C-RISe
COASTAL RISK
INFORMATION SERVICE

Cotiére Manakara, Madagascar

C-RISe Coastal Risk Information Service

Case Study

October 2020

Executive summary

Coastal Risk Information Service (C-RISe) provides satellite-derived data on sea level, winds, waves and currents to support vulnerable coastal populations in adapting to the consequences of climate variability and change.

The project enables institutions in the partner countries of Madagascar, Mozambique and Mauritius, to work with the C-RISe products to inform decision-making. It enables effective uptake of C-RISe data by commercial and operational sectors in the region and contributes to the improved management of coastal regions, enabling these countries to build increased coastal resilience to natural hazards.

- C-RISe provides data essential for understanding coastal vulnerability to physical oceanographic hazards not otherwise available to partners, due to the lack of tide gauges in the region and the expertise required to process the satellite data.
- Software and training materials enable partners to validate and analyse these data in ways that are relevant to their specific needs and activities.
- Capacity building increases the understanding of the value of these data in addressing coastal risk. It also increases the number of organisations and individuals capable of working with satellite data, and facilitates work towards the application of data within Use Cases.
- The Use Cases facilitate operational uptake by the partners, integrating C-RISe data into their work streams and providing examples for dissemination and training.

The C-RISe project is now in the legacy phase, having successfully delivered all its intended milestones, it is continuing to support partners in using the data. All data sets are currently being updated to extend the time coverage to 2020 and increase the spatial resolution of the sea level data using data from Envisat and AltiKa satellites.

The project offers several opportunities to expand, including increasing the range of data and information provided; increased geographical coverage; and a wider capacity building remit. In building local capacity and focusing on the development of Use Cases in line with our partners' needs, C-RISe has demonstrated the vast range of issues that these data can be used to understand and address.

Project team

C-RISe is led by SatOC with partners from the UK, South Africa, Madagascar, Mozambique and Mauritius: National Oceanography Centre (NOC), Bilko, Council for Scientific and Industrial Research (CSIR), Centre National de Recherches Océanographiques (CNRO), Conservation International, WWF, Centre de Fusion d'Informations Maritimes (CFIM), Instituto Nacional de Hidrografia e Navegação (INAHINA), University of Mauritius, Universidade Eduardo Mondlane, Institut Halieutique et des Sciences Marines (IHSM) and Direction Générale de la Météorologie (DGM).

C-RISe is funded by the UK Space Agency (UKSA) under the International Partnership Programme (IPP), which is committed to using the UK's space sector research and innovation strengths to deliver sustainable economic, societal and environmental benefit to those living in emerging and developing economies. IPP is part of the UK Government's Global Challenges Research Fund (GCRF), supporting research and innovation on global issues affecting emerging and developing countries. IPP is fully ODA compliant and delivered in alignment with UK aid strategy and UN Sustainable Development Goals (SDGs).

Project partners:

Project funded by:

Project overview

The challenge

It is well established that, due to a changing climate, global sea level is increasing and that large-scale weather patterns are changing. However, these changes are not geographically uniform and are not steady in time, with short-term variability on a range of time scales (seasonal and inter-annual). It has been shown that, taking into account socio-economic factors, several regions are particularly vulnerable to changes in sea level. At highest risk are coastal zones with dense populations, low elevations, appreciable rates of subsidence and inadequate adaptive capability.

There is a strong imperative to improve awareness of coastal hazards and promote sustainable economic development in marine areas. A key challenge in the implementation of coastal management is the lack of baseline information and the subsequent inability to effectively assess current and future risk.

Access to enhanced regional information on coastal risk factors (sea level, wave and wind extremes) improves planning to protect coastal communities and safeguard economic activity. This information can contribute to increased industrial and commercial competitiveness in the maritime sector, which is heavily dependent on access to accurate relevant oceanographic information. For port operations, sea level heights and tidal currents are vital for operational efficiency. Wind and wave climatologies are fundamental to infrastructure design and operational planning of offshore activities. Coastal tourism and human settlement are equally affected by these parameters and therefore sharing skills and enabling access to currently difficult to obtain satellite data are significant development steps.

The challenge is to provide access to data on sea level, wind and waves and to support understanding of variation in these key ocean features as they change seasonally, inter-annually and due to climate change. It is important to measure and understand these regional and short-term variations, so that appropriate planning and adaption measures can be implemented. This will enable organisations to better plan operational activities, infrastructure development and the protection of communities, ecosystems and livelihoods.

The context

It has been shown that, taking socio-economic factors into account, several regions are particularly vulnerable to changes in sea level. In the Western Indian Ocean, Mozambique, Madagascar and Mauritius are also highly exposed to the surges associated with cyclones, which become significantly more damaging when they coincide with high tidal levels and are also elevated by an underlying trend of increasing sea levels. Since 1980, 18 tropical cyclones have impacted Mozambique, affecting millions of people and resulting in over 2000 fatalities[1] (Emerton et al., 2020). Madagascar is hit by three or four tropical cyclones on average every year, causing loss of homes and livelihoods[2]. The impacts of coastal hazards are increasing due to many factors, such as growing populations, changes in coastal land use and loss of natural coastal protection.

Whilst data are required to inform risk assessment, planning and operations, there is a lack of in situ data on sea level, wind, waves and currents for the Western Indian Ocean region. In particular, Madagascar currently has just one operational tide gauge at Toamasina on the east coast, which has been monitoring sea level since 2010. In situ data are expensive to collect and instruments such as tide gauges are costly to maintain, particularly in remote, difficult to access locations.

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[1] Emerton, R., Cloke, H., Ficchi, A., Hawker, L., de Wit, S., Speight, L., Prudhomme, C., Rundell, P., West, R., Neal, J., Cuna, J., Harrigan, S., Titley, H., Magnusson, L., Pappenberger, F., Klingaman, N. and Stephens, E. (2020) Emergency flood bulletins for Cyclones Idai and Kenneth: A critical evaluation of the use of global flood forecasts for international humanitarian preparedness and response, International Journal of Disaster Risk Reduction, Volume 50, Article 101811

[2] Randrianalijaona (2018) Measuring the economic impact of cyclones in Madagascar, The Conversation https://theconversation.com/measuring-the-economic-impact-of-cyclones-in-madagascar-90946

How space can help

Satellite data are understood to bring value and benefit to regions with sparse in-situ observations, as well as providing current information, it allows us to go back in time and examine periods for which no in situ data are available. Satellite altimetry data represents a cost-effective method of monitoring sea level, giving good spatial coverage over large, inaccessible areas. These data are now available for an 18-year period, providing a suitable information to identify trends in sea level rise across the region. Wave height and wind speed data from satellites is available from 1992 onward, enabling the identification of seasonal variation and trends. The spatial coverage of the data sets also allows better understanding of regional variation in these parameters.

C-RISe demonstrates the value that satellite data can bring to regions with sparse in-situ observations, and provides the skills to adopt space technology for more effective coastal management and positive socio-economic development.

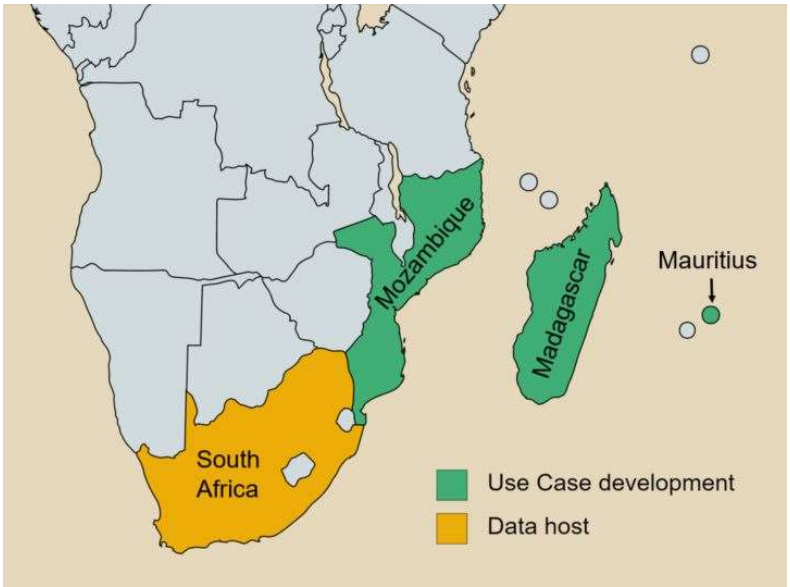
C-RISe aims

The C-RISe team have identified three project goals, two short term and one longer term. The short-term goals are: to enable institutions in the partner countries to work with the C-RISe products to inform decision-making; and to enable operational uptake of C-RISe data in commercial and operational sectors in the region. In the longer term, achieving these goals, with delivery of the underlying project outcomes, will contribute to the third goal of improving management of coastal regions and enable these countries to build increased coastal resilience to natural hazards.

Towards these goals, we identified the following objectives:

1. To work with local partners to deliver a Coastal Risk Information Service, providing satellite-derived information about coastal vulnerability to environmental threats such as sea level rise and extreme wind and wave events.
2. To apply and evaluate the C-RISe service through a set of Use Cases, which will apply the C-RISe Coastal Risk products to individual end use applications meeting local priorities.
3. Build local capacity to use coastal altimetry data on sea level, wind and waves with other data sets and information sources to provide scientific decision support for strategy development, governance and management of coastal areas to increase resilience to coastal hazards.

Countries of focus



Contribution to the United Nations Sustainable Development Goals

Our partners are using the data provided by C-RISe in a wide range of projects; therefore, C-RISe is able to contribute to several United Nations Sustainable Development Goals (UN SDGs).

	SDG 1.5 Building the resilience of the poor and those in vulnerable situations and reducing their exposure and vulnerability to climate-related extreme events and other economic, social and environmental shocks and disasters.
	SDG 9.A Facilitating sustainable and resilient infrastructure development in developing countries through enhanced financial, technological and technical support to African countries, least developed countries, landlocked developing countries and small island developing States.
	SDG 13.1 Strengthening resilience and adaptive capacity to climate-related hazards and natural disasters in all countries. SDG 13.3 Improving education, awareness-raising, and human and institutional capacity on climate change mitigation, adaptation, impact reduction and early warning.
	SDG 14.2 Sustainably managing and protecting marine and coastal ecosystems to avoid significant adverse impacts, including by strengthening their resilience, and take action for their restoration in order to achieve healthy and productive oceans. SDG 14.A Increasing scientific knowledge, developing research capacity and transferring marine technology in order to improve ocean health and to enhance the contribution of marine biodiversity to the development of developing countries, in particular small island developing States and least developed countries.

Project partners

C-RISe involves a consortium of international commercial, institutional, academic and NGO partners from the UK, South Africa, Mozambique, Madagascar and Mauritius.

Partners Based in the UK

Satellite Oceanographic Consultants Ltd (SatOC) is an SME specialising in the development and promotion of practical applications of satellite oceanography, by working with industry, the research community and commercial and institutional end users. SatOC is the prime contractor and project manager for C-RISe.

satoc.eu

Bilko Development Limited was formed to provide satellite image analysis software for UNESCO. Bilko distributes free software and hands-on tutorials to users in 174 countries. It moved to the Intergovernmental Oceanographic Commission in 2003, when it became the training tool of choice for GOOS-Africa, providing support for capacity development in marine remote sensing and developing software and tutorials to meet requests from African marine scientists.

bilko.org

National Oceanography Centre (NOC) undertakes integrated ocean research and technology development from the coast to the deep ocean. It provides long-term marine science capability including major facilities; sustained ocean observing, mapping and survey; data management, and scientific advice. The NOC is the UK's leading institution for sea level science, coastal and deep ocean research and technology development.

noc.ac.uk

Meeting with students at UEM, School of Ocean Sciences, Quelimane, Mozambique

Meeting with WWF, Antananarivo, Madagascar

Partners based in South Africa

Council for Scientific and Industrial Research Ocean and Coastal Information Management System (OCIMS) data portal will be used as the delivery platform for C-RISe. It will remain a resource for the region, facilitating the application of EO data and geospatial information to operational monitoring.

csir.co.za

Partners based in Mozambique

Instituto Nacional de Hidrografia e Navegação (INAHINA) are the hydrographic office for Mozambique, as such they are the primary holders of marine data for Mozambique and are responsible for evaluating coastal development plans. INAHINA are a Government agency with mandate to contribute to national efforts to build coastal resilience and strengthen disaster prevention capacity.

inahina.gov.mz

Universidade Eduardo Mondlane (UEM) Escola Superior de Ciências Marinhas e Costeiras (School for Coastal and Marine Studies), a department of the Universidade Eduardo Mondlane, based in Quelimane, Mozambique is the primary national institute for applied coastal and oceanographic research.

uem.mz/index.php/sobre-a-escmc

Partners Based in Madagascar

Conservation International (CI) Madagascar national offices are responsible for ensuring sustainable, safe and equitable use of natural resources provided by coastal and marine ecosystems. To achieve these goals they work closely with other NGOs (e.g. Blue Ventures), universities and government agencies. They will use the new data products to inform on-going activities, supporting community managed marine and coastal areas.

conservation.org

Institut Halieutique et des Sciences Marines (IHSM) Madagascan University Department for Marine and Fisheries Research which hosts the Malagasy National Oceanographic Data Centre. Has close links to Government and developmental organisations and use research to influence policy and development priorities.

ihsm.mg

Direction Général de la Météorologie (DGM) headquartered in Antananarivo, Madagascar, are the National Government Department responsible for delivering national forecast services. Services include weather forecasting, daily marine forecasts, and delivery of cyclone and tsunami warning alerts.

meteomadagascar.mg

Centre National de Resherches Océanographiques (CNRO) is Madagascar's National Centre for applied Oceanographic Research tasked with responding to government needs and required to both directly implement research activities and coordinate collaborative research with other institutions. Currently involved in projects concerned with pollution, coastal management, ocean acidification and coral reef monitoring.

cnro.recherches.gov.mg

WWF Madagascar national offices are responsible for ensuring sustainable, safe and equitable use of natural resources provided by coastal and marine ecosystems. To achieve these goals they work closely with other NGOs (e.g. Blue Ventures), universities and government agencies. They will use the new data products to inform on-going activities, supporting community managed marine and coastal areas.

wwf.mg/en/

Partners Based in Mauritius

University of Mauritius Faculty of Science is a major facility for education and research development of the country. The Mauritian Government has stated its intention to optimise and build on the rich potential of the faculty to strengthen its national scientific and technological capabilities.

uom.ac.mu/

Centre de Fusion d'Informations Maritimes (CFIM) is headquartered in Antananarivo, Madagascar. It is funded by the Malagasy government to promote inter-administration collaboration in the exchange of maritime information amongst national departments and agencies, working in the maritime field, in order to ensure maritime safety and security.

cfimmadagascar.org/

Meeting with INAHINA, Maputo, Mozambique

Solution overview

C-RISe is delivering access to satellite-derived data, alongside capacity building, with the goal of enabling our partners and other stakeholders to use this information to improve resilience to coastal hazards.

Data provision

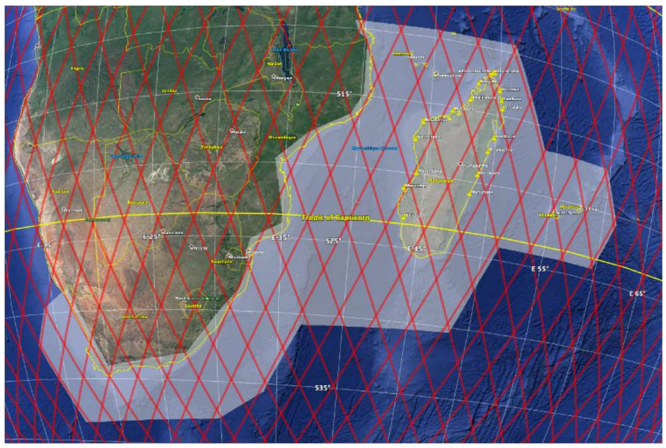
C-RISe is providing the following satellite data sets for a range of parameters, detailed in the table below, for the area of the Western Indian Ocean outlined in the figure below, to support Use Case applications.

- Historical climatologies of ocean winds, waves and surface currents
- Along-track satellite altimeter data, reprocessed by NOC, in coastal geophysical data records, and time series at nominal points on the satellite track
- Near real time (NRT) satellite measurements of ocean winds, waves and surface currents

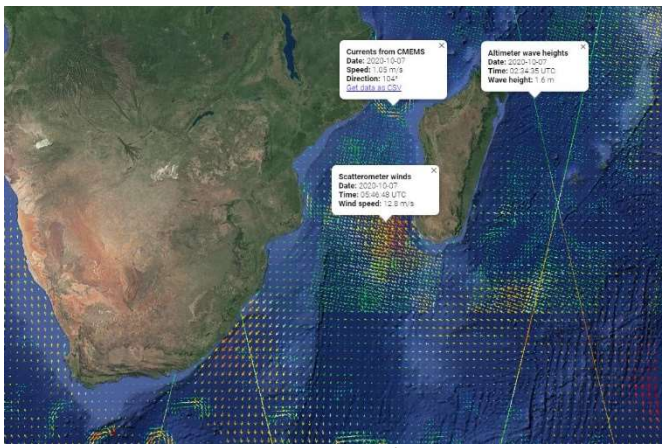
Historical climatologies and sea level data are available through a web-based data portal hosted by CSIR. The NRT (available within three hours of measurement) data are available through a demonstration web page, hosted by SatOC.

Table 1: Satellite data included in C-RISe service

Parameter	Description	Time Coverage	Satellites
Total water level envelope, significant wave height, surface radar backscatter	Along track data from the NOC coastal processor	2002-2019	Jason-1, 2 and 3
Significant Wave Height climatologies	Monthly, 1° x 1° gridded climatologies, sourced from Globwave	1992-2019	ERS-1, ERS-2, Envisat, Topex, Jason-1, 2 and 3
Ocean Wind Speed and direction climatologies	Monthly, 0.25° x 0.25° gridded climatologies, (CMEMS)	2007-2019	Metop-A, Metop-B
Total surface current (geostrophic + Ekman)	Daily, 0.25° x 0.25°, gridded climatologies, sourced from Globcurrent	1993-2019	Envisat, Jason-1, 2 and 3
Significant Wave Height, wind speed	Near Real Time along track data	Daily updated	Jason-2 and 3, AltiKa, Sentinel-3
Wind speed and wind direction	Near Real Time data across scatterometer swath (25km resolution)	Daily updated	Metop/ASCAT-A
Total surface current (geostrophic + Ekman)	Near Real Time data, 0.25° x 0.25°	Weekly updated	Jason-2 and 3



Coverage of C-RISe data products. The shaded area gives the overall coverage of the project. Red lines are ground tracks for Jason-series satellites.



Example of near real time data for 7th October 2020

Capacity Building

One of the primary C-RISe objectives is to build local capacity in using satellite data to provide scientific decision support for strategy development, governance and management of coastal areas to increase resilience to coastal hazards. Satellite oceanographers and sea level experts from the NOC and SatOC provide training and support to local partners to access, validate, process and interpret data using Python based software developed for C-RISe and Bilko, a tool first developed for UNESCO.

To date, C-RISe has delivered five training courses to over 70 individuals from 15 organisations in Mozambique and Madagascar. It also hosted a 2-day workshop in Antananarivo, Madagascar for 45 participants including representatives from government agencies, NGOs and research institutions from across Madagascar.

Training participants in Madagascar and Mozambique

Use Case development

Supported by the C-RISe project team, African coastal and marine scientists are using the C-RISe data, alongside other information sources to quantify coastal hazards and incorporate the information into on-going development and disaster prevention initiatives.

Our partners have developed a range of 25 Use Cases, designed to embed the skills to work with satellite data (learned through our training workshops) into their organisations for the long term. Use Cases were shared at regional workshops and conferences in Madagascar, Mozambique and Mauritius and are available through the C-RISe website. This allows other organisations to understand how these data can be used and fosters local cross-organisational working.

Sustainability model

In order to sustain the impact of C-RISe the project must ensure continuity of attained capacity. This will comprise maintained access to the processed sea level, wind, wave and current climatology data and continued provision of the NRT service.

The project also offers several opportunities to expand, these include:

- Expansion of data and information service range, by including a wider range of EO data sets, adding modelling capability and introducing relocatable tide gauges.
- Increased geographical coverage, to include a wider Indian Ocean region and potential new regions such as Caribbean.
- Wider capacity building remit to include support in development and implementation of coastal resilience measures.

The strength of the C-RISe project is that in building local capacity and focusing on the development of Use Cases in line with our partner's needs, it has demonstrated the vast range of issues that these data can be used to understand and address.

Although we have not yet secured firm budget commitments to fund C-RISe after the current grant ends, we have received funding for several projects, which build on the achievements of C-RISe. Some of these enable us to continue working in partnership with current project partners in Madagascar and Mozambique, whilst others focus on new regions, such as West Africa and the Caribbean.

The project team are currently investigating a range of funding pipeline options that centre on opportunities for C-RISe to work with other organisations, initiatives and donors in southern Africa. We are currently developing an initiative focused on coastal and marine resilience in Madagascar, using C-RISe datasets, Use Cases and capacity building experience.

Boats on a beach near Toliara, Madagascar

Project results

Through provision of a range of data sets, capacity building and development of Use Cases, C-RISe has

1. Enhanced the service capabilities of partners through access to C-RISe Near Real Time products, improving their ability to respond to coastal hazards and safety of lives at sea.
2. Strengthened resilience towards natural coastal hazards associated with changing marine conditions through integration of improved knowledge into coastal management strategies.
3. Improved management of Marine Protected Areas and mitigation measures to reduce impact of changing marine conditions on marine ecosystems.

These results were achieved through the 25 Use Cases developed with our partners. Use Cases covered a broad spectrum of topics linked to environmental protection, ecosystems management, fisheries management, better understanding of sea state and safety at sea. Five Use Cases have already been identified as having achieved impact, two of these were run by NGOs, two report into SWIOFish, a World Bank project in the region, and one is improving maritime security operations.

Impacts from these include:

- Enabling law enforcement in cases of drug trafficking and illegal migration.
- Improved management of mangroves and reefs.
- Improved management of Marine Protected Areas, leading to their expansion.

Service capability enhanced through access to Near Real Time (NRT) products

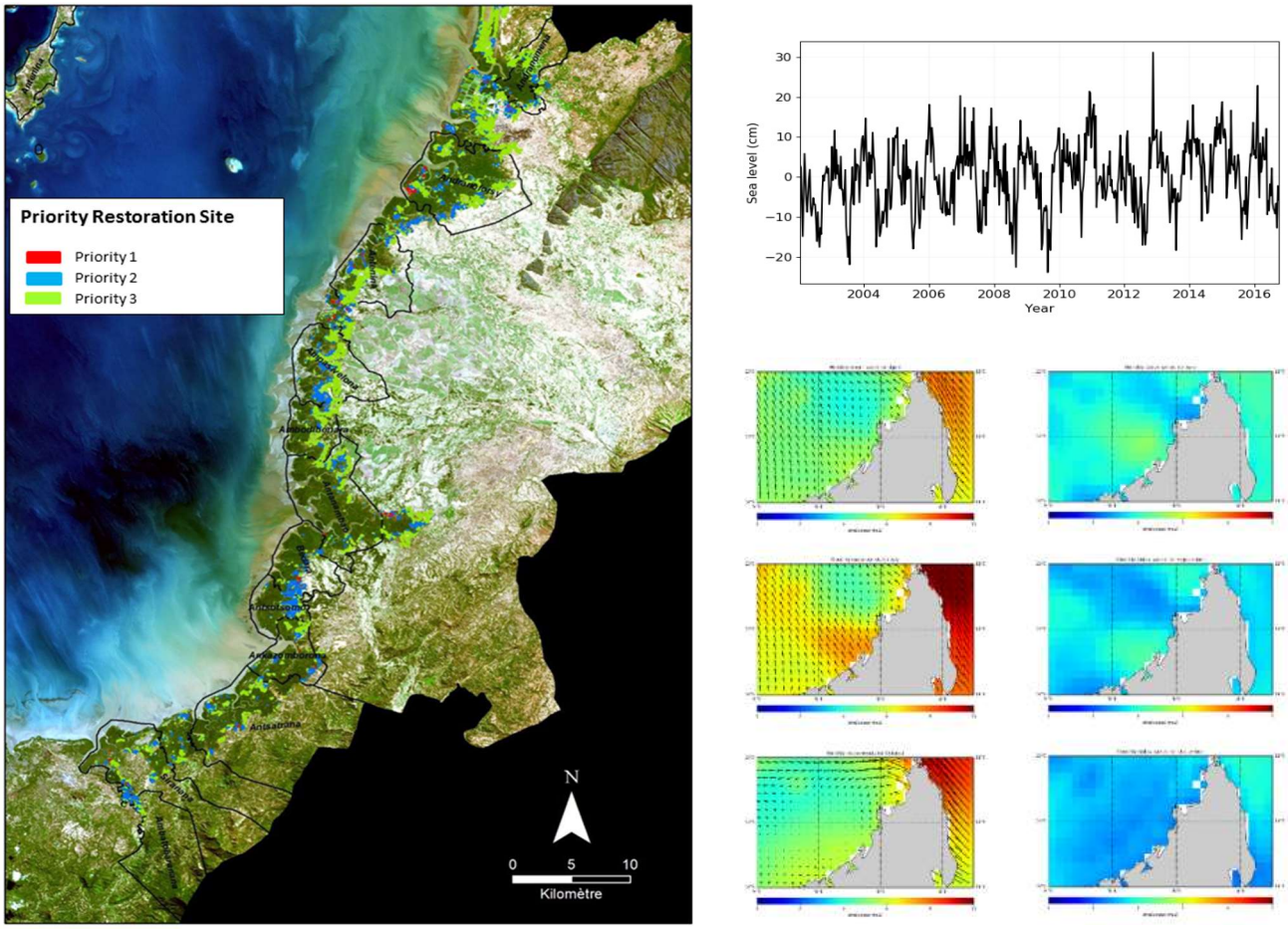
In Madagascar the Centre de Fusion d'Informations Maritimes (CFIM) have used the C-RISe NRT data to supplement existing information used in operational planning. The sea state data are used to support analysis of shipping movements and to predict and analyse perceived threats to maritime security in the North West of Madagascar from Cap d'Ambre to Cap Saint-André, including the ports at Nosy-be and Mahajanga. This has enabled CFIM to provide sea state information to the ports and navigational users enhancing risk assessment for port operations and coastal navigation. These data have also been successfully used, in conjunction with AIS, to predict the estimated time of arrival at port of vessels in security cases, enabling vessels interception. When CFIM are alerted to potential illicit shipping activities (people smuggling, drug trafficking, illegal oil transhipment), they have used wind, wave and current information provided by C-RISe to predict the transit route and time of arrival of suspect vessels. These predictions were accurate within 5 to 15 minutes, enabling local law enforcement to take action.

Presentation of CFIM Use Case at Madagascar Workshop, February 2020

Integration of improved knowledge into coastal management strategies

Madagascan mangrove areas are among the largest in East Africa, and provide a variety of ecosystem services of local and national importance. These coastal ecosystems are highly exposed to climate hazards. WWF Madagascar have worked with C-RISe data to assess mangrove habitats as well as reefs and fisheries at several locations in Madagascar.

WWF Madagascar used C-RISe data to explore seasonal cycles in wind speeds and direction and variability and trends in sea level at Manambolo Tsiribihina (Menabe and Melaky Region) and Ambaro Bay (Diana Region). Better understanding of marine climatology and sea level has enabled WWF Madagascar to identify vulnerable mangroves and appropriate restoration sites, and promote sustainable and safe fisheries. This clearly demonstrates how C-RISe data contributes to decision making and integrates this with other data to inform WWF Madagascar's coastal management strategies.



Results of WWF Madagascar Use Case to analyse vulnerability of mangrove forest at Ambaro Bay

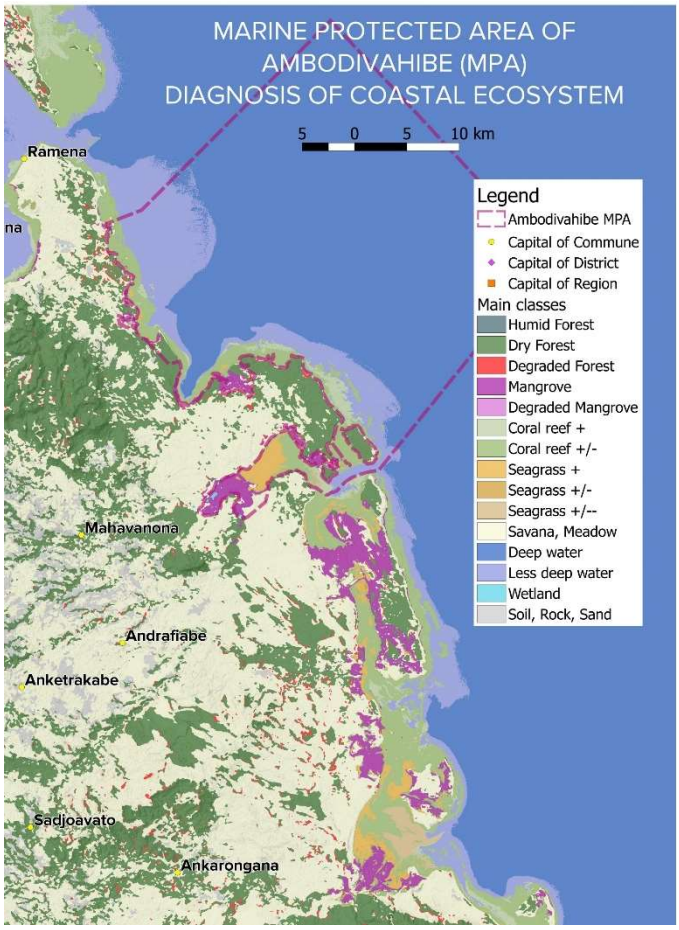
Improved management of Marine Protected Areas

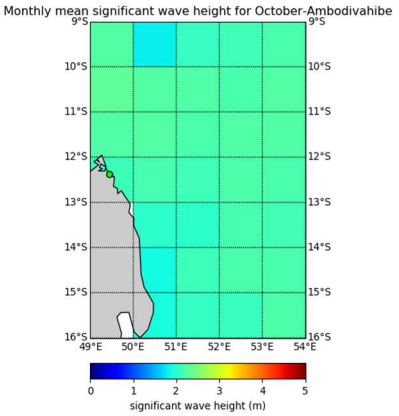
Ambodivahibe Marine Protected Area (MPA) has been managed by Conservation International (CI) Madagascar with the cooperation of local communities since 2006. C-RISe data (sea level, wind and wave climatologies) and techniques acquired through the C-RISe workshops in the use of python and Bilko software were used in the development of a new Management and Development Plan (Plan d'Amenagement et de Gestion, PAG). The PAG required a review of the current MPA, including marine and coastal ecosystem evaluation; a projection of possible climate change impacts; and consultation with communities and stakeholders.

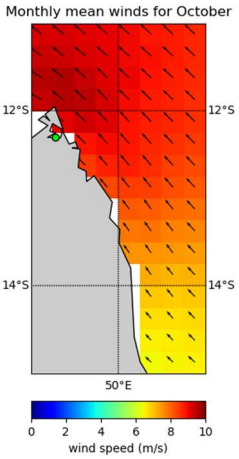
C-RISe data have been used to:

- Map and classify the Ambodivahibe MPA ecosystem
- Analyse seasonal variability in key marine environmental parameters
- Development of a management plan for the Ambodivahibe MPA

The improved management of the Ambodivahibe MPA by CI is a considerable and important success story for the implementation and operation of MPAs in Madagascar. The Use Case developed a new methodology for ecosystem evaluation and assessment, which is now being applied to other locations managed by CI in Madagascar.







Results from Conservation International Use Case at Ambodivahibe Marine Protected Area

Conclusions and lessons learnt

The C-RISe project is now in the legacy phase, having successfully delivered all its intended milestones, it is continuing to support partners in using the data.

All the C-RISe data sets are currently being updated to extend the time coverage to 2020. As well as supporting the continuation of Use Cases, which are part of longer-term activities of our partners, maintaining data provision during the legacy period is important to maintain user buy-in to the C-RISe service whilst we work on the sustainability of the project. A further sea level data set using data from Envisat and AltiKa satellites will increase the resolution of data available to partners, addressing a concern raised by them, thereby increasing the value of these data.

The creation of compelling narratives and the connection of EO data to clearly defined, policy relevant questions, to show how C-RISe data can complement data from other sources to resolve policy challenges, will enhance policy impact. It is also necessary to engage actors with knowledge of policy issues, to ensure maximum impact. We are therefore compiling policy briefs, which will be used to further engage managers and politicians to promote the issues addressed and the availability of the data and local capacity.

The main learning points from C-RISe are around the method of data supply, communication, training and connectivity within and between countries in the South West Indian Ocean region.

One of the major issues that we have come across in the course of the project is to do with internet connectivity. Connections are generally poor and intermittent in both Madagascar and Mozambique (although they are slightly worse in Madagascar). This is true for the cities and more remote locations, with the situation worsening further from large populations. This issue had several knock on effects for the project and was the problem most often cited by our project partners.

A major effect of poor internet connectivity is on how our partners access the C-RISe data. It was envisaged that it would be available online through a data portal developed and maintained by CSIR and that project partners and other users would access and download data independently. Whilst the data are available in this way, the majority of our project partners prefer to receive data on a USB. Internet connectivity has also presented a problem for users trying to access free satellite data from other sources during the project and had some impact on the time taken to complete Use Cases. This problem must be considered in the design of any future data delivery; it is a major hindrance to the uptake of EO data by these countries.

Throughout the training, we used freely available software in consideration of sustainability of the project and the ability of partners to access the software in the future. However, there were issues with accessing the correct versions of software and problems around the age and maintenance of computer hardware.

A major challenge for stakeholder engagement was due to changes in leadership in our partner organisations. This was particularly evident when working with government agencies as directors changed following elections and contacts were lost. Good relationships with managers at lower levels of organisations were vital to re-establishing contacts with leadership following restructuring.

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