Development of an online ocean digital atlas for the Seychelles EEZ and neighbouring ocean regions

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Abstract

Variability and trends in the ocean conditions form a set of information that can be used in fisheries management, inshore and offshore, and assist in spatial planning to design specific boundaries in the areas under national jurisdiction of the coastal states. A French funding (FSPI) dedicated to develop innovative projects in the Blue Economy space in 2021-2022, has been the opportunity to develop an online digital ocean atlas for Seychelles . This project is run jointly by a locally-based software development company and a research institute. The project is developing a web-based application to produce a variety of outputs, such as maps, line plots, hovmoller plots and vertical profiles. Here, we present the variables handled by the atlas, the various functionalities, the expected deliverables and the requirements set for the database management and the programming language in order to conform with international standards.

Introduction

It is widely acknowledged that information pertaining to the structure and dynamics of the ocean is essential to understanding the fluctuations and functioning of the marine ecosystem, with implications on fishery resources (Brander, 2009; Marsac, 2017). Life-history traits, population growth rates, movements and stock abundance are influenced by factors other than fishing (MacKenzie et al., 2008; McClatchie, 2014). Oceanographic data can improve our understanding of fish stocks fluctuations and vulnerability to gears. Other sectors where oceanographic data are seen as an asset are those in relation to conservation, by characterizing habitat features of marine protected areas (Kelleher, 1999), risk assessment in marine pollution, or shipping, by optimising maritime routes (Chang et al, 2015). Ocean observing systems have been widely developed during the past two decades, and most of the data is accessible in open-access on the web. However, the data providers and the data sources are very diverse. They include discrete observations (i.e. non-evenly distributed) at the surface and through the water column, synoptic satellite imagery (surface only) and ocean models reanalyses or forecast that represent the state of the ocean in continuous fields at a range of time scale, from hours to weeks and months. Such diversity in observations is a true asset for ocean monitoring, however, it might be difficult for a non-expert to take advantage of these potentially valuable sources of information.

The development of an electronic atlas of oceanic data through a user-friendly web interface has therefore the potential to become a valuable management tool for fisheries, conservation purposes and more generally, in marine spatial planning. This project is being developed in the Seychelles ocean domain, with the support of the French Ministry of Foreign Affairs (FSPI - *Fonds de Solidarité pour Projets Innovants*) and the Institute of Research for sustainable Development (IRD), in the framework of the "Blue Economy year" of the *Commission de l'Océan Indien* (COI). This programme is designed to promote innovative development in the Blue Economy space in eight countries in the Southwest Indian Ocean.

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The Seychelles Digital Ocean Atlas (SDOA), covering the whole of the Seychelles EEZ and beyond, is designed for a range of users: scientists, NGOs, fishery managers and fishing operators, and possibly the general public. This set of information links directly to the Blue Economy Roadmap of Seychelles. Decisions must be informed using the best available science. Putting the essential scientific data on the marine environment at the fingertip of stakeholders is an important step towards transparency and efficiency in management actions.

Objectives

In the long-term, the SDOA will encompass a wide range of information in the coastal and marine environment, building on long time series. However, under this specific funding to be used in a limited timeframe (June 2021 – February 2022), short-term objectives must be identified. The project outcomes are:

i) to set up a database of oceanic products covering the EEZ of Seychelles and the neighbouring ocean regions (Fig. 1), and make it accessible from a dedicated THREDDS data server;

ii) to develop 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);

iii) to train Seychellois personnel in order to secure the maintenance of the database on the long run, also for keeping contact with the service provider of the application for possible new developments.

Expected deliverables

The following functionalities were defined for the project:

1- System administration
- Contain an audit trail of all operations conducted in the system, including printing of certificates.

2- Maps and plots
- View a map for a given ocean variable at a selected time and depth over the whole area (standard) or in smaller user-defined areas
- Overlay bathymetric contours and EEZ contours on any map
- Plot a section along a transect (drawn interactively on the map)
- Plot a time-series (and associated statistics) at a given location
- Plot a time series (and associated statistics) in a given polygon drawn on the map
- Plot space-time diagram (Hovmoller plot) with a spatial dimension on one axis and a time dimension on the other axis
- Plot a vertical profile, from surface to 800 m, for any variable, at any location on the map

3- Animations
- Create animations on the screen after selection of a range or months/years

4- Data export
- Export selected data to text files (.txt, .csv) and to “shape” files compatible with GIS software
- Export maps in various image formats (jpg, png, TIFF)
- Export animations in Animated GIF images

5- Summaries
- Produce statistics summary reports (mean, average, standard deviation, minimum, maximum, coef of variation, median, quartiles) for the selected variables and plots.

Methodology

1. App's development team

A local software development company and the IRD team in Seychelles are developing the application jointly. After a call for bids, the company Space95 was selected to work on this project. Space95 is a locally-based technology company founded in 1995, providing an extensive range of products and services expanding across various sectors that supports the progressive use of technology in business and administration in Seychelles. The company has extensive experience in AS400 / Windows/Linux based and Web based software development. Amongst the company client's software portfolio includes Government of Seychelles, and large/ SME companies.

2. Data standards and coding language

In order to conform to international standards, requirements were set for the file formats, database management system, and for the programming language of the application:

- The data files are in NetCDF. Network Common Data Form (NetCDF) files are a standard for the exchange of scientific data in binary format that are platform-independent and self-describing (files contain a header and file metadata in the form of name/value attributes). See the UCAR Unidata website[3] for more information)
- Data will be available through a THREDDS Data Server (TDS), which is a web server providing metadata and data access for scientific datasets, using OPeNDAP, OGC WMS and WCS, HTTP, and other remote data access protocols. See https://www.unidata.ucar.edu/software/tds/current/ for more information.
- R (R Core Team, 2021) is the language selected for coding the application. The frond-end user interface is developed in Shiny, a R package designed to build interactive web apps straight from R (https://shiny.rstudio.com/)
- The site administration backend, which generates statistics on users, is coded in PHP. The metadabase containing the available products used by the SDOA is a SQL relational database. The backend portal will also provide login access, permission control, audit log, administrative and management reports as requested by the project's administrator.

3. Area selection

The project's focus is on the Seychelles EEZ, but the information available in the app extends beyond the EEZ boundaries. It covers a rectangular area from 5°N to 13°S in latitude, and 41°E to 70°E in longitude (Fig. 1) representing an area of 5.2 million km². The observations cover the deep sea and the shallow waters over the banks (illustrated in light blue).

4. Variables and data sources

The parameters selected are related to fish habitat (and potentially influencing catchability in large pelagic fisheries) and to activity sectors as stated in the introduction. They can also define sensible areas for conservation purposes. For the pilot phase of the project, we only consider ocean model products and satellite products. In a second phase, discrete observations could be added.

We selected the European Copernicus Marine Service (CMEMS) to download a range of ocean models and satellite products. The CMEMS provides free, regular and systematic authoritative information on the state of the Blue (physical), White (sea ice) and Green (biogeochemical) ocean, on a global and regional scale. Scientists, policy makers, stakeholders of the civil society can access and use the data and services for marine policy implementation and to support Blue growth and scientific innovation (https://marine.copernicus.eu/)

[3] https://www.unidata.ucar.edu/software/netcdf/?_ga=2.110035781.1702584956.1636807167-445150330.1636807167

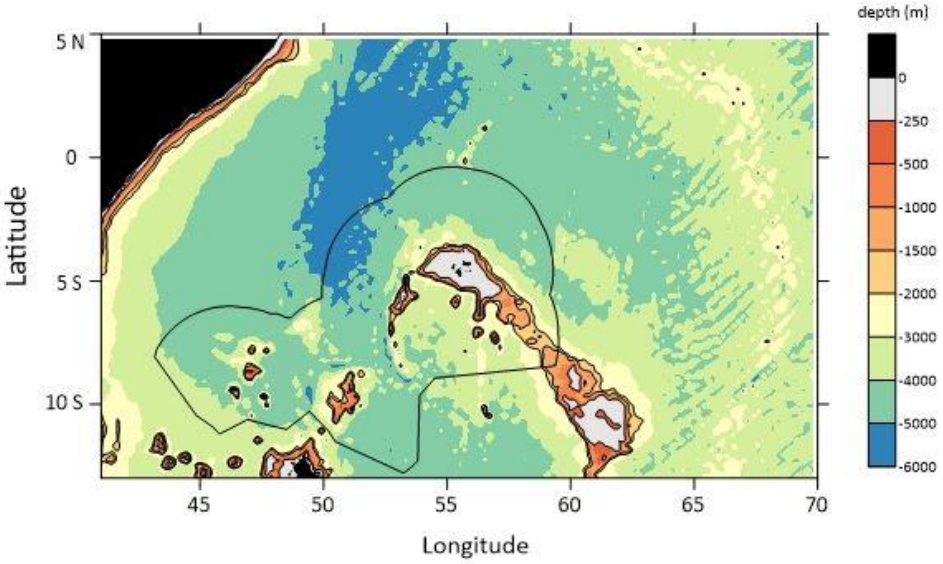

Figure 1 - Study area showing the boundaries of the Seychelles EEZ (Exclusive Economic Zone) and neighbouring oceanic regions. The color shaded background is the ETOPO1 seabed topography

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The 12 variables included in the current version of the SDOA are listed in Table 1. They are composed of two groups: i) datasets directly downloaded from data centres, and ii) calculated variables through specific R scripts that are processing the input files. For instance, the 20°C isothermal depth is generated from the interpolation between successive depth levels of temperature at depth in the GLOBAL_REANALYSIS_PHY_001_030 or GLOBAL_ANALYSIS_FORECAST_PHY_001_024 files. Similarly, the depth of the 2.5 ml l^{-1} oxygen concentration is calculated in the upper 150 m by interpolating dissolved oxygen (DO) concentrations between different depth levels. This specific DO concentration was selected in relation to lethal levels for surface dwelling tunas such as skipjack. The last dataset is the seabed topography provided by the ETOPO1 Global relief Model, at a 1 nautical mile (1.852 km) spatial resolution (https://www.ngdc.noaa.gov/mgg/global/).

In terms of period coverage, the model products start in January 1993 and are available on a monthly basis. The Reanalysis datasets range from 2013 to 2019. The information from 2020 onwards requires accessing the Forecast datasets. Both datasets are quite consistent as they are both data-assimilated products. Therefore, it is possible to draw plots encompassing the two periods for the physical variables. However, this is not the case for the biogeochemical products. The BIO Reanalysis product (2013-2019) using the PISCES biogeochemical model, does not assimilate data. By contrast, the BIO Forecast product assimilates satellite chlorophyll and uses a slightly different atmospheric forcing. Therefore, differences exist in the maps generated from both products. This means time series plots connecting these two periods are not recommended, as they will show a disruption in the values represented.

Current status of the application

The application is under development, and here we describe the main structure of the front and back ends.

1. Application's front end (user's interface)

When accessing the app for the first time, a user must create an account (register) with a login and password and indicate the category he belongs to: fisherman, researcher, manager, NGO… (Fig. 2). The

registration is free. Any further access to the app goes through a sign-in page. Then the home page opens to select which variable is to be plotted, the name of the dataset and the depth level. The selection is assisted with drop-down menus (Fig. 3). Then the user indicates one among four types of plots: map, line plot, Hovmoller plot or vertical profile. Four different function pages will be launched to enter additional selection for each type of plot. Details on the content of each function page are displayed on Figures 4 to 7.

Statistics about a plot (mean, average, standard deviation, minimum, maximum, coefficient of variation, median, quartiles) are produced by checking the Summary report box.

Each set of selections made on the function page will activate a command line in R-Shiny to produce the requested plot. Then plots can be saved in standard formats, or exported as data files to be used by other software (e.g. Excel). Examples of saved outputs are provided in Figure 8.

The map function page produces different types of outputs:

- The spatial distribution of the variable for a given month at a given depth level;
- The spatial distribution of the anomalies for a given month at a given depth level;
- The climatological mean of the variable for a given month map at a given depth level;
- A computed map, such as the difference between two maps, the average over a series of months, or the standard deviation over the series, at a given depth level;
- Animated maps for a given time series at a given depth level.

2. Application's backend

The backend is the administration engine of the application. This allow the system administrator to manage the different transactions made on the datasets, and to check the user's activity, login history, user category (Fig. 8). The backend has access to a MySQL metadatabase. Each time a new dataset is entered in the SDOA metadatabase will make it accessible to the front end (Fig. 9).

Way forward

The pilote phase of the SDOA should be completed by February/March 2022. In the months following the release of this intial version, an assessment will be conducted on the interest raised by this initiative, the type of users and the frequency of use of the application, and the type of products most commonly requested by the users. From this assessment, improvements may be developed.

This application is presented at the WPDCS as it can also serve as a model for an ocean-climate web page at the IOTC.

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Table 1 – Characteristics of datasets used by the Seychelles Digital Ocean Atlas (pilot phase)

Variable	**Depth range**	**Spatial resolution**	**Period**	**Source**	**Product name**
Temperature Salinity Current (zonal u and meridional v components)	0–763 m (34 levels)	1/12 degree (~9 km)	January 1993 To Present (monthly)	Model (CMEMS)	*PHYsical files :* Reanalysis: GLOBAL_REANALYSIS_PHY_001_030 Forecast : GLOBAL_ANALYSIS_FORECAST_PHY_001_024
Mixed layer depth	1 layer				
Dissolved oxygen	0-773 m (44 levels)	¼ degree (~25 km)			*BIOgeochemical files* Reanalysis : GLOBAL_REANALYSIS_BIO_001_029 Forecast : GLOBAL_ANALYSIS_FORECAST_BIO_001_028
20°C isothermal depth	1 layer	1/12 degree (~9 km)			Calculated from PHY source files
Vertical Current shear	1 layer				Calculated from PHY source files
Depth of 2.5 ml DO (in the upper 150 m)	1 layer	¼ degree (~25 km)			Calculated from BIO source files
Integrated Chlorophyll content 0-300m	1 layer				Calculated from BIO source files
Surface chlorophyll concentration	1 layer (surface)	4 x 4 km	Sept 1997 to present (monthly)	Satellite merged products	OCEANCOLOUR_GLO_CHL_L4_REP_OBSERVATIONS_009_082
Sea level anomaly	1 layer (surface)	¼ degree (~25 km)	April 2019 to present (daily)	Merged altimetry products	SEALEVEL_GLO_PHY_L4_NRT_OBSERVATIONS_008_046
Seabed topography	1 layer	1 arc-minute (~1.8 km at the equator)	n.a	Merged bathymetric databases	ETOPO1

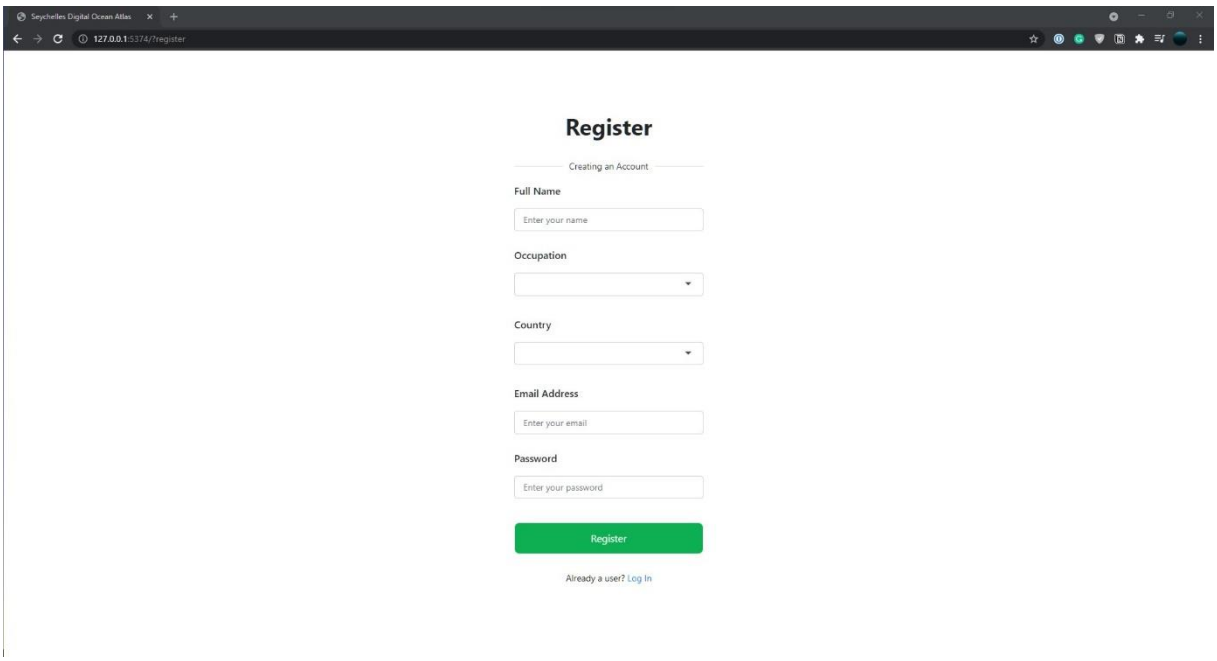

Figure 2 – SDOA registration panel

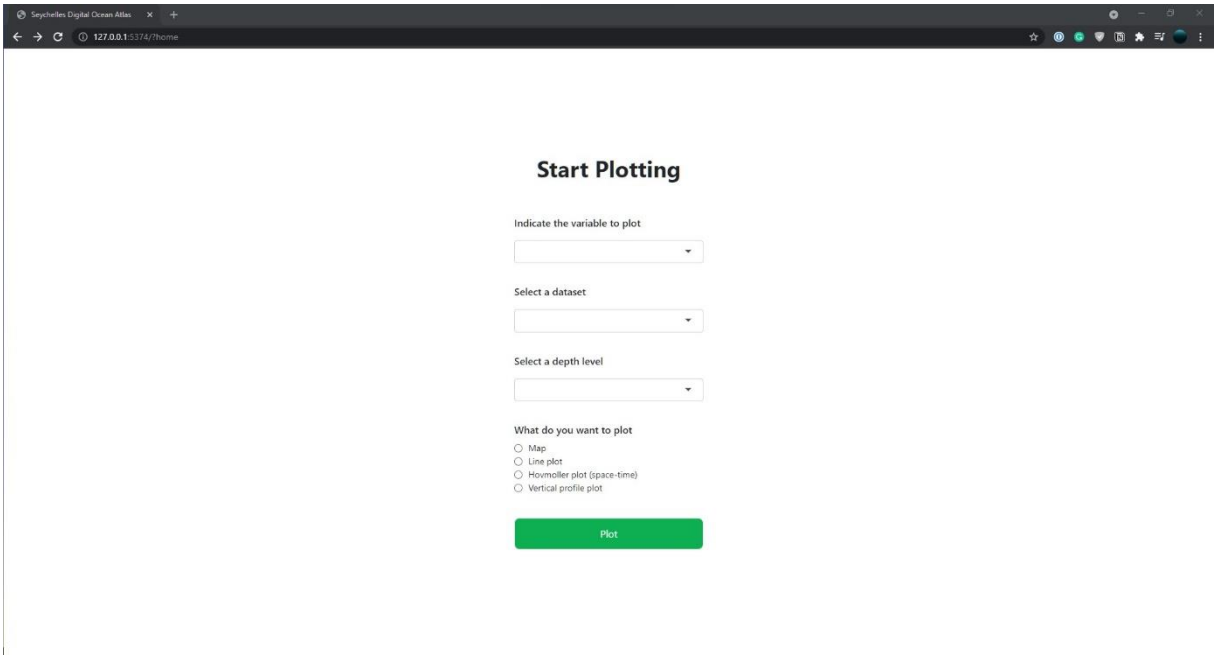

Figure 3 – Home page to select variables and attributes, and the type of plot

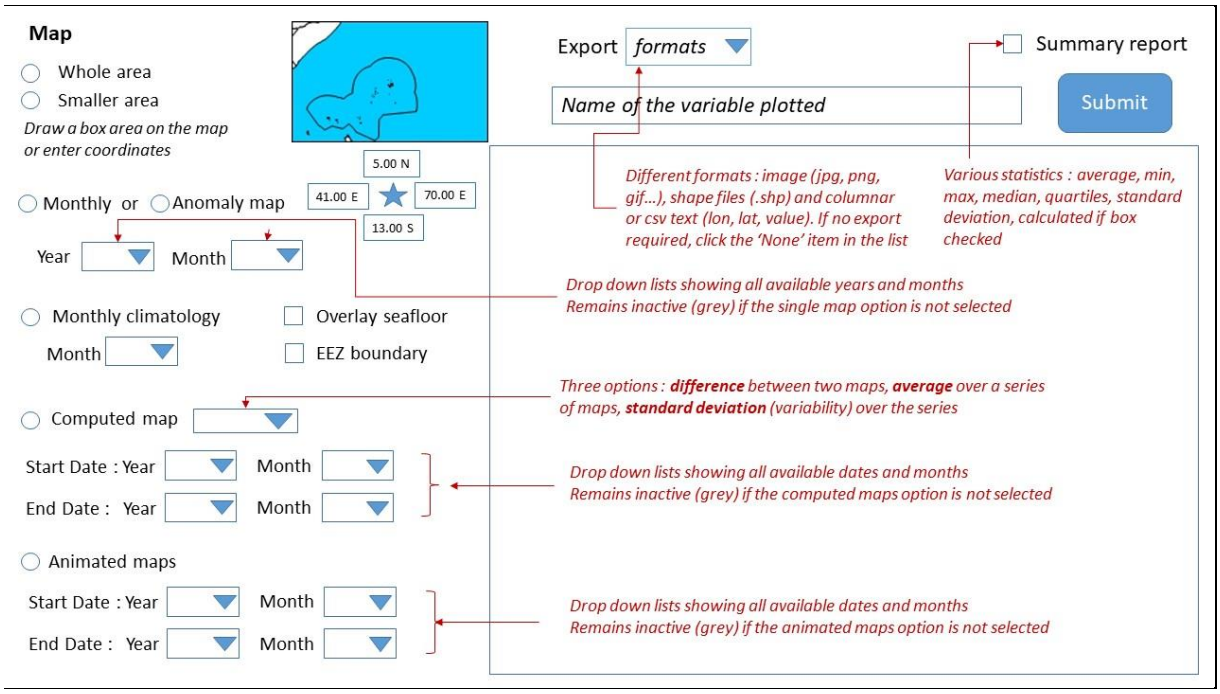

Figure 4 – Details of the Map page. The plot will appear inside the frame

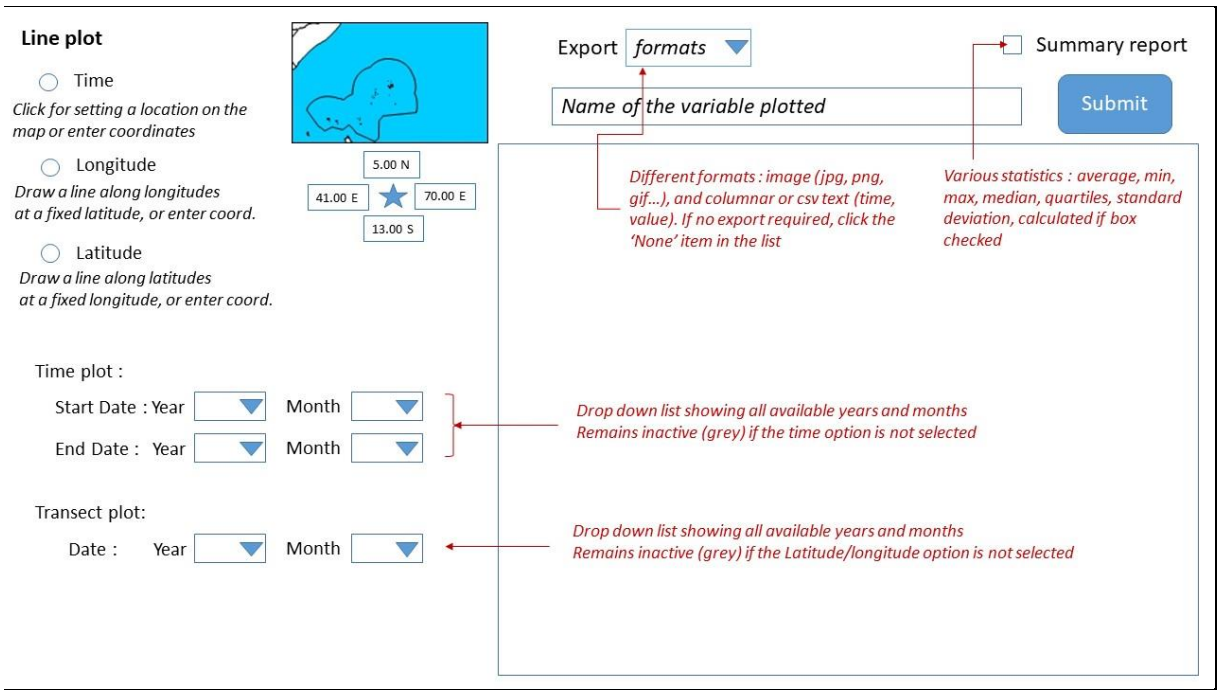

Figure 5 – Details of the line plot page. This page can draw time series (time plot) or the variation of a variable along a transect drawn on the map (Transect plot). The plot will appear inside the frame

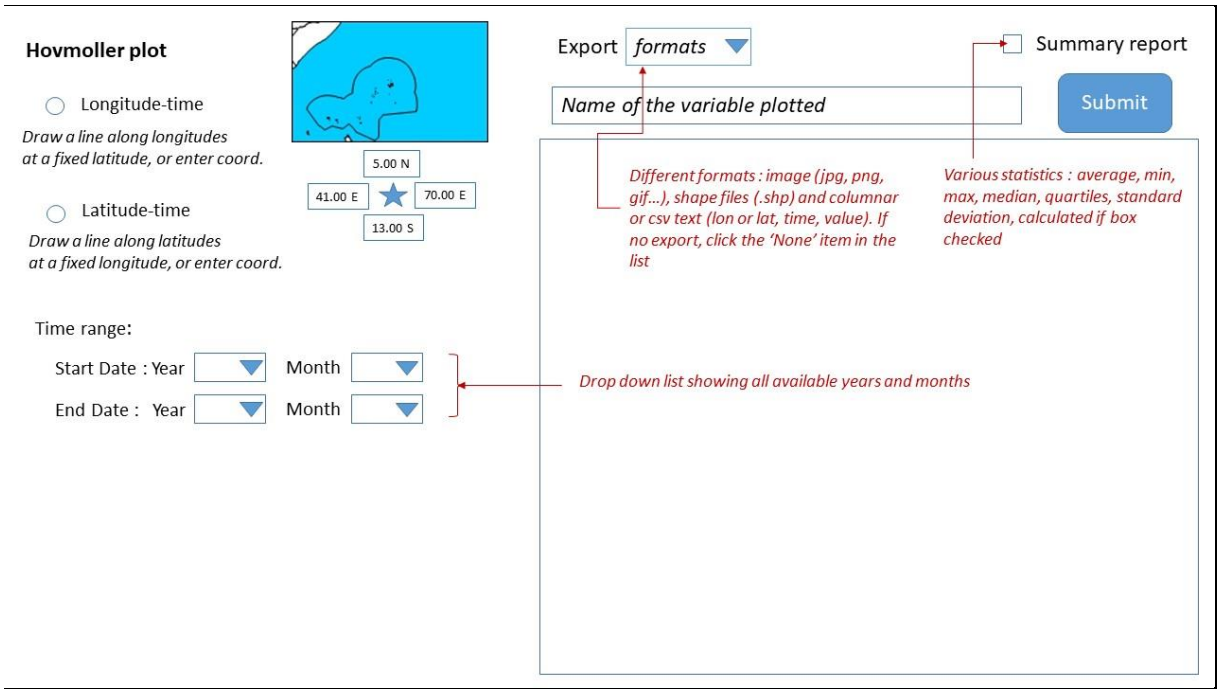

Figure 6 – Details of the Hovmoller plot page. The plot will appear inside the frame

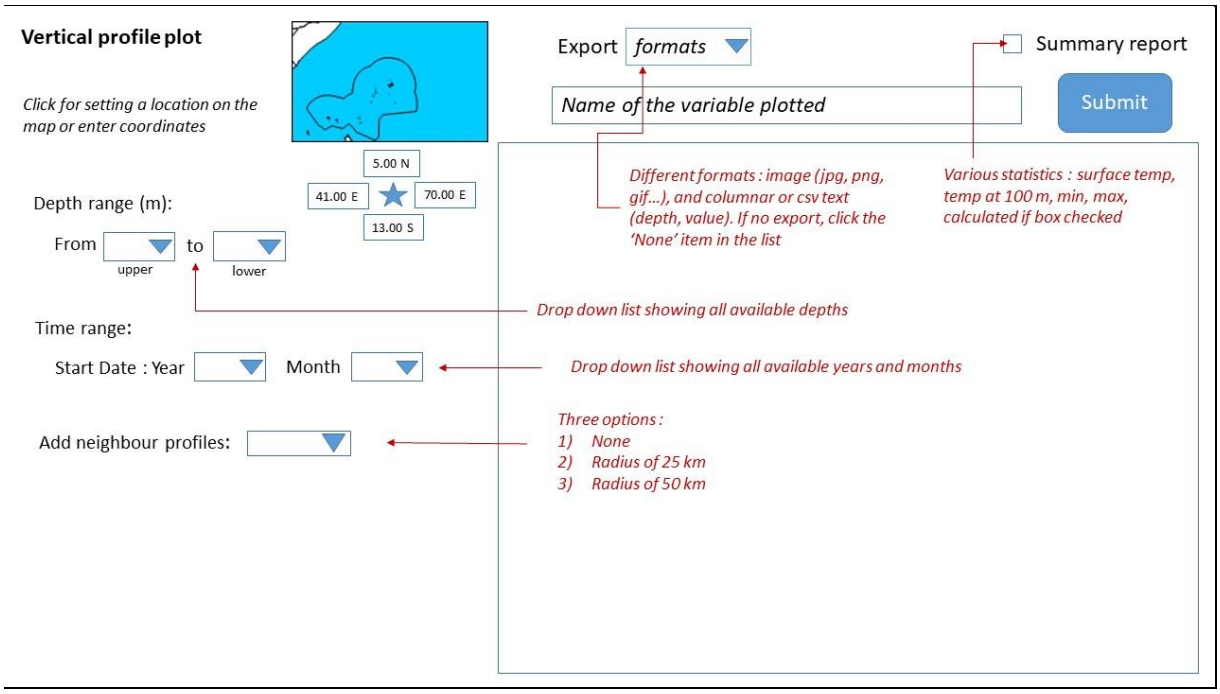

Figure 7 – Details of the Vertical profile plot page. The plot will appear inside the frame

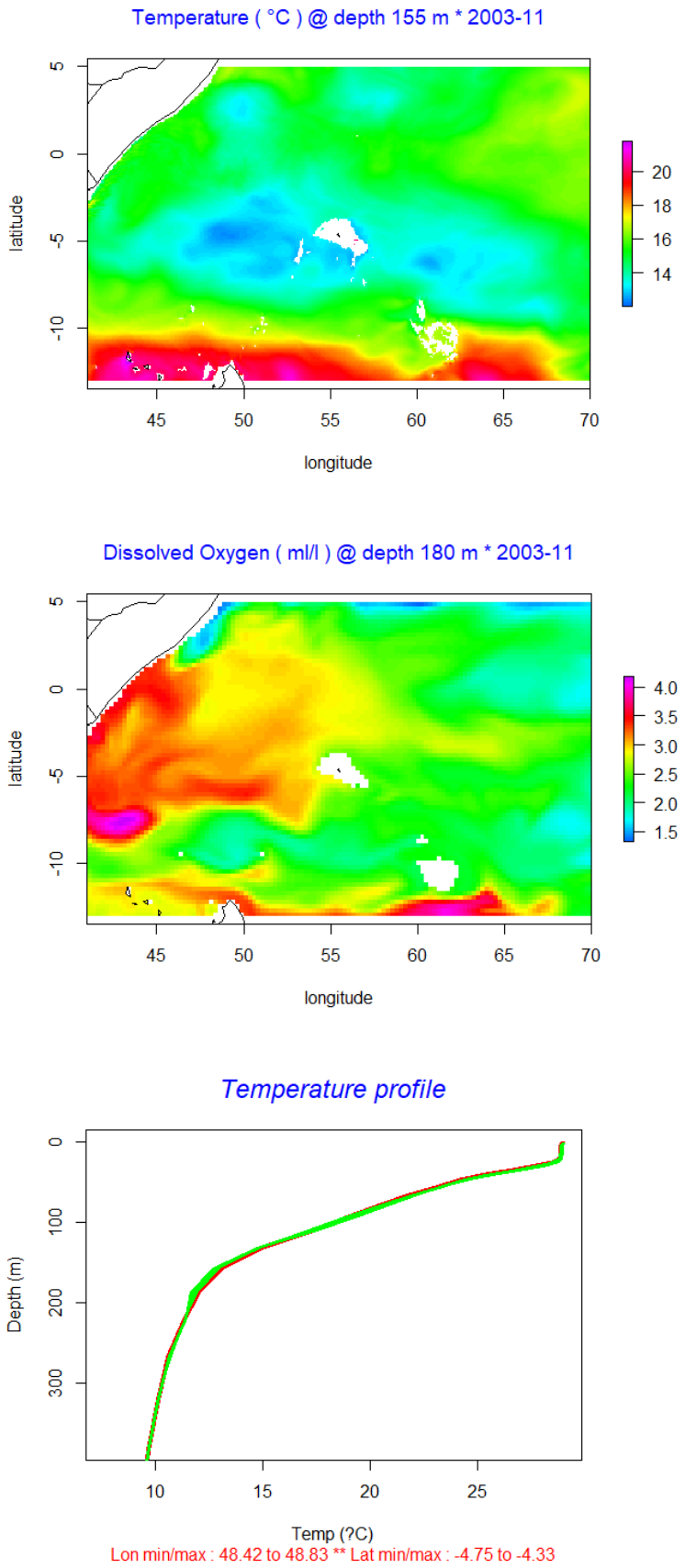

Figure 8 – Examples of maps (upper panel: temperature; middle panel: dissolved oxygen) and temperature profile plot (bottom panel).

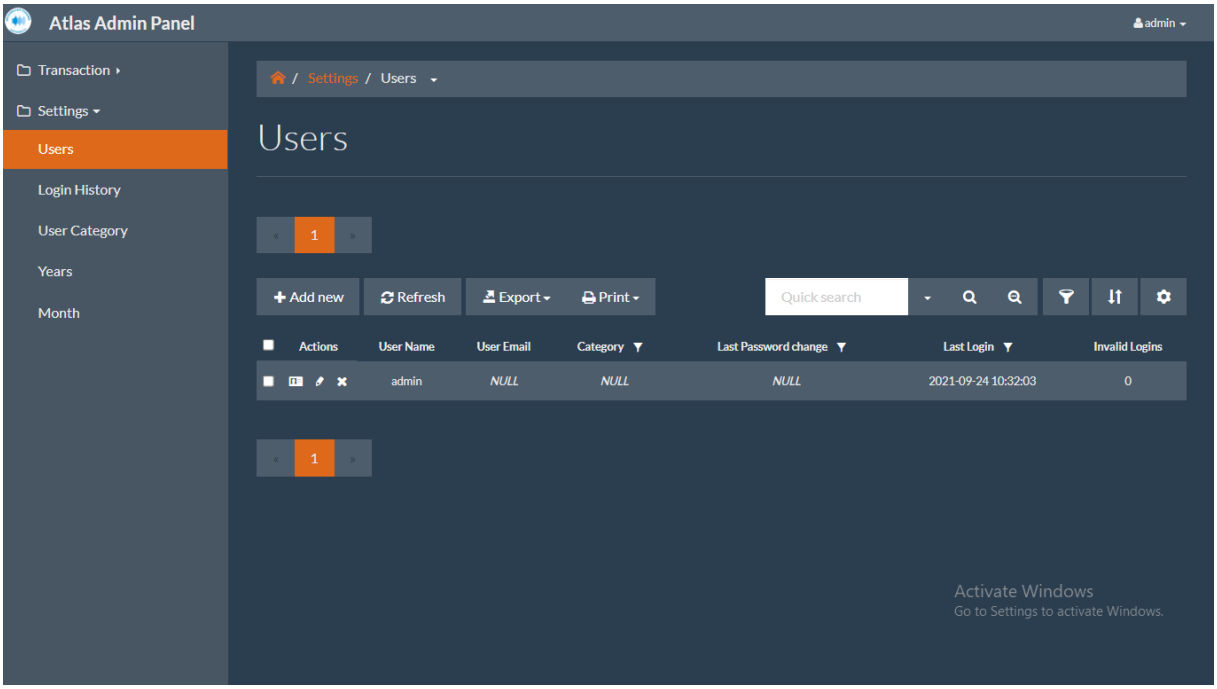

Figure 9 – Users's management page of the SDOA admin panel

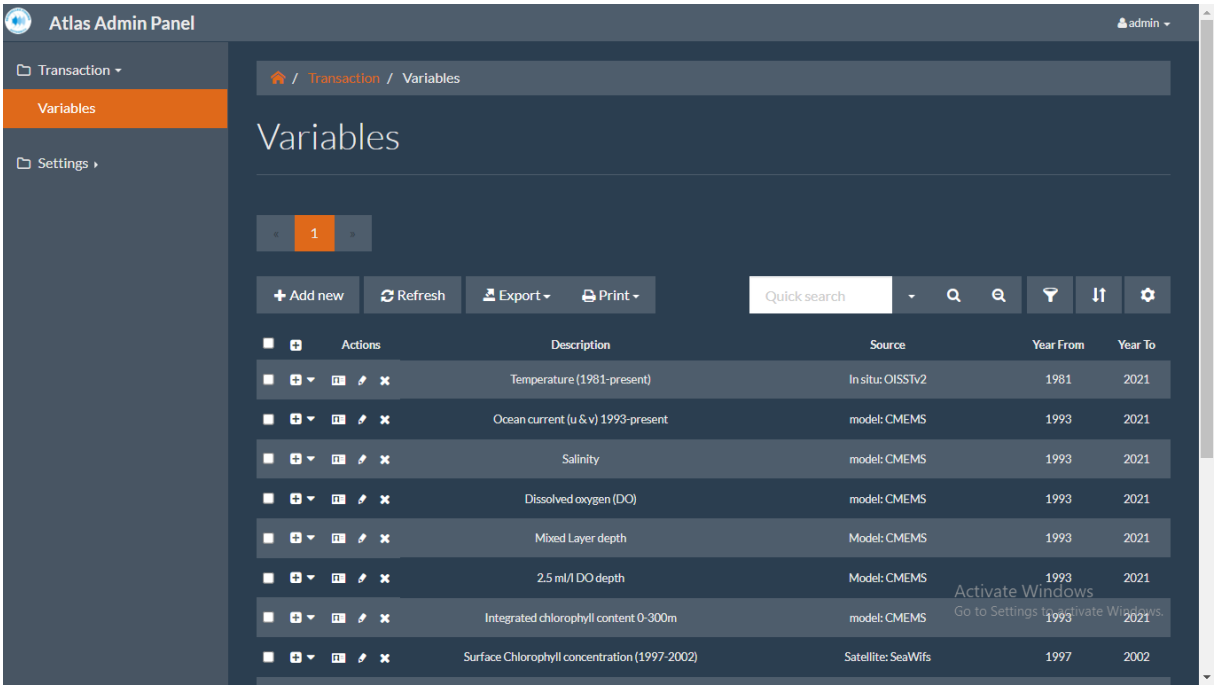

Figure 10 – Transaction page (variables description) of the SDOA admin panel