AFRICAN CAPACITY BUILDING IN SATELLITE ALTIMETRY WITH THE UNESCO-BILKO PROGRAMME

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ABSTRACT

Capacity building in remote sensing is an important component of the first 5-year plan of GOOS-Africa. Training future scientists and environmental managers in the use of satellite data is part of this strategy. The Bilko software is well suited for the African capacity building effort. It is specially written for education use, demands only moderate computer resources, is free to registered users and comes supported by images and lessons suitable for users working alone or in groups without direct access to remote sensing expertise. In 2004 the first Bilko lessons in satellite altimetry were tested during a workshop in Kenya, where participants gained hands-on experience in the application of altimetry to marine and coastal management. Three lessons were developed for the workshop, on sea-level change, on seasonal variability in eddy activity, and on significant wave height. The workshop was the first in a series. Other African initiatives are under development.

1. BACKGROUND

The ocean exerts a considerable effect on the lives of African populations and the economies of African countries. The ocean's waves, tides, and currents directly affect ships, offshore platforms, coasts and harbours, the supply of fish for food, and the use of the ocean for trade and recreation. Much less well known by the general public is the ocean's very large but indirect effect on weather and climate. Paradoxically, these indirect effects may have the largest impact on lives, property, infrastructure and the economy, through droughts, floods, tropical cyclones and storm surges. Both the direct and indirect impacts of the ocean on humans are becoming more serious because of the steady migration of people to the coast, and the growth of coastal mega-cities.

Rainfall in much of southern Africa is influenced strongly by the El Niño events originating in the equatorial Pacific Ocean. During El Niño years, droughts prevail in much of southern Africa, causing widespread economic hardship. There is also evidence that interannual variability linked to El Niño may influence the Indian Ocean monsoon. The tropical regions of the Indian Ocean generate tropical cyclones that can create havoc when they make landfall on the east African coast. These cyclones derive their energy from the ocean. When they make landfall, their potential for damage is greatly heightened by coincidence with high tides, which create massive storm surges to flood low lying coastal areas. The damage caused by tropical cyclones kill people and cause damage amounting to tens or hundreds of millions of dollars. Cyclones and lesser storms are the chief agents of coastal erosion.

Over recent years African scientists, environmentalists and political leaders have become increasingly aware of the profound influence the oceans have on the African continent, not just in coastal communities that depend directly on the sea for their livelihood and economic growth, but also on the future prospects for land-locked countries, chiefly through ocean-atmosphere interactions and the effect of the ocean on seasonal and interannual variability in rainfall. As a result of this awarreness, capacity building in marine sciences have become an important aim for many African institutions, including the New Partnership for Africa's Development (NEPAD).

It is within this context that African Ministerial Conferences on Marine and Coastal Environment in Maputo and Cape Town in 1998 created GOOS-AFRICA to develop the application of the Global Ocean Observing System in Africa. [1],

The main priorities for African capacity building for sustainable management of coastal and marine resources may be summarized as follows [2].

- The formation of an Africa-wide network of national ocean data centres properly equipped and staffed by trained personnel,
- Upgrading and expanding the present African network of stations for the measurement of tides and seal level
- Creating a network of specialists trained in the use of data acquired by remote sensing, to provide coastal managers with access to this rapidly increasing wealth of spatial data
- Facilitate the further implementation of a modern electronic communication system

These priorities are further addressed in GOOS-Africa's first five-year plan for a Regional Ocean Observing and Forecasting System for Africa (ROOFS-AFRICA) [3].

2. UNESCO-BILKO AND ROOFS-AFRICA

2.1 ROOFS-Africa Capacity Building Programme

The original ROOFS-AFRICA project was formally endorsed by the Heads of States Partnership Conference of the African Process during the World Summit on Sustainable Development (WSSD) in Johannesburg, South Africa 30 August 2002. The project had been updated in line with the NEPAD Environment Action Plan and Development Goals and the Implementation Plan of the WSSD during the African Stakeholders and Resources Mobilisation Workshop organised by UNESCO and its IOC in partnership with the NEPAD Secretariat in Johannesburg, 27-30 October 2003.

A major aim of ROOFS-AFRICA is to improve the ability and capacity of African nations to access and use remotely sensed satellite data, as a regional forecasting and management tool by forging sub-regional co-operation and bridging the digital divide between Africa and other regions. This will be achieved through a five-pronged approach:

- By developing a network of in-situ observing systems,
- By developing regional applications of remote sensing to marine and coastal environments,
- By developing centres of excellence capable of carrying out data assimilation, modelling and forecasting,
- By developing a system for communicating information derived from remote sensing to end users in marine and coastal management, industry and artisanal user communities.
- By education and training to provide a community of specialists trained in the development, production and interpretation of remotely sensed data for coastal and marine environmental management.

As a free, PC-based, simple to use image processing software, UNESCO-BILKO is eminently suited to teaching in an environment where IT resources are limited. The ROOFS-Africa workshop held in Johannesburg in October 2003, recommended that the BILKO software and teaching modules should be extended to include modules developed by partners in ROOFS AFRICA, using African data, and based on issues of importance to African environmental management.

As part of this process a fellowship scheme was envisaged, whereby marine scientists from African countries would spend time at the National Oceanography Centre (NOC), Southampton, UK, to work with members of the Laboratory for Satellite Oceanography (LSO) to develop teaching materials using Bilko to demonstrate different applications of satellite remote sensing to integrated management of the African marine environment. The first of these felloes, David Kirugara from the Kenya Marine and Fisheries Research Insitute (KMFRI) spent six weeks at the NOC in spring 2004 at the National Oceanography Centre, Southampton, UK, working with members of the LSO to develop lectures and hands-on practical exercises for use in African capacity building in the application of remote sensing in general, and altimetry in particular, to the management of Western Indian Ocean coastal and marine resources. The lessons developed were to be tested at a workshop in Kenya later that year, and subsequently added to a pool of teaching materials relevant to African environmental interests, to be distributed via the UNESCO-Bilko programme.

2.2 The Bilko Approach to Capacity Building

More than just software, Bilko is a complete tool for teaching and learning image processing techniques and marine and coastal applications of remotely sensed data. The Bilko project has four main components:
1) The Bilko software, 2) tutorials that introduce the software features and basic image display and processing routines, 3) a series of thematic lessons on different applications of remote sensing and 4) a network of users and lesson producers that exchange ideas, run workshops, produce lessons and generally work to enhance and develop the project. All are important components of the UNESCO-Bilko system. Software and lessons are distributed free of charge to registered users via the Bilko website at www.unesco.bilko.org.

The original aim of the project was to facilitate "hands-on" training in coastal and marine remote sensing for those traditionally excluded from such training by the high cost of commercial image-processing software, the need for expensive computer equipment to run that software, and the difficulty of acquiring remotely sensed images for teaching purposes. Some of these constraints have eased significantly since 1987, but the continued worldwide success of the UNESCO-Bilko project (which surprised its originators) bears witness to the widespread demand for the training in countries both with limited and advanced remote sensing capabilities.

Since the start over 600 research institutions, universities and colleges and more than 3000 individual in over 90 countries have registered to download Bilko software and lessons. Figure 1 shows their professional composition. The fact that a third of registered users are university lecturers indicates that the true user group is much larger, as organisers of courses and workshop organisers will have been sharing the software and lessons with colleagues and students. Through feedback from a number of users it is clear that many have produced their own Bilko-based teaching materials to fit their specific requirements. The list of registered users is thus likely to underestimate the true user number.

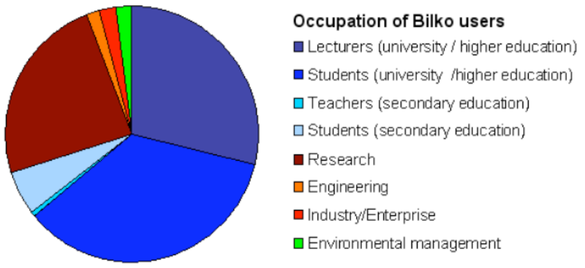

Figure 1. *Occupation of Bilko users registered during the year October 2004 to December 2005. Two thirds of registered users are in universities and other higher education establishments. Of the remainder the majority are researchers.*

The Bilko project has four guiding principles [5], which are at the root of its success.

i) The software should be designed to run on low-cost computers rather than specialist equipment. Applying this principle from the outset, when the software had to run on basic PCs with DOS, led to a fast image processing package that demands only modest resources in terms of computer memory and processing speed, even though the software functionality has increased dramatically over the years to keep pace with the increasing computer power and rapid growth in remote sensing technology.

ii) The software should be supported by lessons that exemplify its use and teach fundamentals of image analysis and interpretation through hands on practical exercises exploring different types of image data. The emphasis on student understanding has produced a transparent set of routines that allow the students to see what is happening and avoid the 'black box' approach wherever possible.

iii) The software, lessons and associated image data should be distributed free of charge to registered users. Teachers may freely modify and distribute Bilko teaching materials for their own educational use, provided that it is never sold, and that any copyright or ownership information is distributed with the lessons.

iv) Students and teachers should be encouraged to share, assess, criticise and enhance Bilko, thus providing feedback for further development of software and lessons.

These principles remain unaltered, although the software, the lessons and the images used to teach satellite applications have changed in many ways in the years since the project's inception. Today, more than ever, the project relies on its network of users and lesson producers to test new software routines, review lessons, provide feedback on existing material, and to produce new lessons and ideas for further project developments.

2.2 Main Features of the Bilko Software

This is not the place to provide a detailed list of the Bilko software features. However, a quick overview is appropriate, and may also act as an indicator of the subjects covered in the introductory tutorial that accompanies the software.

Bilko supports common image formats such as Envisat-N1, HDF, NetCDF, GeoTIFF, and USGS Mapgen formats. A selection of these are explored in the first section of the tutorial, where the student learns how to open and display the images, how the files are structured, how to derive numerical information from the images, and how to select image sub-sets and save them as new images.

Basic image manipulation and display tools such as contrast stretching, and a tool for the design of colour palettes are available. These are presented in the software and lessons in such a way that students gain understanding of how numerical data are translated into image brightness values on the screen, and how these in turn are related to colours in the display. Recently developed tools include a dialog window for customising the stretch used to redisplay 16 and 32-bit image data by mapping the digital values to the 255 brightness values used in a standard computer display.

Bilko can handle up to 64 linked images - a capability that may be used to open data from multi-band sensors, or a time series of images. There are plans to extend this to 256 linked images. The data coring tool allows a spectrum (or time series) to be extracted at a specific location. The transect tool allows the extraction of multiple transects, which may then be displayed either as a multi-series plot of data values against distance, or used to create a new 2-D image such as a Hovmöller plot. The animation tool and step-by-step scrolling through stacked images allows the student to visualise 3-D data sets. Colour composite images may be created from any 3 selected channels. All these aspect of the software are demonstrated in the tutorial using images from Envisat and ERS sensors.

One of the most flexible and powerful software tools is the Bilko 'formula document'. This allows the student to perform image calculations, apply flags and masks, create composite images and apply simple algorithms of their own choice. Figure 3 shows how this tool may be used with MERIS level 2 flags to mask pixels affected by cloud. Data analsis tools also include a series of spatial filters, principal component analysis, and supervised and unsupervised classification routines.

Image resampling and rectification tools allow the automatic geo-correction of geo-coded Envisat data. Geo-correction and co-registration of images may also be carried out using tables of tie-points or ground control points. Other tools include filters, (automatic filters, and a dialog window that allows users to create their own custom filters), histograms, transects, scatter-plots, principal component analysis, and (from late 2005) a classification program. A context sensitive Help facility guides users through the different aspects of the software.

3. W. INDIAN OCEAN CAPACITY BUILDING

3.1 Overview of regional capacity building efforts

About 30% of the 100 million inhabitants of the Western Indian Ocean region reside in coastal areas and are heavily dependent on marine resources for their livelihoods.

Figure 2. *IOC member states in the Western Indian Ocean (WIO) region.*

The region faces a number of challenges related to sustainable management of marine resources, and there is an increasing awareness of coastal and marine environmental issues as demonstrated by the launch of the African Process for the Development and Protection of the Coastal and Marine Environment in Sub-Saharan Africa. Organisations contributing to capacity building in the region include the IOC, the International Maritime Organisation (IMO), the World Meteorological Organisation (WMO), the Western Indian Ocean Marine Science Association (WIOMSA) and a number of non-governmental organisations such as the World Wide Fund for Nature (WWF), which focuses on sustainable manament of marine resources, and the International Ocean Institue (IOI), with focus on improving the livelihood of coastal communities.

The main IOC initiative in the region is the Ocean Data and Information network in Africa (ODINAFRICA), which is holds a number of data sets, including African tide gauge data and meteorolocial data. The main objectives of capacity building in the WIO region are summarised in the Implementation Plan for IOC Capacity Builidng [4]:

(i) Improve the understanding of marine and coastal ecosystem dynamics

(ii) Improve the monitoring and forecasting of coastal and oceanic processes, and enhance participation in global research programmes
(iii) Improve the skills and facitilites available for marine related teaching, research and resource management.

As part of the effort to achieve these objectives WIOMSA, with support from IOC and other organisations is running a series of regional training courses in remote sensing and integrated management of coastal and marine resources.

3.2 WIO Regional Course in Satellite Altimetry

The regional training course on the Application of Satellite Altimetry to Oceanography, held in Malindi, in the Luis Broglio Space Centre, in Malindi, Kenya, from 6-17 September, 2004 was the first in a series of WIOMSA courses dedicated to application of remote sensing to integrated management of marine and coastal resources series. The training course was intensive and comprised lectures, practical exercises, presentations by participants and discussion sessions. The following topics were covered during the course:

- Principle of satellite altimetry and applications to sea level studies
- Ocean circulations/currents and eddies from altimetry
- Marine gravity and geoid from multi-satellite altimetry and applications
- Altimeter waveform tracking for land/ocean use
- Bathymetric estimation from altimetry

- Improved methods/theories of altimeter data processing
- Inland sea/lake monitoring using altimetry
- Operational oceanography using altimetry

Though altimetry and the BILKO software formed the core of the course and practical exercises, other sensors (e.g. SST from AATSR and AVHRR) and software (eg ENVI, MatLab) were also presented in order to enable participants to compare and appreciate the possibilities provdided by a selection of available resources. The practical exercises included:

(i) The use of altimetry to study circulation patterns in the Western Indian Ocean: The practical highlighted seasonal changes taking place in the ocean circulation and eddy variability of the Western Indian Ocean during the spring and the summer monsoon, and the use of Sea Surface Height Anomaly (SSHA) to study seasonal and interannual patterns. Participants carried out a step by step procedure to calculate SSHA from single overpass Envisat-RA2 data and compared this to sea surface temeperature (SST) data from AATSR on the same overpass (see figure 3.). They also calculated eddy kinetic energy based on AVISO SSHA data, and investigated seasonal differences in EKE.

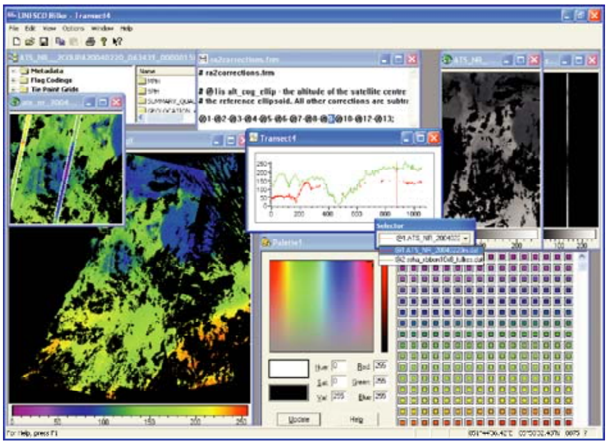

Figure 3. *Screenshot from one of the Bilko exercises demonstrating synergistic use of altimetry and sea surface temperature data.*

(ii) Sea Level Changes: The participants investigated the way in which sea-level data have been used to look at climate change, and compared results obtained from tide gauge data for the WIO region with altimetry data from the same period. As part of this exercise they looked at the local short term trend for two different stations (Mahe-Seychelles and Zanzibar-Tanzania) and the correlation between the in situ tide gauge data and the altimetry data for each station. The stations were chosen to demonstrate the limitations of the altimetry signal close to large land masses, thus a much greater correlation was demonstrated at the Seychelles location. A longer time series of tide-gauge and altimetry data from the North Atlantic was used to demonstrate long term trends. The participants then compared and discussed these two studies to identify possibilities and limitations of tide gauge data as a method of detecting regional and global sea level change.

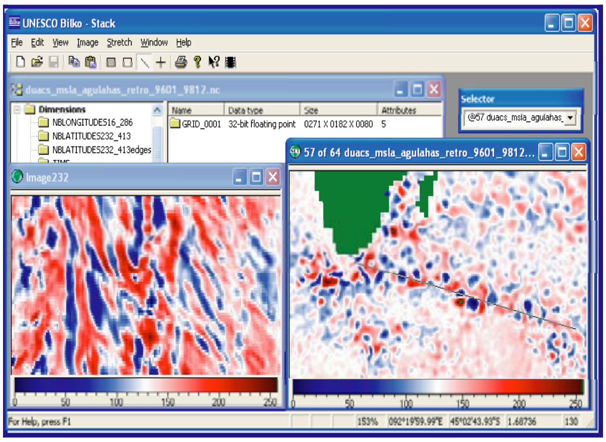

Figure 5. *Bilko screenshot showing analysis of SSHA data from the Agulhas Retroflection*

(iii) Significant Wave Height: Using the monthly significant wave height data set for the years March 1985 – Jan 2000 (15 years of data), the participants prepared an animation of the annual cycle, created monthly climatologies, obtained the mean annual SWH signal, and seaonal variability, and also investigated interannual variability by comparing the monthly means to single months. Using these derived data sets, they investigated the effect of the monsoon on the region, and observed the effects of El Nino on the seasonal monsoon signal.

As part of the course, and in an effort to identify areas for future collaboration, each participant provided a presentations of the remote sensing related work carried out at the institutions which they represented.

4. FOLLOW-UP ACTIVITIES

In the discussions following the course participants focused on identifying resources available (facilities, equipment, software, literature, datasets, other information sources) available in the region, which could be used in an integrated way to develop East African capacity in remote sensing application generally, and regional applications of altimetry in particular. The group identified a number of regional problems that might be addressed using skills acquired in the training course, products derived from satellite data that might help address these problems; and potential end users of these derived products.

***Figure 4**. Particpants in the Malindi workshop form the core of the newly formed Western Indian Ocean Satellite Altimetry Group.*

As a result of these discussions the participants agreed to set up a regional network for regular contact, including an e-mail forum, to be moderated by David Kirguara (KMFRI) and Resah Badal from Maurtius Oceaongraphic Institute (MOI). One of the main tasks of the group would be to collaborate with the San Marco Research Centre to develop satellite derived products for use in the wider management of Western Indian Ocean marine resources.

In the year and a half since its inception the Western Indian Ocean satellite altimetry group has been instrumental in developing a substantial number of proposals for regional applications of satellite data, subsequently presented to national, regional and international organisations involved in African capacity building for sustainable management of coastal and marine resources.

Teaching materials developed for the altimetry course and refined following suggestions from workshop participants have subsequently been made available to other users in Africa and internationally through the UNESCO-Bilko website at www.unesco.bilko.org.

5. ACKNOWLEDGEMENTS

The training course was organised by the Western Indian Ocean Marine Science Association (WIOMSA) with support from the Intergovernmental Oceanographic Commission (IOC) of UNESCO. The Italian Space Agency (through the San Marco Research Centre) provided free accommodation and training facilities. Satellite data for the hands-on lessons were provided by ESA and AVISO, and the lessons for the course were developed through the UNESCO-Bilko programme with support from ESA, IOC and the Western Indian Ocean Satellite Applications Project (WIOSAP).

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