BILKO AND AFRICAN CAPACITY DEVELOPMENT IN COASTAL AND MARINE REMOTE SENSING

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ABSTRACT

In much of Africa barriers still exist to the effective use of Earth observation in marine and coastal research and management. To remedy this, the development of data access and processing capacity must go hand in hand with hands-on training in the use of satellite data. The Bilko project has been providing training resources suitable for this for 25 years. In recent years marine scientists from Africa and Europe have been using Bilko to develop lessons based on African examples taken from image data disseminated via GEONETCast in two EC funded projects. The work is part of current efforts to develop MSc level and professional training courses for use in Africa, and shows how the contribution of African experts in the development of new lessons contributes to making these more relevant.

Index Terms— *Africa, marine, coastal, education, software*

1. INTRODUCTION

The Ocean has a profound effect on the lives of coastal populations and on the economies of coastal countries and island states. 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. The ocean also has a large, but indirect effect on weather and climate, which in turn impacts lives, property, infrastructure and economies through droughts, floods, tropical cyclones and storm surges. These hazards are expected to increase over the next few decades due to climate change and growing coastal populations. Coastal communities in poorer countries are particularly vulnerable to natural hazards and climate change. They often depend directly on their supporting ecosystems with few alternatives when these are damaged and their services reduced. Low income limits the capacity of many developing nations to prepare for and recover from natural disasters, and also reduces their capacity to adapt to environmental change. At the same time growing coastal populations, particularly in urban areas, is increasing pressure on coastal environments and resources, and placing communities and their supporting environments at risk.

There are many barriers to sustainable development of coastal areas. One is a lack of adequate environmental observations to support prediction, resource management and development planning. In Africa this lack is often particularly severe. Capacity to carry out sustained in situ observations is limited by national income, so organisations with marine and coastal remits see Earth observation as a key tool for monitoring the environment and providing operational services. This is the main motivation behind an on-going effort by remote sensing experts in Africa and Europe develop training resources for use in African universities and professional development courses in coastal and marine remote sensing.

2. BARRIERS TO THE USE OF MARINE EO DATA

Around the world satellite data are increasingly used to monitor the environment, understand variability and change, inform simulations and forecasts, manage natural resources, and provide support for humanitarian aid and the management of natural and man-made emergencies. The benefits of earth observation are now familiar to a growing community of scientists and engineers, planners; natural resource managers, policy makers and industry leaders. However, for most African nations there is still a long way to go before society can benefit fully from the opportunities afforded by the increasing availability of satellite data. This

is particularly the case for marine and coastal applications, as the marine science community appear to be behind the their colleagues in land remote sensing when it comes to accessing and using satellite data in their work. The main reasons for this are a lack of capacity to transfer large data volumes, lack of processing capacity to handle the large marine datasets, a lack of affordable and suitable software, and a lack of experience and skills needed for data analysis and interpretation.

The marine environment varies on a range of temporal and spatial scales, and the data volumes needed to monitor and understand this variation may be considerable. Even when analysis requires only regional datasets, these may have to be extracted from global data that must first be downloaded. The data volumes involved are prohibitively large for users with slow and unreliable internet connections - still an issue for many organisations, despite recent efforts to improve Aftican internet connectivity. The lack of access affects not only data availability for research and monitoring; it also the ability to select and disseminate datasets suitable data for training. This in turn has a direct impact on the ability of African institutions to develop the necessary hands-on expertise and train new generations of marine scientists in the use of satellite data. In many organisations there is also a lack of the computing infrastructure required to store, process and analyse large data sets. This applies equally to hardware, software and human capacity to provide the necessary computing support. Finally there is a lack of experience among marine scientists with the many different marine data products that are now available, and a lack of appreciation of how the data may be applied to different areas of marine environmental research and management. Solving these problems requires action on several fronts: improvement of internet connectivity and data access, increase in computing power and processing capacity, availability of free or open source software to display, process and analyse the data, and last but not least the development of a research and training infrastructure give marine scientists develop the knowledge and skills needed to use the data effectively in their day to day work. The UNESCO-Bilko project is contributing to the last two by providing free image analysis software, supported by tutorials and images specially developed for education use.

3. THE BILKO APPROACH

Bilko began in 1987, at a time when marine remote sensing was almost entirely limited to specialists working on expensive, high-specification computers [1]. This limited the ability of universities around the world to offer hands-on training in remote sensing to their students - essential if remote sensing were to become a routine observational tool in marine environmental research and management. Bilko was set up to overcome the obstacles by providing free software that could run on low cost computers, supported by training material that included everything teachers and students would need for hands-on practical exercises: images, processing tools, and carefully selected image data.

Since then both the software and lessons have undergone many modifications to keep pace with the development in marine remote sensing technologies. Day to day work and minor modifications based on volunteer efforts have been supplemented with more extensive funding for specific shorter projects from the European Space Agency (ESA), the Gobal Environment Fund (GEF) and the European Commissions (EC). Today Bilko provides (i) free software that is easy to use and runs on low-cost computers with an operating system in common use (Windows); (ii) an intuitive interface that makes image processing easy to grasp for beginners, but is complex enough to provide more advanced processing and analysis routines; (iii) facilities for more users to develop their own formulae (Bilko mini-programs) to access, display, process and analyse image data; (iv) tutorials that introduce the different software fcompontents and demonstrate their use in various contexts; (v) thematic lessons on marine and coastal applications of remote sensing data from a variety of sensors, and (vi) a growing network of users and lesson producers that exchange ideas and share resources such as processing tools, example data, case studies and lessons. A guiding principle of Bilko is the way all these go hand-in-hand [3].

The structure and format of Bilko lessons is one reason for their consistently high quality and pedagogical value. The lessons are designed for students and teachers working on their own with limited technical support or backup. This demands that everything required to complete a lesson must be provided: data, processing tools, instructions for use, and background information to aid interpretation. Lessons must be complete (as far as practically possible), and written in a direct but clear style. Authors attempt to foresee the questions students may ask and provide examples and additional information that help to avoid misunderstandings. Feedback loops are included to check understanding and focus attention on key points. Reasoning is repeated, though not by simple word repetition, a technique known as 'constructive redundancy' [3]. In the absence of an instructor lessons are written to promote active learning by interspersing information with hands-on activities and questions. All questions are provided with model answers that explain the reasoning behind the interpretation given.

One of the few inflexible rules of Bilko is that every lesson must begin with (i) a brief topic outline, (ii) a statement of the learning objectives, (iii) a content list of activities linked to these, and (iv) a list of the EO data and other tools needed to carry out the activities. This will allow potential teachers or students to assess quickly whether the lesson is suitable for their use. This introduction is followed by the body of the lesson, which intersperses brief explanations with detailed instructions for hands-on activities using the Bilko software. The lesson ends with a summary of what has been learnt, thus allowing teachers and students to check that the learning objectives have been

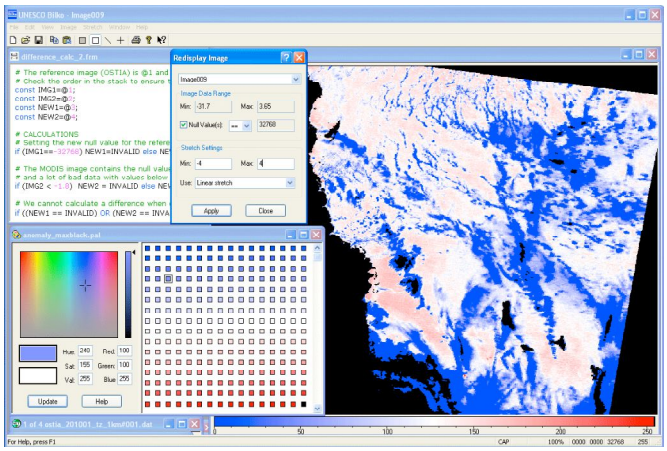


Figure 1. Bilko screenshot showing a difference map calculated as part of a lesson on quality control of SST data using an example from the EAMNet Tanzania region.

achieved. Where activities and interpretation require specific background information on sensors technologies, data products, or the environment from which the images were obtained, this will be briefly summarized in the lesson, with reference to more detailed information contained in additional documents. This background provided detailed information and is supplemented with links to further information or suggestions for additional reading.

4. DEVELOPING AFRICAN LESSONS

Local image examples are important in order to make teachers and students see remote sensing lessons as relevant to their needs. Bilko tries to provide images from around the world, but inevitably lesson content is determined by the data available to lesson authors through their own research. Considerable effort is currently being made to increase the number of lessons using African examples. These lessons, many still under development in collaboration between African and European experts, use up-to-date image-data to tackle African problems and support African environmental management. Lesson development is linked to the development of university courses at MSc level, and to hands-on professional training in workshops of 1-2 weeks duration. An example of such a lesson is shown in figure 1, and demonstrates quality control of sea surface temperature data for use in assessing coral bleaching risk, currently being developed for a training course in Tanzania.

Offering advice and support for training courses is an important task for the Bilko team. In return the courses provide important user feedback, and provide an opportunity to bring new contributors into the community of Bilko authors. For example, the Envisat lesson on eddies in the Western Indian Ocean was developed initially for a WIOMSA workshop on combining satellite altimetry with other remote sensing techniques in 2005 [4], whilst the popular Bilko lesson on Coral Bleaching was developed as a result of a collaboration started at the WIOMSA/CRTR workshop on the monitoring of coral reefs held in Zanzibar in 2008. A new lesson on variability in the equatorial Atlantic is intended to provide relevant material for the introduction of marine remote sensing into courses on Hydrobiology and Fisheries at the University of Buea in Cameroon. Another lesson on fronts in the Gulf of Guinea is being developed for use in Oceanography courses at the University of Ghana and other West African universities. Some African universities have been developing their own hands-on training material in marine remote sensing for several years, using local examples rather than those available from the Bilko website. This the case for example at the universities of Cape Town, Dar-es-Salaam and Ghana, where students routinely use Bilko both in organised practical sessions and as a tool in their own research projects. It is a key ambition of the Bilko project to build on the expertise of these African users to develop training examples with a wider geographical spread and covering new application areas. A new project, LearnEO, recently started with support from ESA may contribute to making this dream a reality.

5. MARINE COMPONENT OF GEONETCAST

The ability to take advantage of African expertise to develop new lessons is brought closer by GEONETCast, a global network of low-cost satellite-based data dissemination systems designed to distribute near real time remote sensing and in situ data, metadata and products to diverse user communities in developing countries. The system has been employed for some time to broadcast meteorological data. In the past 5 years or so GEO has been extending this to include other types of data from land and marine application domains. Several receiving stations have been installed in Africa, many at African universities or research institutes. Marine data available through GEONETCast includes 1km ocean colour and SST data for African shelf seas (see figure 2) from the EC-funded projects DevCoCast (2008-2011) and EAMNet (Europe Africa Marine EO Network), which is still ongoing. The two projects have also developed several Bilko lessons train users in applying the data to their work. Lessons teach quality control, analysis of spatial and temporal variability and synergistic use of data from different sensors. The lessons are part of a wider effort to develop a marine training infrastructure that will enable African trainers to draw on the expertise of African and European centres of excellence (COEs) in marine remote sensing, and share training resources across national divides. To this end EAMNet has developed short remote sensing courses MSc level and tested at the universities of Cape Town, Ghana and Dar es Salaam.

5. A DIVERSITY OF APPROACHES

A key lesson that has emerged is the need for a variety of approaches to capacity development. Africa is a continent

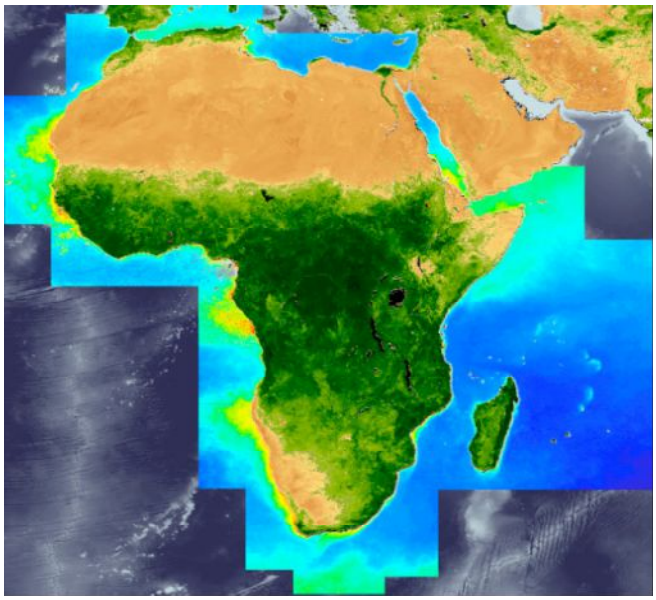


Figure 2. The EAMNet data regions

with wide scientific and digital divides. There is a great diversity of human and technical infrastructure, both within and between countries, and the needs for capacity development in the applications of marine remote sensing are also very diverse. Africa has several COEs, but limited infrastructure to link these to similar organisations in other countries. Mid-career scientists with considerable local expertise in their field have much to contribute, but often lack the opportunity to participate in international research and development, and pass on their knowledge to colleagues in other countries. In some countries university courses have limited or no Earth observation content; in others the capacity to deliver relevant training is good. Capacity also varies with application area and sensor technologies. For example, science-based management of marine ecosystems is relatively well developed, and the use of ocean colour and sea surface temperature for ecosystem studies and management of natural resources is well developed at African COEs. Data analysis skills in this area disseminated through student exchanges and research collaborations. Other applications areas are less developed. This includes the use of satellite altimetry, scatterometry and SAR data to retrieve met-ocean parameters (wind, waves, currents, sea level). An EAMNet user survey in 2010 also showed that programming skills required for operational monitoring and forecasting are limited to relatively few individuals.

Bilko is a non-specialist image processing software. The project provides training resources at beginner to medium advanced level. It is thus ideal for teaching image analysis interpretation to students from late high school to post-graduate level, and is also suitable for marine scientists who are not remote sensing experts, but wish occasionally to use remote sensing observations in their work. It is not suitable for large-scale operational data processing or for training scientists planning a career as remote sensing experts. Such users will need more advanced programming skills and access to software capable of processing large data volumes quickly with minimal hands-on input. Training remote sensing professionals to advanced level goes beyond the capacity of the Bilko project. For them one-to-one, on-the-job training through fellowships and secondments is a better option. However, even such advanced users sometimes use Bilko to quickly display images or try out new ideas. If they retain an interest in the project, they will be eminently suited to carrying the project forward through developing new training resources and the teaching of future generations.

6. FUTURE CHALLENGES

Looking back it seems clear that Bilko has largely achieved its original aim of making hands-on training in coastal and marine remote sensing widely available. However, the digital divide still represents a major challenge and is one reason for the under-representation of African examples in existing lessons. Another challenge is the need to remain up-to-date with developments in computing, remote sensing technologies and the growing number of applications areas. Development of new applications are a result of interaction between remote sensing experts, scientists involved in mainstream coastal and marine research, and professionals in more applied fields such as marine forecasting, pollution control, coastal engineering and environmental protection [5]. Development of training resources to teach the new applications depends on a corresponding collaboration between these experts and educators with experience from development of distance learning resources. The demand for training material relevant to Africa is growing. Bilko's ability to meet this demand in the future depends on continued software updates, including support for new African satellites. More importantly, it depends on the availability of new examples from African research and environmental management and the willingness of African experts to take on the work of lesson development.

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