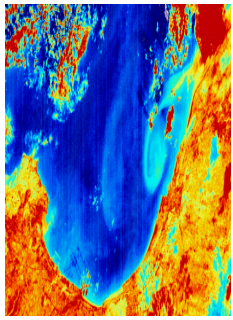
As for the Arzew Gulf, Salinity values are quite low in comparison with typical Mediterranean waters. Temperature in the Gulf is warm in summer (18.15’ to 26.15°C) and cold in winter with 7° difference between seasonal averages.

A series of successive images from ALSAT-1 covering a period of time (August – December) relatively sufficient for this type of study have been used to understand the waters movement and circulation in the Arzew Gulf in order to propose a general circulation scheme for the region.

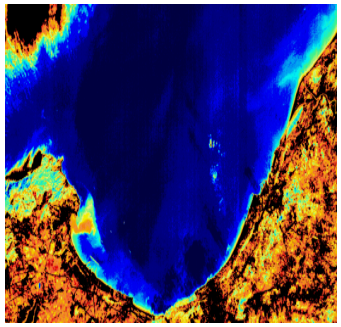
The image of December 13th, 2003 (figure 3) clearly confirms the existence of coastal counter currents **Cr** which always appears in the same place and keeps the same movement and direction (according to ten Alsat-1 images, fig.7). A succession of cyclonic swirls is created thereafter: **C1**, **C2**, **C3** and **C4**.



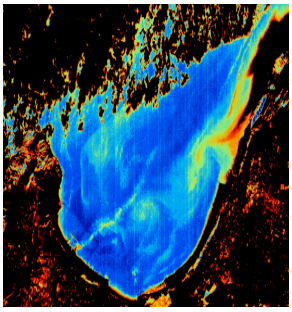
Alsat-1 image August, 26th, 2003



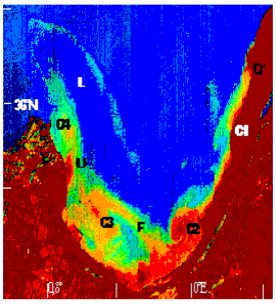
Alsat-1 image August, 31 2003



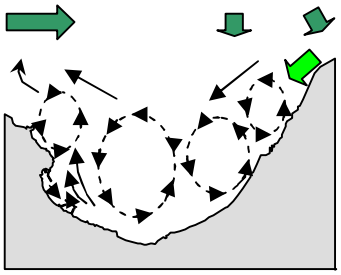
Alsat-1 image September, 21st, 2003



Alsat-1 image November 30th,2003



Alsat-1 image December, 13th 2003



A proposed general water masses circulation scheme over the Arzew Gulf.

Figure N°7. Water Mass circulation at the Arzew Gulf using ALSAT-1 images. A series of successive images from Alsat-1 from August to December 2003, have been used to understand and to propose a circulation scheme at a macro scale level over the Arzew Gulf.

We also observe a mouth of water **L** very contrasted and small upwelling **U** induced by the displacement of **C4** towards the North-West under the action of the flow of the coastal current **Cr**. Which explains the strong activity of this current in the Gulf. A filament **F**, quite visible, explains the cyclonic movement of the swirl **C3**, and its displacement towards the West coast of the Arzew Gulf.

This first flow chart (figure 4) is not yet final. Continuous in situ measurements and permanent follow-up with ALSAT-1 images are necessary to improve it. But, it is a convincing test of presentation of water masses circulation study at macro scale level.

3.8. Monitoring protected areas

Along the Algerian coastal zone, there are many ecologically fragile areas that are designated as '***Protected Areas***'. Some of these areas are wetlands and classified as of international interest as stipulated by Ramsar convention. To be preserved and conserved such ecosystems should be monitored in regular basis, to assess impact of conservation measures as well as anthropogenic activities. The repetitive coverage of Alsat-1 and the other satellite from the DMC provide conservation managers a useful tool.

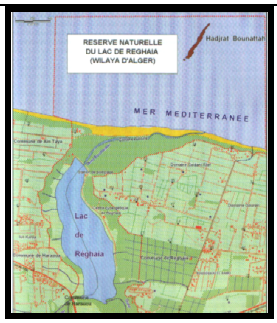
During the Alsat-1 pilot project, images of the National Reserve of **Lake Reghaïa,** one of the sites classified of the Ramsar Convention, were captured and processed to evaluate the interest of this imagery for monitoring purposes. The site is located 30km East of Algiers (fig.8).

The protected area covers 2km of coastline and a small island, "*Ile Agueli*", located at 1,000m offshore. The hole protected area covers 130ha (80ha terrestrial zone and 50ha marine zone).

The Reghaia Lake protected area is characterised by the existence of a permanent saline lagoon and marshland in a shallow depression surrounded by hills. The marsh is separated from the coast by sand dunes at the mouth of Oued Reghaia. It is characterized by a semi-arid Mediterranean bio climate with average annual temperatures of 22°C, and precipitation of 625mm. There is a number of different terrestrial and aquatic habitats within the reserve. It also maintains a small numbers of breeding, migrant and wintering waterfowl.

The area is facing major environmental problems such as heavy summer tourism pressure, industrial and urban pollution from heavy industry and urban expansion.

Figure N°8 Reghaia Lake and national reserve



Topographic map 1/25.000

Aerial photography Marsh, 9th 2003

Alsat-1 image May 24th, 2004

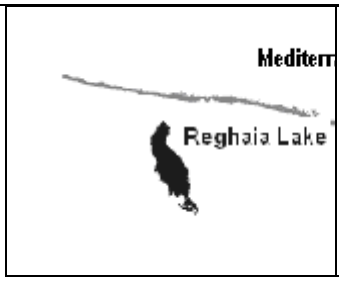


Figure 9. A processed Alsat-1 image of Reghaia lake and national reserve. It shows clearly the limit of the water bodies (The Mediterranean and the lake). This could be used as historical data to monitor the changes.

4. CONCLUSION

The study results showed that, even with a limited spatial and spectral resolution microsatellite data are very useful for coastal areas managers. These data could be used as historical data for environmental changes monitoring. It meets many data needs for local and national decision makers in the context of sustainable development.

In ALSAT case, the upcoming developments with Alsat-2 with a spatial resolution of 2.5m are very encouraging. The most interesting for the coastal areas manager is the complementarity between different satellites of a constellation.

References

1. Barale. V., Folving, S. **Remote sensing of coastal interactions in the Mediterranean Region**. In Ocean & Coastal Management vol. 30, no. 2-3, pp. 217-233, 1996

2. Grimes S. (2002). **Plan d'action national pour l'inventaire et la mise en place d'aires marines protégées en Algérie**. *Contrat PNUE/CAR ASP*, 120 p.

3. Grimes S. (2005). Stratégie opérationnelle pour la gestion intégrée de la zone côtière en Algérie. Banque Mondiale & MATE, 2005.

4. Mega, N. (2003). **Détection et suivi des phénomènes de méso-échelle dans le bassin algérien (NOAA/AVHRR) et la baie d'Arzew (ALSAT-1) : Journée d'étude sur le réseau national des données marine, ISMAL avril 2003.**

5. Rachedi A. & all. (2004). **Alsat-1: First Results of Multispectral Imager ThS 3: Small Satellite for Earth Observation.** XXth ISPRS Congress, 12-23 July 2004 Istanbul, Turkey

6. Rajendran. S., Chandrasekaran. V.A. (2005). Expected new developments and a need for small satellite mission programme in developing country.

7. Underwood, C. & all. (2003). Evaluation of the utility of the disaster monitoring constellation in support of earth observation applications. 5th International Academy of Astronautics (IAA) Symposium on Small Satellites for Earth Observation. April 4 - 8, 2005, Berlin, Germany.