

A coordinated proposal by the European Space Agency, the Italian Space Agency and the University of Rome to support the development of Remote Sensing applications over the African continent

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Abstract

The European Space Agency (ESA) through ESRIN, its facility located in Frascati (Italy), coordinates a network of ground stations acquiring remote sensing satellites. Within the above mentioned network of ground stations an outstanding role, due to their position, is carried out by Broglio Space Centre (BSC, Malindi, Kenya) of the San Marco Project Research Center (CRPSM) of the Università di Roma "La Sapienza", and by the Matera Station, that is part of the Space Geodesy Center (CGS) of the Italian Space Agency (ASI).

Both locations, besides performing the data acquisition activity, are also involved in data archiving and processing and, in particular, the Matera CGS is the ASI Center for all Earth Observation activities related to data exploitation (including development of products and services) and CRPSM is in the front-line in the developing of the applications for Central and Eastern African countries.

ESA acts as data provider by means of national stations that ESA member States make available and that are operated through annual ESA contracts.

Data provision can also be ensured by ASI through direct agreement with providers who are not ESA distribution partners.

Several applications for the African continent, that have been developed on the base of the acquired data, may result of particular significance and are very relevant to the theme of the Workshop.

After a summary description of the proposed Network, the paper describes some suitable applications and a proposal to improve, through a joint ASI-University of Rome action, CRPSM capabilities in EO data processing, to the benefit of the region, both in terms of education/training and of application development.

1 The Network

1.1 The ESA Network Architecture

Among others (systems development, applications development, etc.) ESA/ESRIN collects remotely sensed data acquired by a network of coordinated ground stations.

Gathered data are processed on request to full resolution to generate products for final user in quasi real time (within few hours from acquisition) for oil spill and natural disasters monitoring services and off-line for applications of other kind.

Fig. 1 shows ESA ground segment data flow.

Acquired data are also used to generate a catalog information (quick-look and metadata) and then sent to archiving centres that, for data over Africa, are as follows: Matera for ERS and

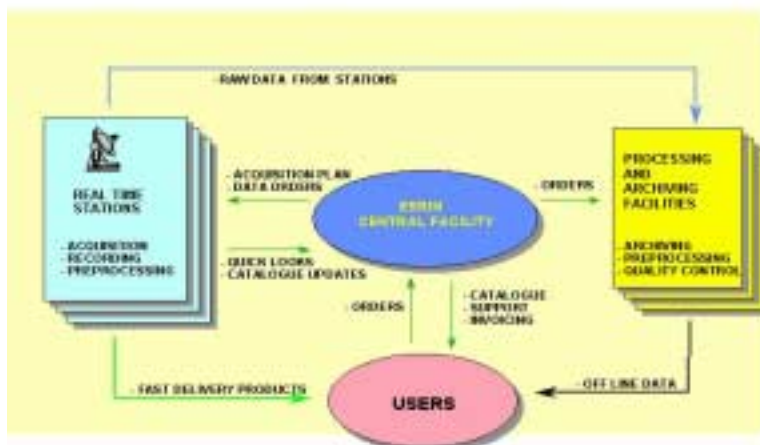


Fig. 1 – Remotely sensed data flow from acquisition to final user.



Fig. 2 – ESA/USER interface.

LANDSAT satellites, Toulouse for SPOT and ALOS, DLR for data acquired at Libreville.

Images available at the archiving centers are listed in the catalog that can be looked up at the web site <http://odisseo.esrin.esa.it/eoli/eoli.html>

Data for applications labeled as CATEGORY 1 (scientific, pilot project, etc.) are distributed directly by ESA, while appointed distributors deliver data devoted to commercial applications. Fig. 2 shows a scheme of the interface between ESA and final users.

Table 1 provides a summary of the facilities acquiring and/or archiving and processing data over Africa and the related Earth Observation missions

handled. Toulouse SPOT facility is coordinated by Spot Image.

TAB. 1 – ESA coordinated facilities.

	ERS	ENVISAT	LANDSAT	SPOT	TIROS	MODIS	SeaWiFS	ALOS
MALINDI	X	PLANNED	X		X	X	X	PLANNED
MASPALOMAS	X	MERIS	X	X	X	X	X	
MATERA	X	ASAR/MERIS	X		X	X	X	PLANNED
LIBREVILLE	X	PLANNED	X					
TOULOUSE		DORIS/RA		X				PLANNED
FRASCATI		X						

Fig. 3 shows the distribution of the users of data provided by ESA. ESA counts 7300 EO users in 131 countries.

1.2 Additional capabilities

In addition to the satellites acquired by ESA network, possibilities to acquire other satellites by the Matera station are currently under evaluation by ASI.

This applies to Radarsat, for which the relevant facilities are under development, and to other satellites (both commercial and scientific/preoperational, like NASA satellites).

Access to Spot 5 is under discussion with CNES.

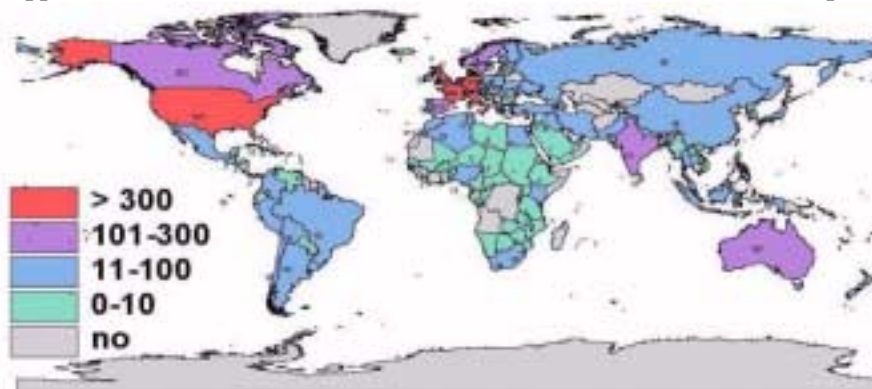


Fig. 3 – World wide distribution of ESA EO users.

2 Remote sensing data exploitation for the African continent

2.1 General

A number of applications could be envisaged to become the core of pilot project(s) with the clear objective to demonstrate the importance, and in certain cases, the uniqueness of the exploitation of satellite data to provide essential information and a basis for decision in a number of applications.

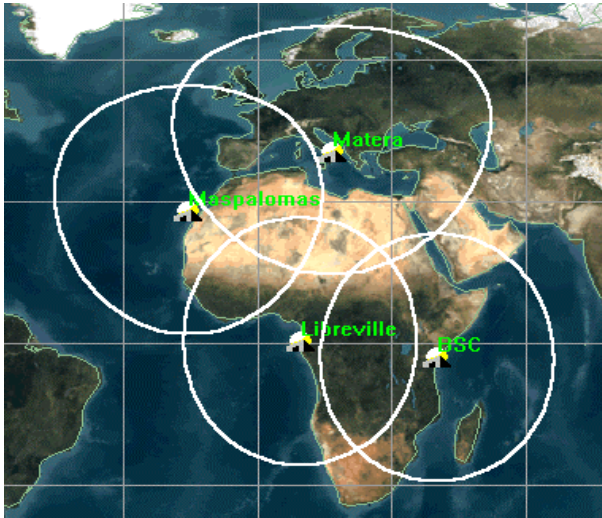


Fig. 4 – Acquisition footprint of Africa by the proposed network.

The following list is not to be considered a complete one. It has been compiled putting together the priorities expressed by the Kenyan Government and the applications considered of interest, already developed in Italy and/or within ESA, that have as common denominator the possibility to be immediately adapted to the African situation and needs.

2.2 KECCEM: Kenyan Coastline Evolution and Mapping

The objective of this project is to monitor the evolution and identify coastal change processes through the change detection analysis of optical sensors (LANDSAT, SPOT) data and aerial photographs in order to understand the erosion cycles and coastal changes. High-resolution optical remotely sensed data have been largely used for studying and monitoring coastal environment.

Serious climatic phenomena interesting the Eastern region of the Central Africa (drought, desertification, coastal erosion, etc.) may be a signal of a global climate change. Typical of these regions is the slow but inexorable erosion of the coasts because of the depletion of the mangrove forests, which are a natural barrier to the sea advance. This process is undoubtedly originated by the intense anthropic activities, but concomitant and perhaps determining cause may be the reduction of the extension of the coralline barriers, due to the climatic changes. ERS-SAR images allow not only to determine coastlines, but also to evaluate the state of the mangrove areas and the estimate of the coral reef extension. This will enable a permanent monitoring and a valid aid in the definition of conservation strategies and management.

2.3 SST and LST precise estimate

A very accurate algorithm for estimating the Sea and Land Surface Temperature (SST and LST) has been developed at the CRPSM. In fact, after a selection among 29 algorithms world wider used, ESA employed this algorithm to map world LST. The results were published in 1999. This algorithm, particularly designed for AVHRR images, will be extended to the appropriate MODIS channels possibly taking into account the additional information on the water vapor content obtainable from the MODIS itself and the MERIS sensors. These last data will be combined with “in situ” measurements in an assimilation model that allows to merge data from different satellites passes (NOAA, Seastar, TERRA, ENVISAT).

The possibility of monitoring the state of the sea through the SeaWiFS sensor data (also acquired by the Malindi station) allows to monitor the surface conditions and therefore to carry out studies regarding the temporal evolution of the skin temperature in the western Indian Ocean.

2.4 Oil spill detection

The ability of detecting particular patterns of interest within an extended area has been shown by the application of oil spill detection. In this case an algorithm has been used, along with an adaptive filtering pattern recognition approach, able to detect oil spills on sea surface, under the assumptions of thermal equilibrium between oil polluted areas and the surrounding water and of weak horizontal sea surface temperature gradients in the area of interest. Comparing satellite retrieved polluted areas with in situ

observations available in literature and high-spatial resolution satellite observations (Landsat, SPOT and ERS-SAR), the algorithm has proved to supply satisfactory results in detecting oil contaminated areas.

2.5 Early fire detection

In cooperation with the Italian Fire Department (VVFF), an algorithm has been produced able to detect fire events using a combination of channel 3, 4 and 5 of the NOAA AVHRR images. Such algorithm especially tuned for the Italian region is able to detect fires in nighttime and daytime and, in the case of not saturated pixels, the size and the temperature of the fire can be estimated. The diurnal application of the technique requires the knowledge of the surface characteristics such as the surface reflectance, that can be estimated using a vegetation index (VI) computed by means of channels 1 and 2 of AVHRR images.

A comparison with ground truth areas has been made possible thanks to the VVFF database and the results obtained are very promising. The final goal of the study is the possibility of applying Meteosat Second Generation (MSG) images for monitoring continuously the Italian territory for real time fire warning, which has not been possible so far given the insufficient temporal resolution of low orbit satellites.

Simulating the MSG-SEVIRI images by using MODIS images of Italy, the possibility of detecting fires of 0.3 ha size has been demonstrated.

2.6 Atmospheric aerosols estimate using SeaWiFS images

A preliminary analysis of the aerosol optical-thickness based on more than 1 year of SeaWiFS images acquired at BSC and the characterization of the seasonal behavior of the atmospheric aerosol optical depth and angstrom coefficient has been carried out for clear water conditions.

The estimation of the atmospheric aerosol content is important “per se”, given its relevance in driving climate dynamics as consequence of the alteration induced on the earth’s thermal balance.

From this point of view the research, carried out from the optimal location of the Malindi station, allows the monitoring of the extension of the effect of the highly polluted Indian atmosphere and the Asian and African dust sources (e. g. the Arabian peninsula) on the portion of the Indian Ocean between East Africa and Madagascar. Therefore, the estimation of the optical characteristics of atmospheric aerosols in the visible and near infrared (NIR) spectral ranges combined with the use of atmospheric model, in situ measurements (sounding balloon) and NOAA based atmospheric data (TOVS) allows the improvement of the standard atmospheric compensation algorithm. In fact, the aerosol information, gathered for clear case water, can be integrated into the atmospheric correction algorithm for SeaWiFS satellite images, to provide more accurate interpretation of remotely sensed data over the Kenya coasts.

The knowledge of the tropical atmosphere (and land/sea parameters) of the East Africa coast can help in studying changes in the African continent climate and in monitoring the high pollution sources around the Indian Ocean basin.

Space-borne data can supply repetitive and large-scale atmospheric measurements of the tropical regions. They result more meaningful when supported by periodic balloon-borne measurements, which result necessary for the validation, the assessment of the accuracy and the estimate of the spatial variability of the atmospheric profiles.

Long-term atmospheric measurements from space and from ground over the East Africa coast performed at BSC station can give a valid contribution to the detection of the local climate change and trends.

The CRPSM research activity in the field of the tropical atmosphere, mostly regarding the atmospheric temperature and water vapour profiles aims to compare and merge the data coming from “in situ” and satellite sources to analyse the quality of space-borne remote measurements and to carry out a calibration strategy of satellite data around the Malindi coastal zone in order to setting up a real time instrument for atmosphere characteristics monitoring.

2.7 Seasonal behaviour of the ocean colour and its correlation with the physical environment in the West Indian Ocean

The study is devoted to the monitor the seasonal behavior of the sea surface pigments concentration in the area of the West Indian Ocean. The analysis is based on the SeaWiFS images acquired at the BSC since June 2000.

The availability of ocean color data from SeaWiFS combined with the other oceanographic satellite-derived data allows a better description of the phytoplankton cycle and, possibly, the ocean productivity. Besides other applications this makes it possible to explore the marine living resources.

Extraction of the products from SeaWiFS images, providing information on the state of the marine surface. Such data, have great scientific importance in the biological field, global change assessment and for an accurate evaluation of the surface temperature.

2.8 Drought and Desertification Monitoring

The Kenyan authority, through the University of Nairobi, has evidenced the desertification problem in many parts of Kenya (Land Degradation, Drought and Desertification) and the need to identify its verifiable indicators. The arid and semi-arid environments in Kenya are subject to periodic seasonal droughts of varying severities and duration; the area under study is the Turkana district.

The *general concept* is to integrate all available data. This will include data collected on the ground as well as data acquired by various sensors. This approach includes:

- The identification of ground indicators of environmental changes (degraded condition, stable, restored, etc.);
- The determination of indicators that can be remotely sensed;
- The selection of the most adequate high resolution satellite data (Landsat TM, ERS) to extract land-surface information;
- The refinement and the design of processing algorithms (Image Processing and GIS facilities) and data output;

Expected results are:

- 1) Determination of environmental indicators and land surface information;
- 2) Set up of a GIS system (remotely sensed indicators and ground indicators of environmental changes);
- 3) Change detection over the last 20 years (Degradation, Drought and Desertification hot spot).

BSC offers the possibility to acquire all high and low resolution data necessary for this project. The results of high spatial and spectral resolution satellite images such as from SPOT or LANDSAT and high-frequency low resolution satellite data such those from MODIS and NOAA, combined with the result of the analysis of user data (precipitation and temperature data, climatic map, land use map, topographic and soil map, life zone map, vegetation map historical record of drought, ect.), can be used by the geographic information systems (GIS).

2.9 Landslide Hazard

Landslides in Kenya have been increasing in the recent past. This has both social and economic impacts, namely loss of life, agricultural land and crops as well as destruction of the infrastructure.

The best strategies for mitigating landslide hazards are to avoid construction in hazardous areas and to avoid land uses that cause mass movement. Satellite imagery can be used to make an inventory of previous landslides and to collect data on relevant parameters involved such as those involving soil, geology, slope, geomorphology, land use, hydrology, faults, etc.

The ability to identify the landslide hazards or its potential for occurring depends on the resolution of the image, the acquisition scale of the sensor data, the working scale, scenes free of clouds and heavy haze, and adequate textural and tonal or color contrast. The availability of DEM of the scene being studied can greatly enhance the interpretation.

The use of GIS will permit to categorize the land with regard to the landslide hazards (minor, little, moderate, high, very high)

The GIS will be used to overlay hazard information with socio-economic or infrastructure data-on population density, location of urban areas, ports, airports, roads, electricity network for a preliminary quantitative assessment of people and property at risk.

The methodology consists of

- Integration of satellite data and GIS data in order to produce:
 - Landslide potential map that will be suitable for making recommendations on land use intensity;
 - Landslide zonation map for land use management.

3 A Laboratory for EO data processing

The local exploitation of the satellite data acquired at the Malindi station and the training of the technicians are key factors for the region development process.

Because of that and making full benefit of the CRPSM infrastructure, the proposal is to put in place the initial nucleus (that has been called “Remote Sensing Laboratory”) of a facility that should become the reference Centre in the Region for EO data processing and related applications development.

In direct connection with the proposed network, the Laboratory should include two main functions :

- Education/training, since the beginning
- Development of applications, as a short/medium term objective.

The Remote Sensing Laboratory should be capable to support many activities, such as:

- Hosting Remote Sensing Courses
- Production of Digital Elevation Models starting from Optical and Synthetic Aperture Radar data
- Production of basic terrain classification starting from Optical and Synthetic Aperture Radar data
- Production of thematic cartography
- Continuous monitoring of land/sea and atmosphere evolution.
- Early warning for natural and anthropic hazards.

In order to accomplish the above activities the laboratory could be progressively equipped with :

- Workstations with image processing SW and GIS to enable an interactive map production
- GIS and DEM data server to store results and retrieve already done products
- SAR processors able to process the data acquired in the station
- post-processors able to produce geo-coded imagery.

ASI and CRPSM have already started consultations in order to define a preliminary implementation plan of such facility, with the aim of starting the training activities, as soon as all the necessary political and programmatic aspects are clarified.

The Plan will be presented to Kenyan Authorities for their approval.

ESA support is foreseen in the definition of this project.

4 Conclusions and proposed way forward

If the proposal drafted in the paper is judged interesting by the Governments of the Region and/or by the United Nations, its implementation should include the following items for each of the three areas:

Network

Activation of the proposed acquisition network and periodical definition of the satellites acquisition Plan (this mainly to support the development of agreed applications).

EO Laboratory

- Define layout and functions
- Integrate H/W and S/W to build up initial capabilities
- Define and start educational activities
- Progressively move the “centre of gravity” of applications development to the Laboratory, by improving the general purpose functions and by introducing “ad hoc” capabilities requested by the applications.

Applications definition and development

- Definition of further applications to be developed
- Definition of the contents, of the planning and of the funding sources for the pilot projects to be developed, test and validate the proposed applications
- Start and complete the development and validation and transfer the application to the Final User, for the planned operational use.