Proposal for the development of an ocean-climate web page for the IOTC

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Abstract

In the vein of the growing interest of fisheries scientists from the Indian Ocean to incorporate environmental factors and climate variability in fisheries research and fish stock assessment, we propose to develop an "ocean climate web page" for the Indian Ocean, to be hosted on the FAO/IOTC web site, with regular updates of the information posted on this web page. In this paper, we present a draft of the site structure and possible content that is open to discussion at the WPDCS14. The ocean climate web page is a compilation of selected information produced by ocean data centres and scientific organisations on the status of the Indian Ocean and how it responds to climate variability. This set of information is intended to inform tuna scientists, fisheries managers on the status and trends of essential characteristics in the open ocean ecosystems of the Indian Ocean, with emphasis on tuna habitat.

1. Introduction

It is widely agreed that incorporating information on ecosystem and environmental effects on fish stock assessment can improve the interpretation of historical information and the precision of forecasts (Brander 2009, MacKenzie et al 2008, McClatchie 2014, among others). Life history traits, population growth rates, movements and stock abundance are influenced by factors other than fishing. Ecosystem factors such as species interactions, habitat, and large-scale climate patterns are important components of the marine environment that impact fisheries.

Tunas are species which respond to environmental variability at various timescales. Tunas do not distribute randomly in the ocean. Owing to their high metabolic demand (Sharp 1978, Block & Stevens 2001), tunas must find foraging oases in the middle of vast oligotrophic oceanic regions. Thus, tunas are able to cover long distances to congregate in dense schools in the most favourable (and often transient) areas. In this regard, environmental cues, gradients and fronts of essential abiotic (temperature, dissolved oxygen, currents) and biotic (ocean color, plankton and micronekton aggregations) factors play a key role in tuna movements and aggregations (Marsac 2017).

In the IOTC framework, several working papers relating fisheries patterns to the oceanic environment have been presented during the past 6 years at the WPEB and WPTT sessions. Environmental factors are being incorporated in the standardization of longline and purse seine CPUEs in order to produce abundance indices for the assessment (see an example for purse seine in Isidora et al 2018). However, such initiatives are still underdeveloped in the IOTC community. There are many web-based resources related to oceanographic datasets that are available worldwide, however one main challenge for non-oceanographers is to have access to synthesized information that can be useful for fisheries scientists in their research work and stock assessments. This has been recognised by the WPTT at its 19th session (2017), as stated in paragraph 23 of the report:

"The WPTT NOTED that oceanic climate indices are potentially useful additions alongside the stock status advice as ecosystem indicators for management. One option could be through the addition of a 'Climate Page' on the IOTC website and the addition of environmental/climate indicators in an ecosystem report card being developed to progress on ecosystem based fisheries management, where climatic and oceanographic indicators would be presented and regularly updated. The WPTT ENCOURAGED the authors to develop such an initiative before the WPTT-20 meeting in 2018, in conjunction with those developing report cards. This issue is also of particular relevance for WPEB ".

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It has not been possible to present such climate page at the WPTT-20, however we consider this issue is also relevant for the Working Party of Data Collection and Statistics. In this paper, we outline the main components that could supply an "ocean climate" section in the IOTC website. It is expected that the WPDCS consider and revise the proposal as necessary, and decide whether it should be provided to the SC for endorsement.

2. Rationale

The rationale of such ocean climate web page for the IOTC is to gather information that would inform tuna scientists, fisheries managers on the status and trends of essential characteristics in the open ocean ecosystems with emphasis on tuna habitat in the Indian Ocean. One important aspect is that information will be updated on a regular basis (quarterly or monthly depending on the datasets).

The web page has a triple objective: i) to provide general information on the oceanography of the Indian Ocean; ii) to present easy-to-read and ready-to-use plots and maps; and iii) to give online access to the datasets that are used in plots and maps.

3. Structure and components of the web page

The long title for the IOTC ocean climate web page is "Ocean and Climate trends to inform tuna fisheries assessment in the IOTC".

There are five sections accessible from the home page: 1) Data portal; 2) Patterns; 3) Time series; 4) Maps; 5) Regional analyses. A site map is provided in Fig.1.

3.1. Data portal

This section contains links to major data centres and resources that are categorized in 4 sections:

- *Observations*: **wind data** (pseudo wind stress and blended winds), gridded **sea surface temperature** products of the NOAA/NCEP (Optimum Interpolation Sea Surface Temperature -OISSTv2- and Extended Reconstructed Sea Surface Temperature -ERSSTv4) and all physical and biogeochemical parameters stored in the **World Ocean database** (World Ocean Atlas 2013)
- *Assimilated ocean models*: **Global Ocean Data Assimilation System** (GODAS) of the NOAA/NCEP, and the ocean products of the European **Copernicus Marine Environment Monitoring Services** (CMEMS). GODAS has a global coverage of 0.333 degree latitude x 1.0 degree longitude on a monthly basis starting in January 1980. It includes ocean physical parameters only. CMEMS also has a global coverage and several regional analyses (but the Indian Ocean is not one of those) at various space and time resolutions. CMEMS requires registration (free) to access data, and datasets include physical, biogeochemical and biological parameters.
- *Remote sensing*: **Worldview** allows exploring Earth as it looks right now or as it looked almost 20 years ago through many different satellite sensors; **Ocean color web** gives access to SeaWifs and Modis data from which sea surface chlorophyll-a can be derived; **Ocean color portal** is another resources mapping various indicators (primary productivity of the phytoplankton, chlorophyll-a concentration among other); **Pathfinder**, a collection of global, twice-daily (Day and Night) 4km sea surface temperature; **Multiscale Ultra-high Resolution sea surface temperature** (MUR) is a climate data record (since 1981) combining satellite infra-red and microwave sensors' observations at a 1km resolution-day; **sea surface height** by CMEMS is a multimission altimeter satellite gridded sea surface heights and derived variables (i.e. geostrophic currents) computed with respect to a twenty-year mean, at a ¼ degree resolution starting in January 1993.
- *Browsing tools*: the datasets available from the above mentioned web sites are coded in netCDF format, a binary format that requires specific browsers to be read and mapped. For Linux OS, **ncview** is the most common tool. For all platforms (Linux, MacOS and Windows) two similar products are **Panoply** and **ncbrowse**. These software can be downloaded and installed free of charge from the links provided. There are also R modules that can read and process netCDF

files, but it requires proficiency in R programming. Such R modules are not listed here but can be downloaded from the R forum.

3.2. Patterns

This section is mostly informative. It depicts the main variability patterns for several variables using a type of principal component analysis, the Empirical Orthogonal Functions (EOF). The method is briefly described. The combination of maps (showing how the variability is distributed in space) and time series (showing when the peaks in variability occurred) indicates the response of the ocean in different modes of variability over time. The maps and the time series are displayed in 2 large regions (West and East Indian Ocean) for 3 variables: sea surface temperature, depth of the thermocline and chlorophyll-a concentration. There is a text explaining the figures for each of the variables. An example showing the 1st EOF of the chlorophyll variability pattern is given in Fig. 2.

3.3. Times series

This section includes two groups: time series (1 dimension) and howmoller diagrams (2D spatial time series)

Time series:

- *Southern Oscillation Index*: the SOI gives an indication of the development and intensity of El Niño or La Niña events in the Pacific Ocean. This fluctuations also impact the Indian Ocean through spatial shifts of the atmospheric circulation, especially the limb of the Walker cell over Indonesia.
- *Indian Ocean Index*: the IOI gives an indication of anomalies of the Indian Ocean Walker cell, with above normal sea-level pressure (SLP) over Indonesia and below-normal SLP in the tropical western Indian and East coast of Africa during El Niño (or positive Indian Ocean Dipole) events.
- *Dipole Mode Index*: the DMI gives an indication of the Indian Ocean Dipole which is an irregular oscillation of sea surface temperature in which the western Indian Ocean becomes alternately warmer and then colder than the eastern part of the ocean. Its fluctuations are well correlated with the IOI.
- *Sea Surface Temperature*: the ERSSTv4 time series is a gridded product with a resolution of 2° longitude x 2° latitude, by month starting in 1854. The monthly anomalies (about a climatology computed for 1981-2010) are plotted for 1880 to present (Fig. 3, as an example). A detrended series starting in 1970 is also displayed on the web page.

The monthly values for each of the 4 series, and the smoothed values (5-months moving average) can be downloaded from this web page (csv format). The detrended SST anomalies are also available for download (csv format).

Hovmoller diagrams:

Hovmoller diagrams are 2D plots with one axis representing time and the other representing a spatial variable (longitude or latitude). The variable of interest is represented by shaded fields in this 2D plot, therefore information has to be gridded in space and time beforehand. The variables to display would be:

- Sea Surface Temperature
- Zonal component (u) of the surface current
- Meridional component (v) of the surface current
- Current vertical shear (calculated between 0 and 145 m)
- Thermocline depth
- Surface chlorophyll

The datasets used to create the plots could be downloaded from this web page

3.4. Maps

The current set comprises monthly maps of sea surface temperature, depth of the thermocline (20°C isotherm) and sea surface chlorophyll for the region comprised between 30°E-120°E and 30°N-30°S. Examples of such maps can be found in Fig. 4. The indicator represented is the monthly anomaly.

Other maps for the Indian Ocean could be added in the near future:

- dissolved oxygen at 100 and 200 m depth levels by month (from a CMEMS biogeochemical model)
- monthly climatology of several variables : SST, Depth of thermocline, u and v of the current, current vertical shear, dissolved oxygen, chlorophyll-a

3.5. Regional analyses

The Indian Ocean has been partitioned in 5 main areas: Somali basin (SOM), Maldives (MAL), west equatorial area (WEQ), east tropical area (ETR) and Mozambique Channel (MOZ) (Fig. 5a). Yearly trends in SST, thermocline depth and surface chlorophyll are plotted for each region, with the exception of thermocline depth in SOM and MOZ. In SOM, the area encompasses the upwelling (with shallow thermocline) and the Great Whirl (offshore) with deep thermocline, therefore an average would not have any meaning in such a contrasted region with respect to this variable. Similarly, MOZ is characterized by mesoscale eddies (alternating cyclones and anticyclones) and an average thermocline depth in that region would be a “noisy” indicator.

The plots are bar charts representing anomalies, with one value per year or season (for West Equatorial, December to February). The chlorophyll concentration is expressed as a rate of change (in %) from the average of the whole series (Fig. 5b). Chlorophyll satellite data used here start in September 1997 (SeaWifs). In order to show plots with the same timescale, all the other series presented also start in 1997.

Eventually, a combined time series of surface chlorophyll concentration with all regions is displayed to indicate the yearly changes and trend since 1998.

As in previous sections, the data being used to produce the plots can be downloaded from the web page.

4. Maintenance

The proposal is that the ocean climate page would be hosted in the FAO/IOTC web site. This would require a formal agreement from FAO and the ocean climate page would be managed by the IOTC webmaster. In this scenario, FAO/IOTC would be responsible for designing of the ocean climate page in the most appropriate way in order to ensure an easy access to users.

The content of the page would be provided by IRD (through Francis Marsac) with periodic updates from one month to one quarter (depending on the update of datasets undertaken by the data providers). Text, plots and figures would be sent electronically to the IOTC webmaster to be immediately included in the ocean climate page.

The ocean climate web page should be seen as a living product, which can evolve with regards to requests from the IOTC Working Parties (i.e. inclusion of new variables). However, at the present stage where such work is provided freely as a national contribution (UE-France) to the IOTC, any extension from the current proposal will depend on the availability of human resources on a longer term.

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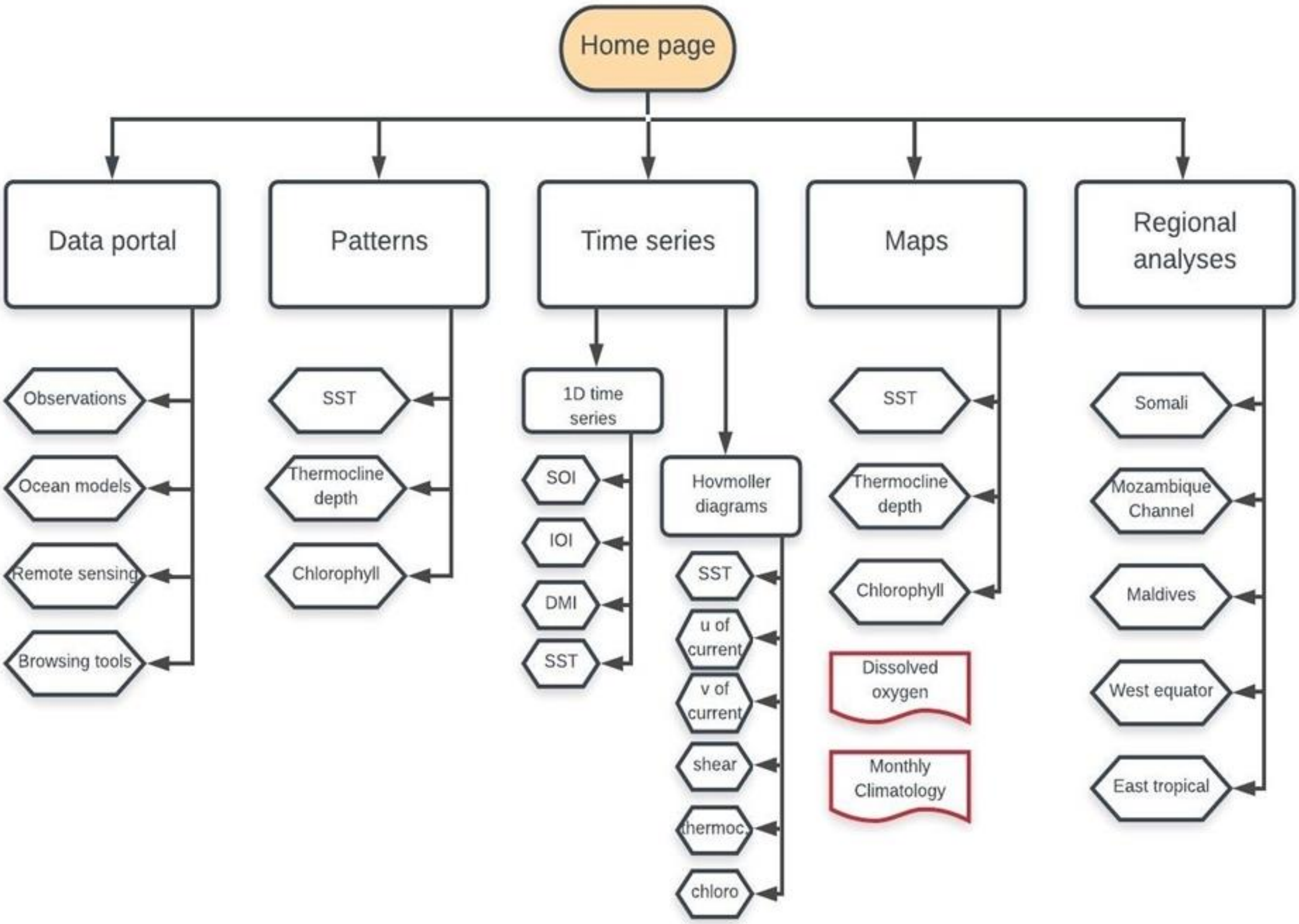


Fig.1 – Provisional site map for the ocean climate web page
(red items are not developed yet)

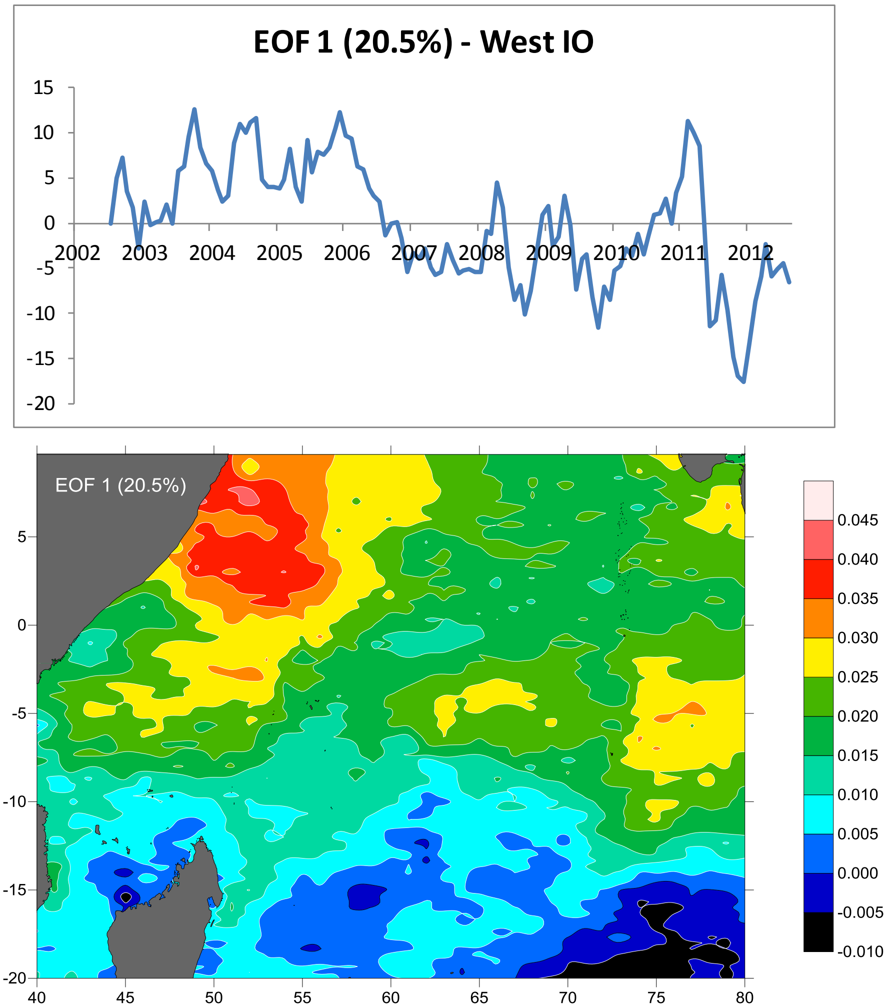


Fig. 2 – Example of EOF map and time series: 1st EOF of the surface chlorophyll in the West Indian Ocean, represented with its time (top) and space (bottom) components. It shows that the greatest interannnual variability occurs off Somalia, with high chlorophyll values reached during 2004-2005 and low chlorophyll values after 2007 (except 2011). The blue areas with low spatial loadings indicate where the interannual variability in chlorophyll is weak.

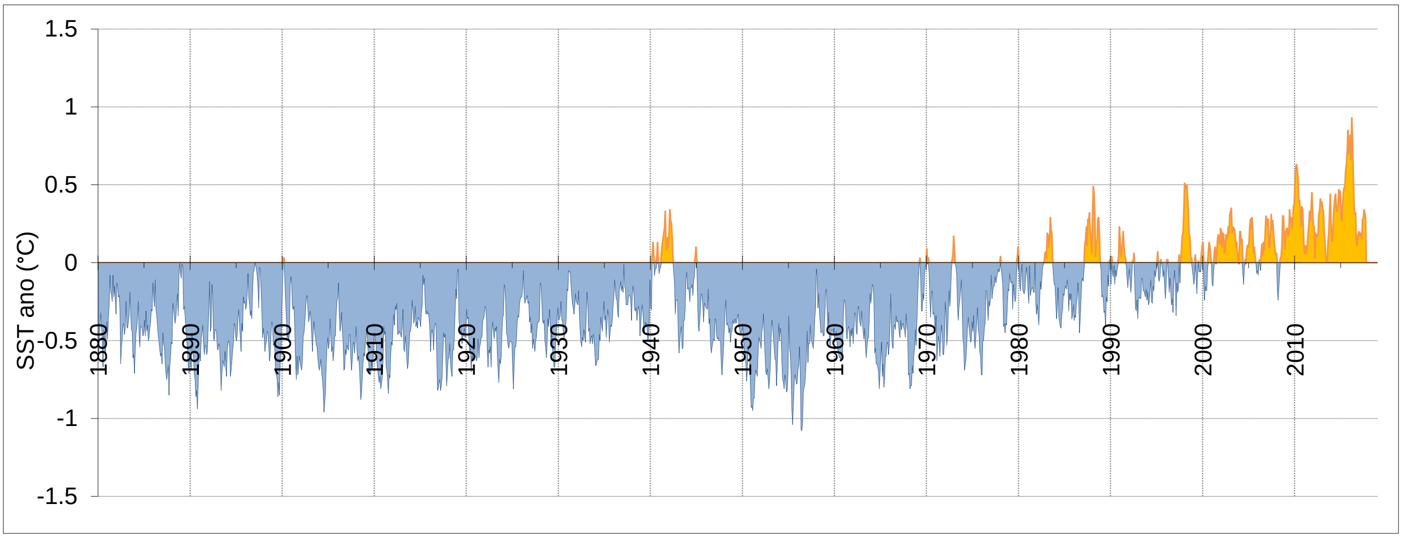


Fig.3 – Monthly sea surface temperature anomalies over the whole Indian Ocean (30°S-120°E / 30°SN – 30°S) during 140 years

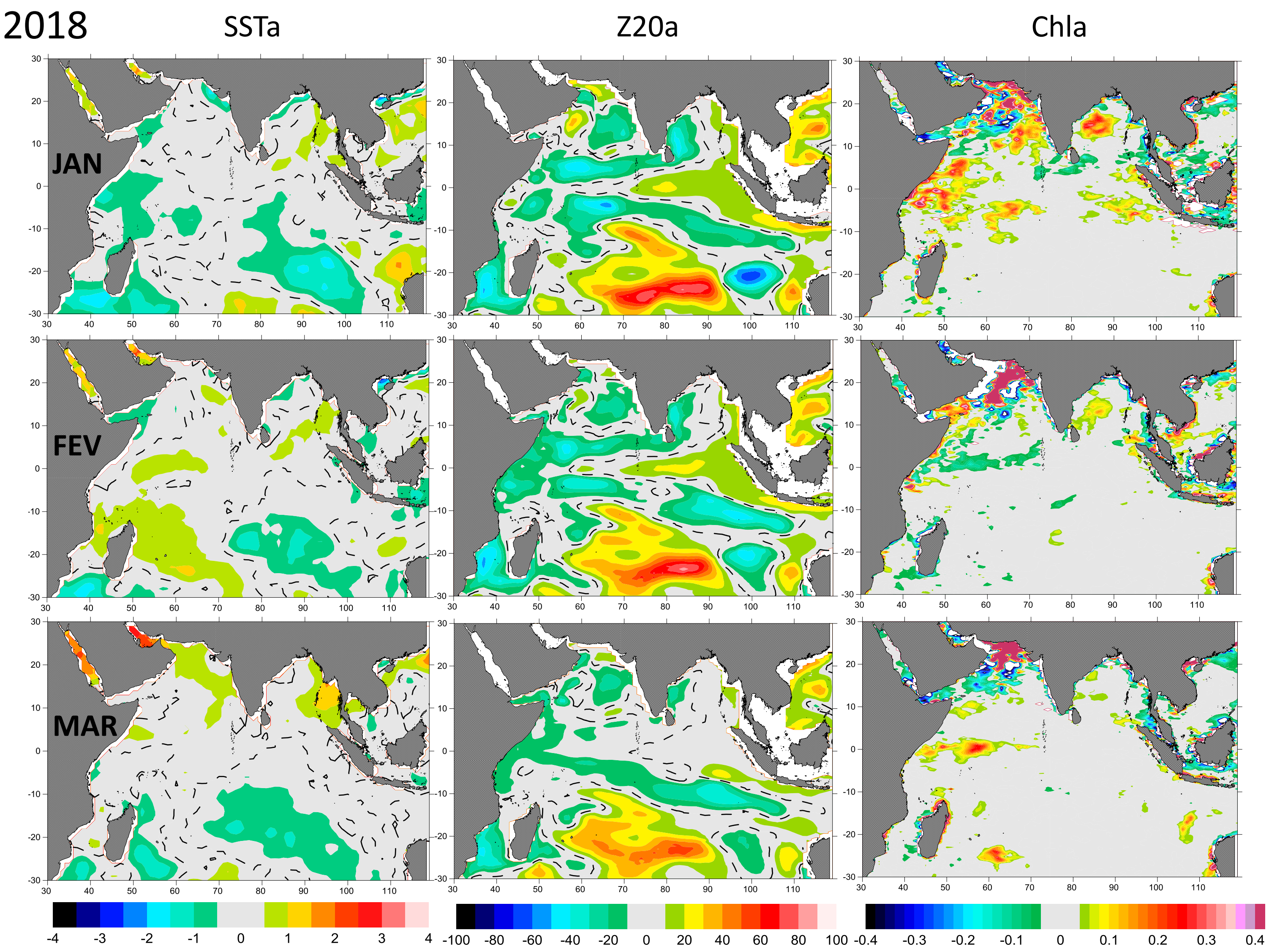
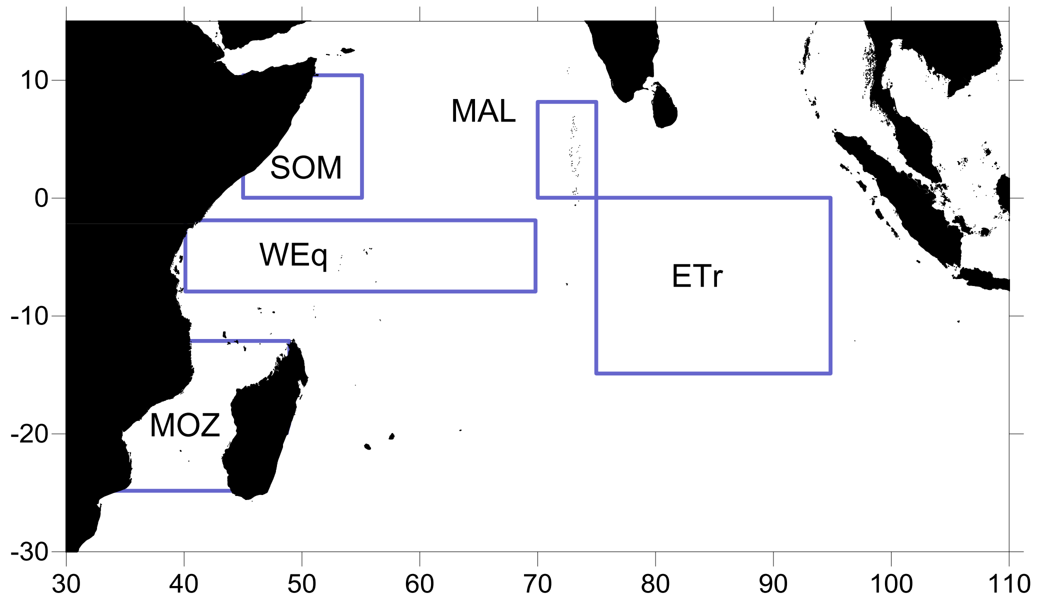


Fig. 4 – Maps of SST anomalies (°C, OISSTv2), thermocline depth (depth of 20°C isotherm in meters, GODAS) and sea surface chlorophyll (mg/m3, Modis) for the first quarter 2018



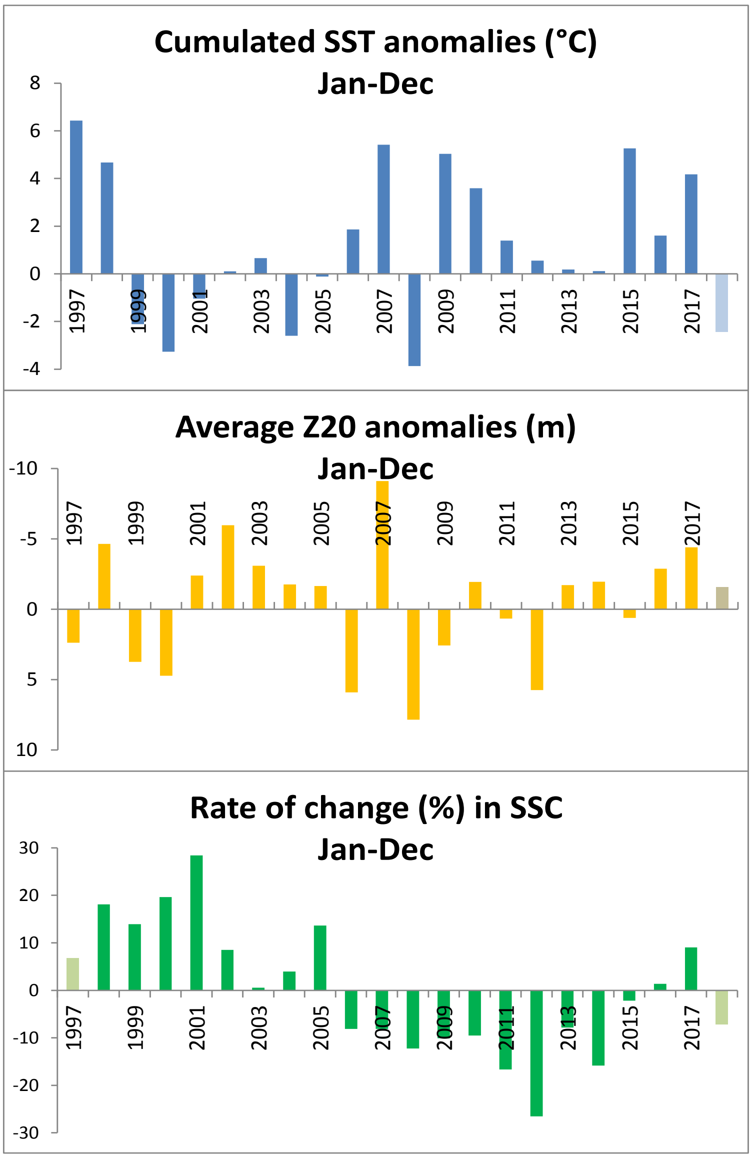


Fig. 5 – Maps of the five study areas (top)
and example of bar plots for Maldives, 1997-2018 (bottom)