
South coast, Mauritius

Accessing satellite-derived marine data for coastal risk management applications

Summary for policy makers

September 2021

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Key messages:

Oceanographic data is needed to understand seasonal climate patterns and how climate is changing. This information is essential to inform management of the coastal and marine environment.

South West Indian Ocean (SWIO) coastal populations are highly vulnerable to the impacts of climate change.

In situ measurements of ocean wind, wave, current and sea level for the SWIO are sparse, but satellite data covering the past 20 years are now available.

Satellite-derived data can be used to characterise seasonal patterns in marine environmental parameters and highlight any changes.

To ensure the best use of satellite data some local capacity building is required.

Access to oceanographic data is essential to informing coastal and marine management and mitigating risks which are increasing due to climate change. Satellite-derived data can supplement sparse in situ measurements of ocean wind, waves, currents and sea-level. There are several sources of freely available satellite derived-data, which can be used in a wide range of applications, although some local capacity building is required.

Background

Due to a changing climate, global sea level is increasing and large-scale weather patterns are changing (IPCC, 2019). These changes are not geographically uniform or steady in time, with short-term variability on a range of time scales (IPCC, 2019, and references therein). 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, high rates of subsidence and inadequate adaptive capability (Niang et al, 2014).

Coastal management is needed to mitigate coastal risk and promote sustainable economic development. 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 data on sea level, wind and waves will allow users to accurately map changes in seasonal and inter-annual variability, and long term climate change trends. This will enable organisations to better plan operational activities and infrastructure development, and improve protection of communities, ecosystems and livelihoods.

South West Indian Ocean Context

Coastal populations in the SWIO are particularly vulnerable to the impacts of climate change. In coastal East Africa, 3.5 million people are at higher levels of exposure to coastal hazard, which will increase if mangroves, coral reefs and sea grasses are lost (Ballesteros and Esteves, 2021). Regionally, Madagascar and Mozambique have the largest proportion of coastline at high exposure to coastal hazard.

These countries are also highly exposed to surges associated with cyclones, which become more damaging when they coincide with high tides and are elevated by increasing sea levels. Since 1980, 18 tropical cyclones have impacted Mozambique, affecting millions of people and resulting in over 2000 fatalities (Emerton et al., 2020). On average, Madagascar is hit by three or four tropical cyclones each year, causing loss of homes and livelihoods (Randriandalijaona, 2018). The impacts of coastal hazards are increasing due to factors such as growing populations, changes in coastal land use and loss of natural coastal protection.

There is a lack of in situ data on sea level, wind, waves and currents for the SWIO region. In particular, Madagascar has just one operational tide gauge at Toamasina on the east coast. In situ data are expensive to collect and instruments such as tide gauges are costly to maintain, particularly in remote, difficult to access locations.

Box 1. South West Indian Ocean Climate Overview – Seasonal Variability

Seasonal variability in the SWIO is driven by the monsoon cycle: The North East monsoon (or rainy season) typically runs from December to March, the South West monsoon (or dry season) runs from June to September (Manyilizu et al, 2016).

The tropical cyclone season typically runs from November to April, largely coincident with the North East Monsoon. Cyclones can bring very heavy rain and strong, destructive winds when making landfall and cause dangerous large waves and storm surges at the coast. On average there are nine named cyclones a year in the SWIO (Landsea and Delgado, 2014).

Many coastal and offshore activities are planned according to the expected seasonal variability, but recent anecdotal reports suggest some localised changes to the duration and timing of the monsoon, and of previously used "weather signs" becoming unreliable. The 20 year plus time series of satellite-derived wind and wave data can be used to monitor variability and inform local communities.

(a) (b)

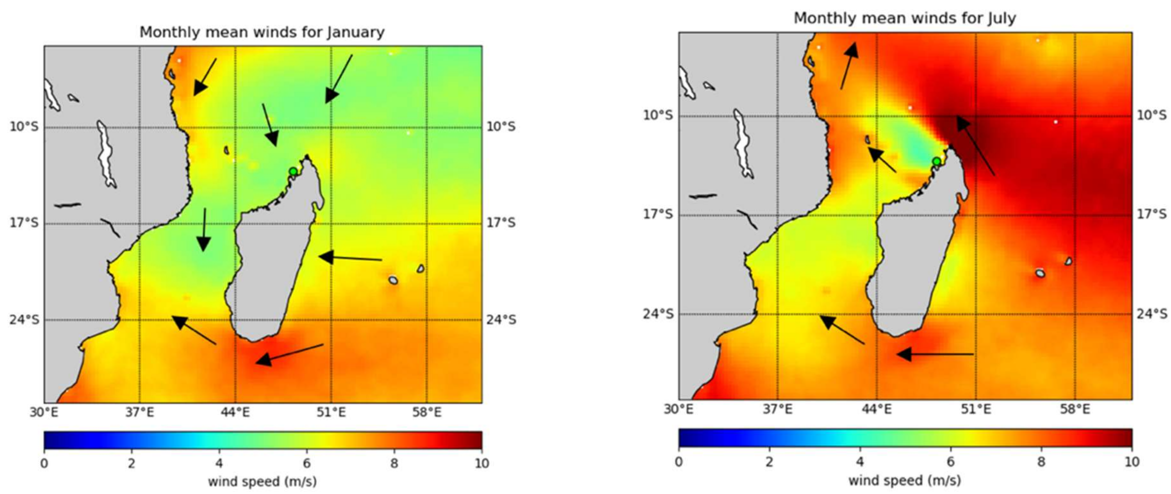


Figure 1. Mean wind speeds for (a) January (NE Monsoon) and (b) July (SW Monsoon)

Box 2. Climate Variability from year to year

There can be significant variability from one year to the next in the extent and characteristics of the monsoon seasons and the numbers, strengths and track locations of tropical cyclones. Some of this variability can be linked to a feature called the Indian Ocean Dipole, first reported by Saji et al. (1999).

There is a second phenomenon in the sub-tropical Indian Ocean, called the Subtropical Indian Ocean Dipole (Behera and Yamagata, 2001). Both the Indian Ocean and Subtropical Indian Ocean dipoles affect wind climate, sea surface temperatures and rainfall.

There is also significant variability between tropical cyclone seasons (Mavume et al, 2010). The 2018-19 season was especially damaging, the worst on record, whereas the 2015-16 and 2016-17 seasons were relatively quiet (with three cyclones in each year).

Changes in sea surface temperature (SST), rainfall and wind climate can impact heavily on coastal and offshore activities. Satellite data can be used to assess local signatures of variability and possible correlation with these larger scale basin scale phenomena.

(a) (b)

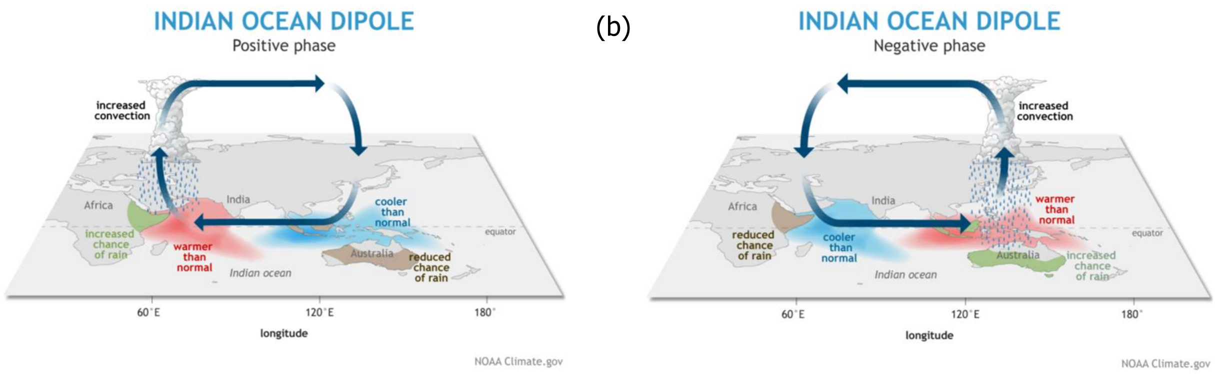


Figure 2. Schematic diagrams of the (a) positive and (b) negative phases of the Indian Ocean Dipole. Source NOAA 2020.

How is the climate changing?

The evidence for human induced long term change in climate, with potentially severe impacts on coastal populations and marine ecosystems, is now incontrovertible. The 2019 Intergovernmental Panel on Climate Change Special Report on the Ocean and Cryosphere (IPCC, 2019), which informed the recently released sixth assessment report (IPCC, 2021), highlighted the following observed changes in marine climate for the Indian Ocean:

- There has been an observed poleward migration of the highest tropical cyclone intensity in the South Indian Ocean.
- The number of intense tropical cyclones increased from 1980-1993 to 1994-2007.

The IPCC makes the following projections for future change, at current emission rates:

- The average intensity of tropical cyclones, the proportion of category 4 and 5 tropical cyclones and the associated precipitation rates are projected to increase (medium confidence)

- Rising mean sea levels will contribute to higher extreme sea levels associated with tropical cyclones (very high confidence)
- Coastal hazards will be exacerbated by an increase in the average intensity and magnitude of storm surge and precipitation rates of tropical cyclones
- Wave heights are likely to increase in the southern ocean due to increased wind speeds, but the lack of long-term sustained Indian Ocean observations, and inadequacies in climate models to simulate the magnitude of trade wind decadal variability, means there is low confidence in future projections of the trade wind system

Satellite data and capacity building

Reliable long-term data sets are needed to accurately understand and monitor the changes in the marine climate. Satellites have now been operating ocean monitoring instruments for over 20 years, providing measurements of sea level, sea surface temperature, ocean winds and waves, and ocean colour. More ocean monitoring satellites are operating than ever before, and much of the data is now widely and freely available through operational data services (Box 3). There can be difficulties in accessing large satellite data sets in locations with limited internet connectivity. Therefore, portals which allow viewing, sub-setting and pre-processing are useful as they can help reduce the volumes of data to be downloaded.

Satellite data are not yet fully exploited by countries in the SWIO and there is scope to build capacity. A mini symposium at the 10th WIOMSA Scientific Symposium in Mauritius, July 2019, identified the following capacity needs for the region:

- A basic understanding of satellite data, how the data are measured, how to interpret the data, and the capabilities and limitations of the data are needed.
- Training in software and tools to read and process satellite data are needed. People who already have a capability to use data want to expand their capability to access and process basic satellite products.

Existing efforts to build knowledge and skills could be complemented by adaptive capacity building activities. This could include the self-supporting regional network to enhance data sharing and learning across organisations and countries. Application of data together with policy considerations to explore future scenarios could enhance capacity to plan for potential changes and develop more effective management responses.

Box 3. Some sources of marine satellite data

- The European Copernicus programme (https://marine.copernicus.eu) provides a central portal for freely available marine environment data (satellite and model). The site gives access to raw and process satellite data and includes tools and tutorials for accessing and visualising the data.
- The NASA Physical Oceanography Distributed Archive Center (PODAAC, https://podaac.jpl.nasa.gov/) also provides global satellite and model data.
- The European Space Agency runs a series of projects producing satellite-derived climate data sets. These are available, together with a toolbox for ingesting and visualising them, at https://climate.esa.int/en/

Box 4. Use Case Studies / applications

The UK Space Agency funded C-RISe project (www.c-rise.info) provided access to satellite data and capacity building for local organisations in Mozambique and Madagascar. These organisations demonstrated and evaluated the use of satellite wind, wave, surface current and sea level data in a range of real-world practical applications. 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.

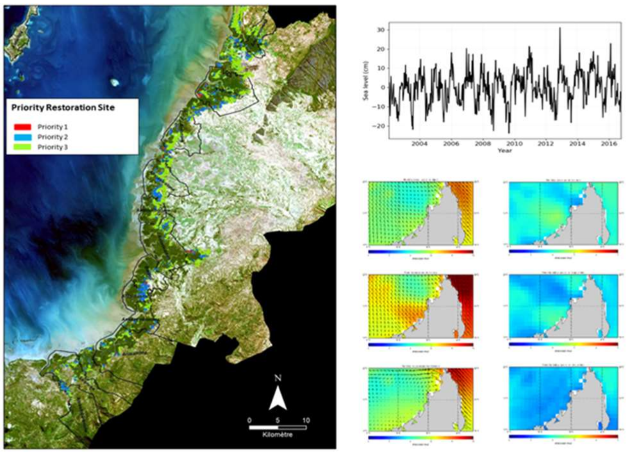
Examples include:

- Sea state information for improving maritime navigation security and safety for Madagascar (Figure 3a)
- Marine protected area management (Nosy Hara and Ambodivahibe) in Madagascar (Figure 3c)
- Impact of coastal climate change on mangroves on Madagascar's west coast (Figure 3b)
- Wave climatology for the Mozambique channel
- Analysis of regional variability in sea level change in Mozambique's coastal seas
- Effects of climate variability on semi-industrial shrimp catches in Maputo Bay, Mozambique

These Use Cases have demonstrated direct impacts of the use of marine satellite data in environmental management and law enforcement. They also provide templates for how satellite data can be applied to real-world problems on a local scale. Use Case results were shared at regional workshops and conferences in Madagascar, Mozambique and Mauritius and are available through the C-RISe website.

(a)

(b)



(c)

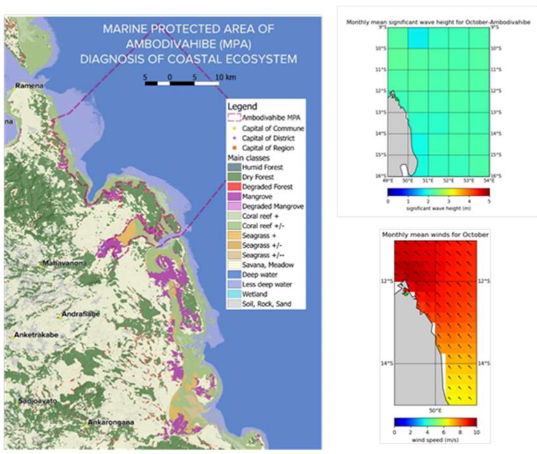


Figure 3. Example Use Case Applications (a) Irregular migration is a maritime security issue in NW Madagascar
(b) Results of WWF Madagascar Use Case to analyse vulnerability of mangrove forest at Ambaro Bay, Madagascar
(c) Results from Conservation International Use Case at Ambodivahibe Marine Protected Area, Madagascar

Conclusion and recommendations

Satellite data on ocean winds, waves, surface currents and sea-level are an important resource to help understand how the changing marine climate has an impact on coastal populations and ecosystems. To best exploit these data sets, some capacity building steps are recommended for scientists and agencies responsible for coastal management and planning. The C-RISe Use Cases can be used as templates for how satellite wind, wave, surface current and sea level data can be applied on a local scale.

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