IODA allows interactive exploration of Indian Ocean dynamics, patterns, and trends

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Purpose, expectation and action intended

The development of a digital, interactive atlas to monitor ocean and climate conditions in the Indian Ocean (IODA) was commissioned by the IOTC in 2026, in line with Resolution 25/01. This paper summarizes the work undertaken by the development team to deliver the product within the planned timeframe.

Discussions

The paper informs meeting participants about the release of the first version of IODA. Time will be allocated for questions and suggestions regarding IODA, as well as discussing possible steps in 2027.

Feedback

The paper presents the feedback received from the Working Parties held in 2026 at which IODA was presented (WPEB22, WPTT28 and WPDCS22). IODA also includes a dedicated feedback page through which users can communicate directly with the development team. Users are encouraged to submit their comments and suggestions via this page

Conclusion

The paper seeks confirmation that IODA meets the expectations of IOTC scientists and can facilitate the integration of environmental and oceanographic data into their research activities.

Recommendation

The paper seeks endorsement of the datasets and methods implemented in IODA. We ask the SC to encourage the use of IODA by the scientific community for fisheries and environmental research.

Decisions

The paper considers the possible extension of the IODA project into a new phase, in line with Resolution 25/01. A decision is required on the future development of IODA and its associated activities.

Abstract

The Indian Ocean Digital Atlas (IODA) is an interactive web-based platform developed to facilitate access to oceanographic and climate information across the IOTC Area of Competence. Initially designed to support the objectives of IOTC Resolution 25/01, IODA provides the scientific community with a harmonised database of environmental information and a set of tools for exploring ocean variability and long-term trends.

The platform integrates 16 physical and biogeochemical ocean variables extending back to 1993, at spatial resolutions ranging from 4 to 25 km, from surface to 900 m. IODA also includes four major climate indices Through an interactive interface, users can generate maps, time series, spatial transects, Hovmöller diagrams and depth profiles, as well as identify environmental anomalies and compare ocean conditions across different periods.

Beyond its initial fisheries-oriented objectives, IODA offers a valuable regional resource for multidisciplinary research, including studies of climate variability and change, marine ecosystem dynamics and marine spatial planning. Its continued development and regular data updates aim to strengthen the use of environmental information in scientific assessments and ecosystem-based fisheries management throughout the Indian Ocean.

1. Purpose and objectives

The Indian Ocean Digital Atlas (IODA) was developed in response to the request set out in IOTC Resolution 24/01, subsequently superseded by Resolution 25/01, for tools that would provide the IOTC Scientific Committee with ready access to oceanographic and climate data and facilitate the integration of this information into the development of management measures for IOTC fisheries.

Climate change is altering the physical structure and functioning of the Indian Ocean. Understanding these changes and their potential consequences for marine ecosystems and fisheries requires sustained access to reliable environmental information over extended periods. Although large volumes of oceanographic data are now available through international observing programmes and data services, these data are distributed across multiple repositories and can be difficult to access, process and interpret without specialised technical expertise.

IODA addresses this challenge by integrating multiple datasets into a harmonised database and providing an intuitive visualisation interface for both specialist and non-specialist users. It enables the exploration of oceanographic conditions across longitude, latitude and depth, and through time, using monthly data records extending back to 1993. The project Terms of Reference are provided in Annex 1.

Initially developed under the auspices of the IOTC to support ecosystem-based fisheries management, IODA has evolved into a multidisciplinary platform with applications extending beyond fisheries. The platform is publicly accessible at https://ioda-atlas.gov.sc

2. Background and project milestones

The concept of a digital ocean atlas for the IOTC Area of Competence emerged from discussions at the Working Party on Data Collection and Statistics (WPDCS) and the Scientific Committee (SC) in 2023. These discussions took place in the context of Resolution 22/01 on climate change as it relates to the Indian Ocean Tuna Commission, which highlighted the importance of assessing the potential effects of climate change on tuna stocks and fisheries. The project subsequently progressed through a series of recommendations and decisions by the IOTC scientific bodies, summarised below.

2023

- WPDCS19 recommended a scoping study to examine how ocean–climate information could be developed and made available by the IOTC, drawing, among other sources, on the Seychelles Digital Ocean Atlas initiative and the indicators presented in document IOTC–2018–WPDCS14–36. The study was also expected to consider how such information could be presented to the SC and its Working Parties, and to assess the resources required to develop online ocean–climate indicators for the IOTC Area of Competence
- SC26 considered the resources required to develop online indicators for the Indian Ocean as a whole and endorsed a scoping study to assess the further development of the indicators presented, potentially through an online atlas, and to identify effective ways of presenting them to the SC and its Working Parties

    ➔ The IODA developers conducted the scoping study in 2024 and presented its results at WPDCS20.

2024:

- WPDCS20 acknowledged the benefits of a web portal providing ocean–climate information for the IOTC Area of Competence and recommended the development and implementation of an online Indian Ocean Digital Atlas in 2025. This was ranked as the Working Party's second-highest priority.
- SC27 noted the project initiated by France-OT to develop an online digital ocean atlas covering the IOTC Area of Competence. The atlas was intended to support the objectives of Resolution 24/01 by providing a tool to assess the impacts of climate change on IOTC fisheries. The SC recognised the potential value of the atlas to the Commission's work and acknowledged that its development would be undertaken by an expert team over a six-month period

    ➔ The design and technical specifications of the interactive ocean atlas were presented at WPDCS21

2025:

- WPDCS21 noted that the project had been delayed and would commence in 2026. The proposed work included developing an online digital atlas for the IOTC Area of Competence, linking it to the IOTC website, and developing ocean–climate status indicators and educational resources for the atlas portal, with implementation planned for 2026–2027.
- SC28 noted that funding had been allocated for the development, in 2026, of the interactive oceanographic atlas to support studies on the impacts of climate change on tuna fisheries. The design and technical specifications of the atlas had previously been presented at WPDCS21.

    ➔ IODA was jointly developed between March and August 2026 by Francis Marsac, the project leader and an oceanographer and fisheries scientist, and Eric Noel, a software developer. The platform was first presented at WPEB22, in September 2026.

3. Data coverage and platform capabilities

IODA currently includes 16 ocean variables (Table 1) describing the marine environment from the surface to 900 m depth, together with four climate indices. Details of the variables and their spatial resolutions were presented at WPEB22 and WPTT28 (Marsac and Noel, 2026). The oceanographic datasets are sourced primarily from the European Copernicus Marine Service, which provides a wide range of ocean products derived from numerical models and satellite observations. Reanalysis and hindcast products were selected because they provide temporally consistent datasets and are updated with a relatively short delay (currently about three months). Product selection also took account of the length of the available time series, with the aim of providing monthly records from January 1993 onwards, except for satellite-derived surface chlorophyll-a, which begins in September 1997. Variables not directly available in the Copernicus products, including thermocline depth, vertical current shear and some biogeochemical

variables, were derived from the source datasets using dedicated scripts written in R (R Core Team, 2025). The Copernicus-derived datasets are stored in Network Common Data Form (NetCDF; .nc) and follow the CF-1.4 convention. Climate indices are stored in CSV format. The longest climate-index records are those for the Southern Oscillation Index (SOI) and the Indian Ocean Dipole (IOD), which begin in 1866 and 1870, respectively. The database covers the entire IOTC Area of Competence, approximately 70 million km² (Fig. 1). The oceanographic database is updated monthly, subject to the availability of the latest validated source products, thereby extending the historical record while providing access to the most recent data available.

The platform provides tools to:

- visualise ocean conditions for a selected month and year, or animations covering selected periods;
- examine long-term environmental variability and trends;
- identify ocean anomalies and extreme events;
- compare current or selected conditions with historical periods; and
- export maps and figures for use in scientific publications and technical reports.

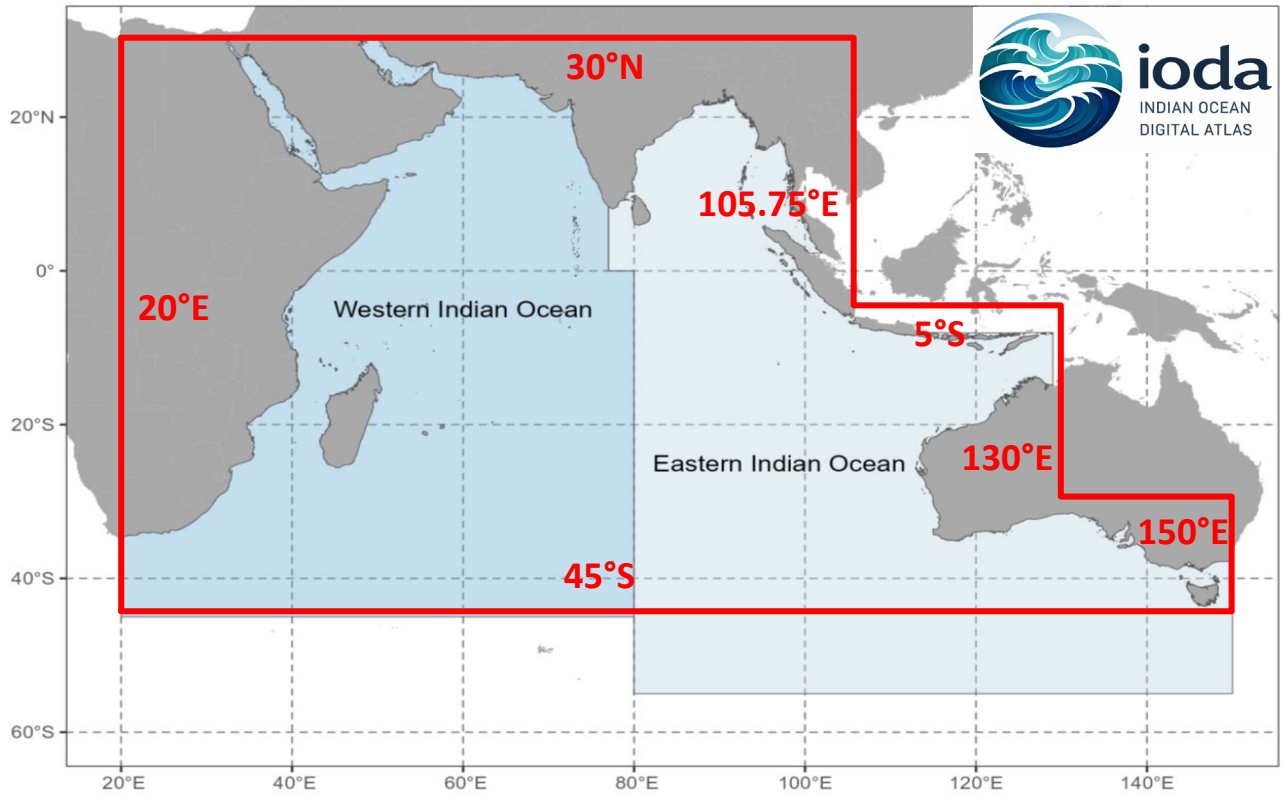

Figure 1 – IODA spatial coverage (red boundaries) in relation to the IOTC area of competence (blue shading)

	Variable	Depth range	Start year	Source	Spatial resolution	Product ID
PHYSICAL	Temperature Salinity Current	0-902 m (20 levels)	1993 - Jan	Ocean model	0.083° x 0.083° (~8km)	GLOBAL_MULTIYEAR_PHY_001_03
	Sea level anomaly	single-layer	1993 - Jan	Satellite altimeter	0.125° x 0.125° (~12km)	SEALEVEL_GLO_PHY_L4_MY_008_047
	Mixed layer depth Thermocline depth Current shear 0-130m Current shear 0-450m	single-layer	1993 - Jan	Ocean model Derived Derived Derived	0.083° x 0.083°	GLOBAL_MULTIYEAR_PHY_001_03
BIOGEOCHEMICAL	Depth of 2.5 ml/l DO	single-layer	1993 - Jan	Derived	0.25° x 0.25°	GLOBAL_MULTIYEAR_BGC_001_029
	Dissolved oxygen Chlorophyll-a Net Primary Prod pH	0-902 m (20 levels)	1993 - Jan	Ocean model	0.25° x 0.25° (~25km)	
	Surface chlorophyll	single-layer	1997 - Sep	Satellite obs.	4 x 4 km	OCEANCOLOUR_GLO_BGC_L4_MY_009_104
	Fmax depth Integrated chl content		1993 - Jan 1993 - Jan	Derived Derived	0.25° x 0.25°	GLOBAL_MULTIYEAR_BGC_001_029
CLIMATE	Dipole mode index Southern oscillation Index Multivariate ENSO index Nino-4 index	single-layer	1870 - Jan 1866 - Jan 1979 - Jan 1870 - Jan	Observations	n/a	n/a
BATHY	Seafloor bathymetry	single-layer	n/a	Composite	~ 500 m	GEBCO 2026 Grid (Sub-ice topo/bathy)

Table 1 –Summary of the datasets available in IODA, including depth range, temporal coverage, source, spatial resolution and product identifier

4. The IODA application

The public-facing atlas is built using R-Shiny (Chang et al., 2026) and provides interactive access to the oceanographic products included in IODA. The application is part of a multi-component web architecture comprising:

- a **public R Shiny atlas** providing interactive maps, time series, transects, Hovmöller diagrams, depth profiles, data and figure exports, user accounts and saved plots;
- a **backend API**, built with Bun/Elysia and PostgreSQL, that manages authentication, plot-option catalogues, administrative operations, metadata, contact messages and saved-plot files. The API provides the authoritative source of plot metadata; the Shiny interface retrieves variable labels, available plot types, depth levels and temporal coverage through this API;
- an **administrative portal**, built with TanStack Start/React, for managing users, variables, datasets, plot options, THREDDS metadata, settings, audit logs, contact messages and operational dashboards. Access is restricted to the data manager;
- file-system storage for the NetCDF datasets used by the Shiny application; and
- a THREDDS Data Server that provides access to the published NetCDF database through catalogue browsing, HTTP file access, OPeNDAP and the NetCDF Subset Service.

4.1 – Thematic products

IODA provides four main types of data visualisation: (1) maps, (2) time & space profiles, (3) Hovmöller diagrams and (4) depth profiles. These products can be accessible directly from the IODA home page (Annex 2).

MAPS. The map catalogue provides monthly maps for individual variables, as well as calculated products (e.g. averages and differences) and animations covering selected periods. Bathymetric maps are planned for a future release. Users can also add overlays, including contours, labels, Exclusive Economic Zone (EEZ) boundaries and external datasets such

as catch and effort data. Additional overlays, including Marine Protected Areas and Important Shark and Ray Areas (ISRAs), are also envisaged.

TIME & SPACE PROFILES. Users can display time series at selected locations and plot spatial transects, including longitudinal or latitudinal sections of variables and their anomalies. Climate indices can also be displayed alongside the time series

HOVMÖLLER DIAGRAMS. These diagrams display a variable, or its anomaly, as a colour field along a spatial axis (longitude or latitude) and a time axis. They are useful for examining the propagation and temporal evolution of oceanographic features, waves and cycles

DEPTH PROFILES. These plots show how a selected variable changes with depth at a specified location.

4.2 – Additional home page functions

About. Provides information on the atlas content and data sources, including digital object identifiers (DOIs) together with the references required when citing IODA.

Contact. Provides a form through which users can submit requests, comments or reports of technical issues. Responses are sent to the email address provided by the user.

Account. Allows users to register and log in. Plots saved during an IODA session are stored in a repository associated with the user's account

Notifications. Displays information about the application, data updates, and other relevant topics.

User Manual. Provides access to the IODA user manual

4.3 – Documentation and contextual help

in addition to the user manual, contextual help is available on each thematic page of the atlas though the help icon.

5. Platform hosting and operational arrangements

During the development phase (March–August 2026), the application was hosted on a test server accessible only to the developers. Although storage capacity was limited, the server was sufficient to test the application using a subset of the datasets. Once development and testing had been completed, a permanent hosting solution was required to make IODA publicly accessible.

Long-term operation requires a secure application server hosted in a national data centre, reliable high-speed internet connectivity and routine technical maintenance. In March 2026, the project team contacted the Seychelles Department of Information Communications Technology (DICT) to explore the possibility of hosting IODA on a public server. Subsequent meetings addressed the technical and operational requirements. The Government of Seychelles expressed strong support for the initiative, and the project team worked with DICT to finalise the arrangements. A dedicated domain name (**ioda-atlas.gov.sc**) was established, and the components of the IODA application were transferred to the national server.

DICT has agreed to monitor the application and undertake the technical maintenance required to ensure continuity and reliability of the IODA service. This hosting and maintenance support is provided to the IOTC as an in-kind contribution from the Government of Seychelles.

6. Data updating and maintenance

The database is updated on a monthly basis, as soon as the latest validated ocean-model outputs become available. Dedicated Python scripts are used to retrieve the source datasets from the Copernicus Marine Service repository, while dedicated R scripts process and integrate the data into IODA. At present, this workflow requires manual intervention. A R-Shiny application is being developed to integrate the database-update workflow and generate the files required for ingestion into IODA.

The Seychelles Fisheries Authority (SFA) has offered to take responsibility for routine data updates. The IODA data manager will therefore be a scientist from the SFA. We gratefully acknowledge the Authority's commitment to maintaining this essential component of the platform.

As of October 2026, the IODA database had been updated through August 2026. This delay reflects the time required by the Copernicus Marine Service production centres to process and validate the latest model outputs before releasing them to users.

7. Feedback from IOTC Working Parties

IODA was presented at WPEB22, WPTT28 and WPDCS22. The discussions generated several suggestions for further development. One suggestion was to allow users to add shapefiles as map overlays. These could, for example, represent Ecologically or Biologically Significant Marine Areas (EBSAs), Important Shark and Ray Areas (ISRAs), Important Marine Mammal Areas (IMMAs) and marine protected areas (MPAs) in the Indian Ocean. At present, the available overlays are limited to contours, EEZ boundaries and georeferenced text-based files.

Another suggestion was to include relevant metadata in every dataset exported from IODA. Further comments and suggestions from the scientific community are welcome.

8. Scientific and operational applications beyond the IOTC

Although IODA was initially developed to support tuna fisheries research and management, its potential applications extend to a broader scientific and operational community. Potential users include:

- marine scientists;
- fisheries scientists and managers;
- marine spatial planners;
- environmental agencies;
- meteorological services;
- universities and research institutions;
- students and educators; and
- regional organisations.

The platform can support a range of activities including marine environmental monitoring, marine spatial planning, climate change adaptation, biodiversity conservation and environmental education.

More broadly, IODA can contribute to several international priorities, including:

- ecosystem-based fisheries management;
- sustainable ocean governance;
- open access to scientific data;
- capacity development; and
- stronger links between science and policy.

By providing open access to harmonised environmental information, IODA has the potential to facilitate regional cooperation and encourage the wider use of oceanographic data across the Indian Ocean.

9. Further development

Phase 1 (2023–2025) covered the identification of user needs, project design and the preparation and signing of the consultants' contract. Phase 2 focused on developing the IODA platform, deploying it on an application server and preparing the user manual. This phase is scheduled to continue until June 2027, at no additional cost, and will include:

- resolving any bugs identified during operations;
- reviewing and, where appropriate, implementing suggestions submitted through the feedback form;
- incorporating IOTC ecoregions into the atlas
- organising in-person and online tutorial sessions; and
- producing short tutorial videos.

From July 2027, a third project phase could be considered to support implementation of paragraph 5(c) of Resolution 25/01, which requests that "the IOTC Secretariat shall continue its work to develop and keep up to date, a dedicated IOTC webpage on climate change and its impacts on IOTC fisheries". This phase could include the development of such a webpage, potentially incorporating a dashboard of environmental indicators and outreach materials. Any extension of the IODA project into a third phase would require discussion and consideration by the Scientific Committee.

10. Conclusion

IODA was developed over five months and became publicly accessible in 2026. It was presented, including through demonstration sessions, at three Scientific Committee Working Parties between September and November 2026. The platform directly supports the objectives of IOTC Resolution 25/01 by facilitating access to environmental and climate information relevant to fisheries research and management. By bringing together long-term oceanographic datasets and climate indices in an interactive visualisation environment, IODA provides a regional scientific resource for investigating ocean variability and change, exploring potential links with tuna stocks and fisheries, and informing ecosystem-based management. Its continued value will depend on regular data updates, sustained technical support and active engagement by the IOTC scientific community

Acknowledgements

We sincerely thank the Government of Seychelles, and in particular the Secretariat for Science, Technology and Innovation of the Vice- President's Office, for authorizing IODA to be hosted on the national server managed by DICT We also thank the Seychelles Fisheries Authority, notably Dr Jan Robinson, Chief Executive Officer, for the Authority's commitment to supporting routine data maintenance and making the relevant budget available.

References

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Annex 1

Project Terms of Reference

Based on Res 25/01 the IODA should provide relevant information on the status of the ocean and its past and ongoing trend in order to support scientific research into the relationship between climate change, tuna fisheries, tuna stocks, bycatch and pelagic ecosystem to which tuna depend on.

The different phases to be undertaken in the IODA development are as follows:

1. Creating datasets of oceanic products covering the Indian Ocean at the highest possible spatial resolution;
2. Developing scripts and a web-based application with a user-friendly interface to select ocean variables to be plotted, either though maps or other types of graphs, exported to standard formats, and to calculate derived products (anomalies and general statistics);
3. Set- up a dedicated THREDDS data server (Unidata | THREDDS Data Server (TDS) (ucar.edu)) hosting the atlas datasets and using a variety of remote data access protocols;
4. Description and implementation of comprehensive system and data maintenance protocols;
5. Developing and maintaining data sharing SOPs (standards of procedures)
6. Contain an audit trail of all operations conducted in the system
7. Training a technical team in the server hosting site to ensure the maintenance of the atlas and to update of the datasets.

The following specific products are proposed:

- View a map for a given ocean variable at a selected time and depth over the whole ocean (standard) or in smaller user-defined areas
- Overlay EEZ contours on any map (optional)
- Plot a section along a transect (drawn interactively on the map)
- Plot a time-series (and produce associated statistics) at a given location
- Plot a time series (and produce associated statistics) in a given polygon drawn on the map
- Plot space-time diagram (Hovmöller plot) i.e. with a spatial dimension on one axis and a time dimension on the other axis
- Plot a vertical profile over the whole depth range at any location on the map
- Create user-defined animated maps along a range or months/years
- Export selected data to text files (.txt, .csv) and to "shape" files compatible with GIS software
- Export maps in various image formats (jpg, png,…)
- Export animations in Animated GIF images
- Produce statistics summary reports (mean, average, standard deviation, minimum, maximum, coefficient of variation, median, quartiles) for the selected variables and plots.

Annex 2

IODA App home page

https://ioda-atlas.gov.sc

