



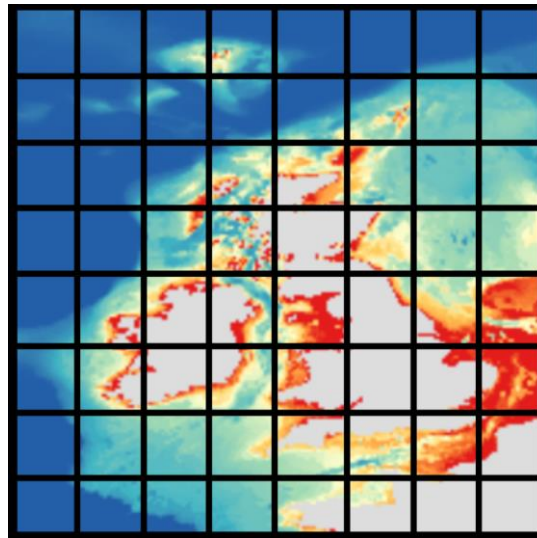
Salvador Fernández - Flanders Marine Institute - Data Centre

## **Bio-Oracle v3.0: Towards the next-gen data for marine ecological modelling**

# What is Bio-Oracle?

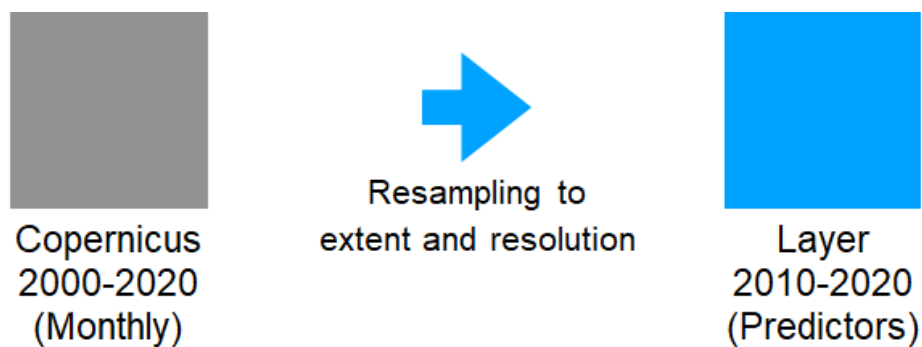


**Bio-ORACLE** is a set of **GIS rasters** providing geophysical, biotic and environmental data for surface and benthic **marine** realms.



## What is Bio-Oracle?

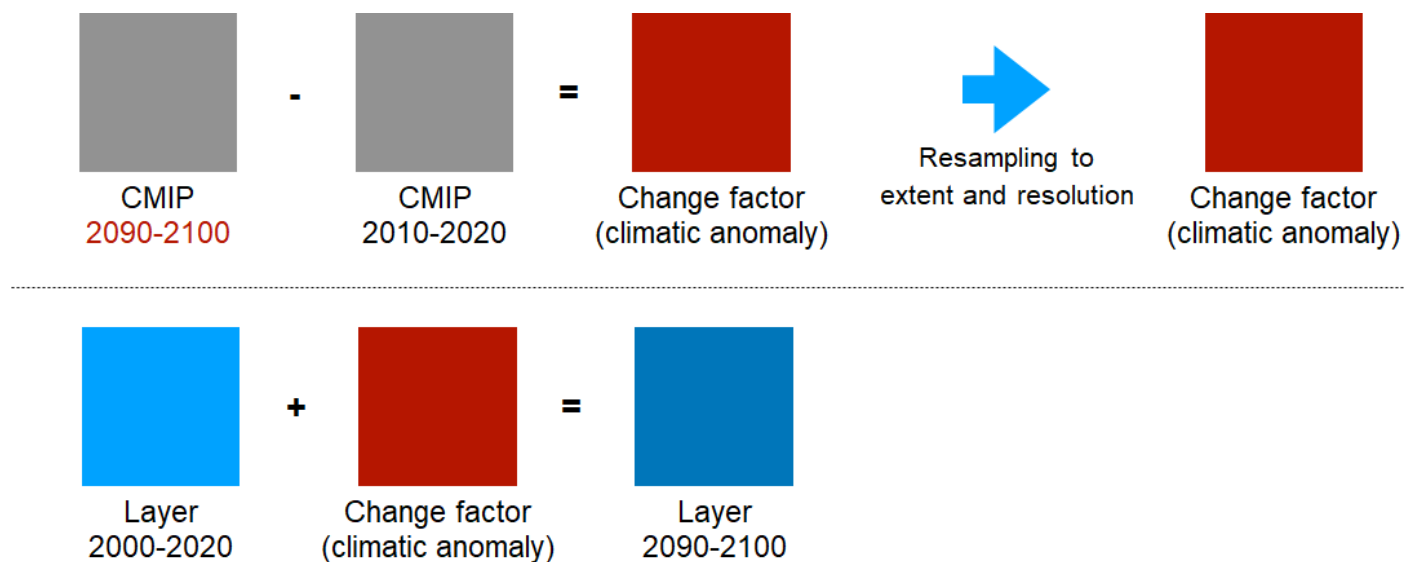
**R functions** resample raw data to a desired extent, resolution and time period, by Inverse Distance Weighting (IDW) Interpolation



Predictors for **present-day conditions** (baseline for model fitting) resampled by direct IDW;  
**e.g., Maximum sea surface temperature of the decade 2010-2020 inferred from monthly Copernicus data**

## What is Bio-Oracle?

For climate change projections, **the change-factor technique** based on applying the projects magnitude of change to the layers produced for the present.

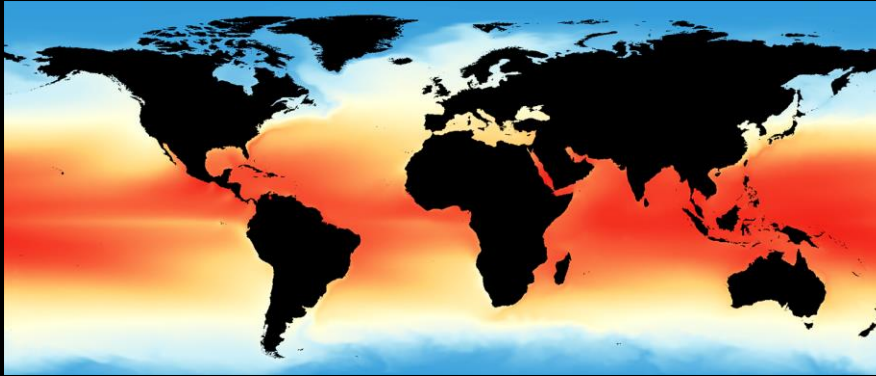


Predictors for **present-day conditions** (baseline for model fitting) resampled by direct IDW;

**e.g., Maximum sea surface temperature of the decade 2010-2020 inferred from monthly Copernicus data**

What is Bio-Oracle?

## There are 18 environmental predictors



**Temperature**

**Salinity**

**Sea Ice Cover**

**Sea Ice Thickness**

**Sea Water Velocity**

**Mixed Layer Depth**

**Diffuse Attenuation Coefficient**

**Photosynthetically Active Radiation**

**PAR at Bottom**

**Oxygen**

**pH**

**Iron**

**Phosphate**

**Nitrate**

**Silicate**

**Primary Production**

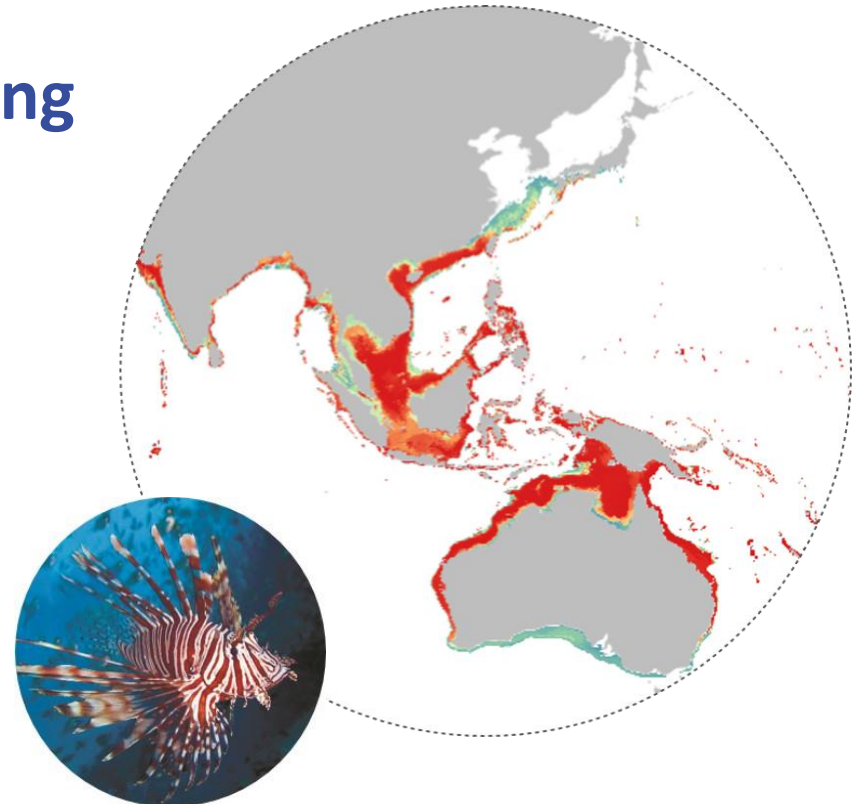
**Phytoplankton**

**Chlorophyll**

# What is the potential of Bio-Oracle?

**Bio-ORACLE** is designed for  
**Species Distribution Modelling**

E.g. predicted distribution of  
the lion fish *Pterois volitans*



## Previously on Bio-Oracle

### Version 1

- 2013 
- 13 predictors
- Surface-Only
- Present-Only
- 4 calculated values:
  - min, mean, max
  - range
- 744 citations

doi: 10.1111/j.1466-8238.2011.00656.x

A Journal of Macroecology

Global Ecology and Biogeography, (Global Ecol. Biogeogr.) (2012) 21, 272–281

**RESEARCH PAPER**



**Bio-ORACLE: a global environmental dataset for marine species distribution modelling**

Lennert Tyberghein<sup>1</sup>\*, Heroen Verbruggen<sup>1</sup>, Klaas Pauly<sup>1</sup>, Charles Troupin<sup>2</sup>, Frederic Mineur<sup>3</sup> and Olivier De Clerck<sup>1</sup>

<sup>1</sup>Phycology Research Group, Biology Department, Ghent University, Krijgslaan 281 S8, 9000 Ghent, Belgium, <sup>2</sup>GeoHydrodynamics and Environment Research (B5a), Université de Liège, Allée du 6 Août 17, B4000 Liège, Belgium, <sup>3</sup>School of Biological Sciences, Queen's University Belfast, 97 Lisburn Road, Belfast BT9 7BL, UK

**ABSTRACT**

**Aim** The oceans harbour a great diversity of organisms whose distribution and ecological preferences are often poorly understood. Species distribution modelling (SDM) could improve our knowledge and inform marine ecosystem management and conservation. Although marine environmental data are available from various sources, there are currently no user-friendly, high-resolution global datasets designed for SDM applications. This study aims to fill this gap by assembling a comprehensive, uniform, high-resolution and readily usable package of global environmental rasters.

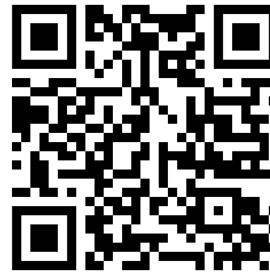
**Location** Global, marine.

**Methods** We compiled global coverage data, e.g. satellite-based and *in situ* measured data, representing various aspects of the marine environment relevant for species distributions. Rasters were assembled at a resolution of 5 arcmin (c. 9.2 km) and a uniform landmask was applied. The utility of the dataset was evaluated by maximum entropy SDM of the invasive seaweed *Codium fragile* ssp. *fragile*.

**Results** We present Bio-ORACLE (ocean rasters for analysis of climate and environment), a global dataset consisting of 23 geophysical, biotic and climate rasters. This user-friendly data package for marine species distribution modelling is available for download at <http://www.bio-oracle.ugent.be>. The high predictive power of the distribution model of *C. fragile* ssp. *fragile* clearly illustrates the potential of the data package for SDM of shallow-water marine organisms.

**Main conclusions** The availability of this global environmental data package has the potential to stimulate marine SDM. The high predictive success of the presence-only model of a notorious invasive seaweed shows that the information contained in Bio-ORACLE can be informative about marine distributions and permits building highly accurate species distribution models.


**Keywords** Bio-ORACLE, *Codium fragile*, ecological niche modelling, environmental data, global, macroecology, marine, oceanography, species distribution modelling.



\*Correspondence: Lennert Tyberghein, Phycology Research Group, Biology Department, Ghent University, Krijgslaan 281 (S8), 9000 Ghent, Belgium.  
E-mail: [lennert.tyberghein@ugent.be](mailto:lennert.tyberghein@ugent.be)

## Previously on Bio-Oracle

### Version 2

- 2017 
- 18 predictors
- Surface and Benthic realms
- Present and future predictions
- 7 calculated values:
  - min, mean, max
  - long-term min, mean, max
  - Range
- 459 citations

doi: 10.1111/geb.12693


Received: 26 July 2017 | Revised: 13 October 2017 | Accepted: 26 October 2017  
DOI: 10.1111/geb.12693

#### DATA PAPER

WILEY Global Ecology  
and Biogeography

A Journal of  
Macroecology

### Bio-ORACLE v2.0: Extending marine data layers for bioclimatic modelling

Jorge Assis<sup>1</sup>  | Lennert Tyberghein<sup>2</sup> | Samuel Bosch<sup>2,3</sup> | Heroen Verbruggen<sup>4</sup> | Ester A. Serrão<sup>1</sup> | Olivier De Clerck<sup>3</sup>

<sup>1</sup>Centre for Marine Sciences, CCMAR-CIMAR, University of Algarve, Faro, Portugal

<sup>2</sup>Flanders Marine Institute (VLIZ), InnovOcean site, Ostend, Belgium

<sup>3</sup>Phycology Research Group, Biology Department, Ghent University, Ghent, Belgium

<sup>4</sup>School of BioSciences, University of Melbourne, Melbourne, Victoria, Australia

**Correspondence**  
Jorge Assis, Centre for Marine Sciences, CCMAR-CIMAR, University of Algarve, Campus Gambelas, 8005-139 Faro, Portugal.  
Email: jorgemfa@gmail.com

#### Abstract

**Motivation:** The availability of user-friendly, high-resolution global environmental datasets is crucial for bioclimatic modelling. For terrestrial environments, WorldClim has served this purpose since 2005, but equivalent marine data only became available in 2012, with pioneer initiatives like Bio-ORACLE providing data layers for several ecologically relevant variables. Currently, the available marine data packages have not yet been updated to the most recent Intergovernmental Panel on Climate Change (IPCC) predictions nor to present times, and are mostly restricted to the top surface layer of the oceans, precluding the modelling of a large fraction of the benthic diversity that inhabits deeper habitats. To address this gap, we present a significant update of Bio-ORACLE for new future climate scenarios, present-day conditions and benthic layers (near sea bottom). The reliability of data layers was assessed using a cross-validation framework against in situ quality-controlled data. This test showed a generally good agreement between our data layers and the global climatic patterns. We also provide a package of functions in the R software environment (*sdmpredictors*) to facilitate listing, extraction and management of data layers and allow easy integration with the available pipelines for bioclimatic modelling.

**Main types of variable contained:** Surface and benthic layers for water temperature, salinity, nutrients, chlorophyll, sea ice, current velocity, phytoplankton, primary productivity, iron and light at bottom.

**Spatial location and grain:** Global at 5 arcmin (c. 0.08° or 9.2 km at the equator).

**Time period and grain:** Present (2000–2014) and future (2040–2050 and 2090–2100) environmental conditions based on monthly averages.

**Major taxa and level of measurement:** Marine biodiversity associated with sea surface and epibenthic habitats.

**Software format:** ASCII and TIFF grid formats for geographical information systems and a package of functions developed for R software.








## What's new in Bio-Oracle v3?

## Some things stay the same

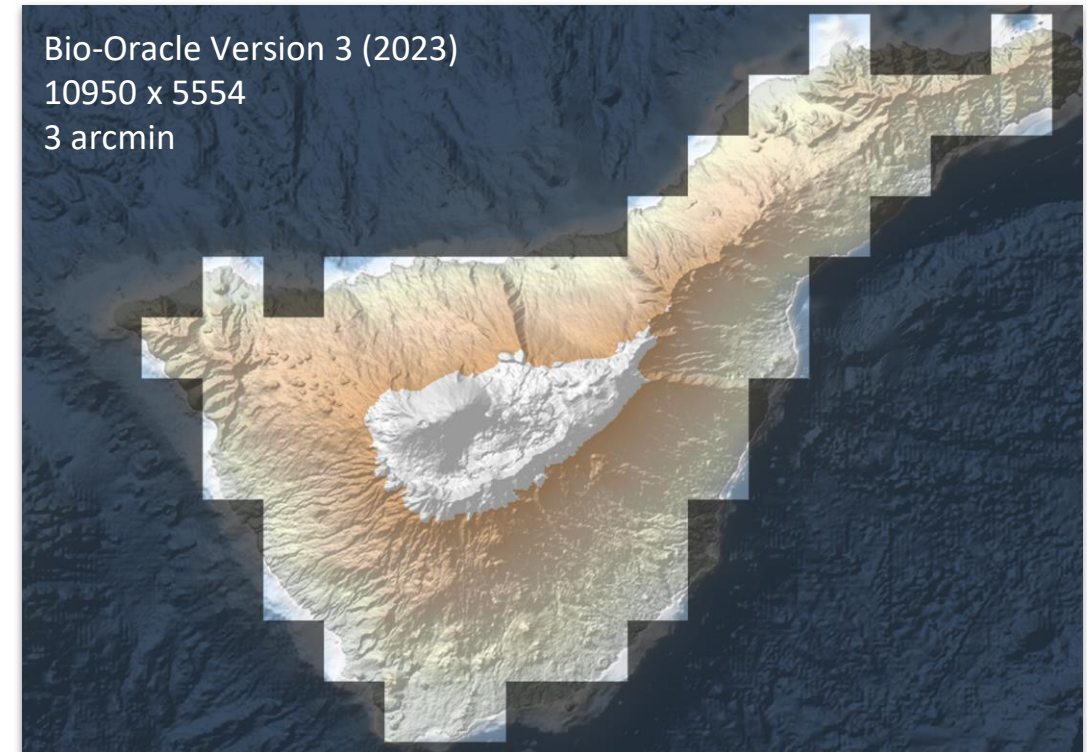
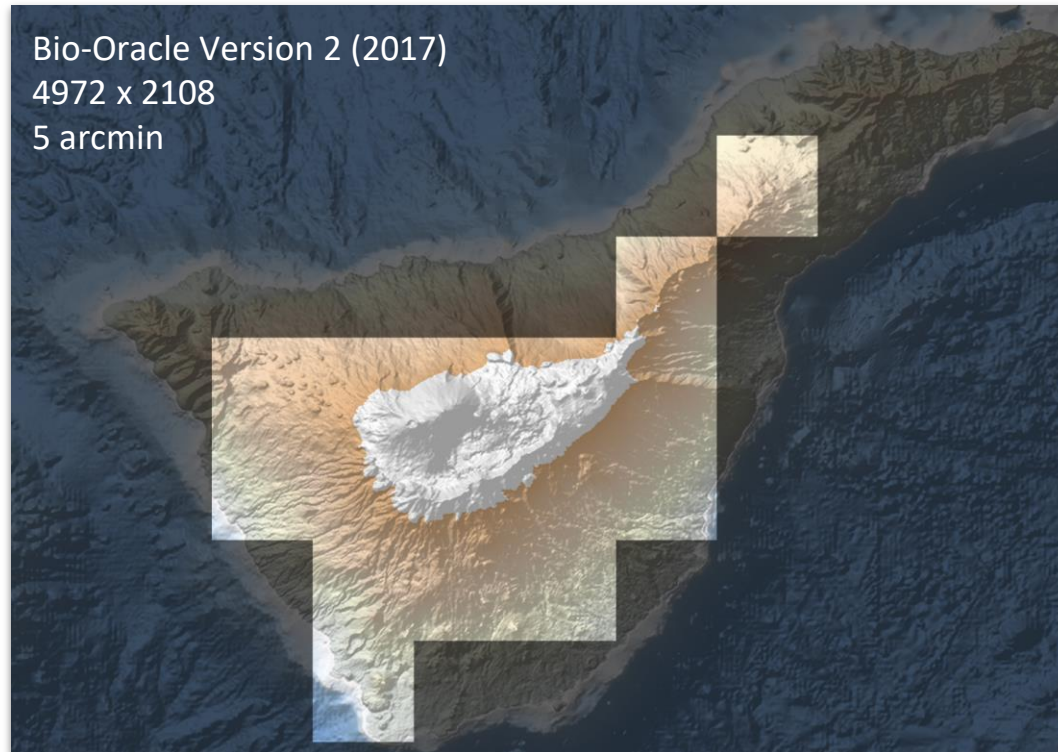
### Version 3

- 2023 
- 18 predictors
- Surface and Benthic realms
- Present and future predictions
- 7 calculated values:
  - min, mean, max
  - long-term min, mean, max
  - range

**But**

What's new in Bio-Oracle v3?

## Higher spatial resolution



## Temporal resolution: 10 decades

### Bio-Oracle Version 2 (2017)

- 2000 - 2013
- 2014 - 2050
- 2050 - 2100

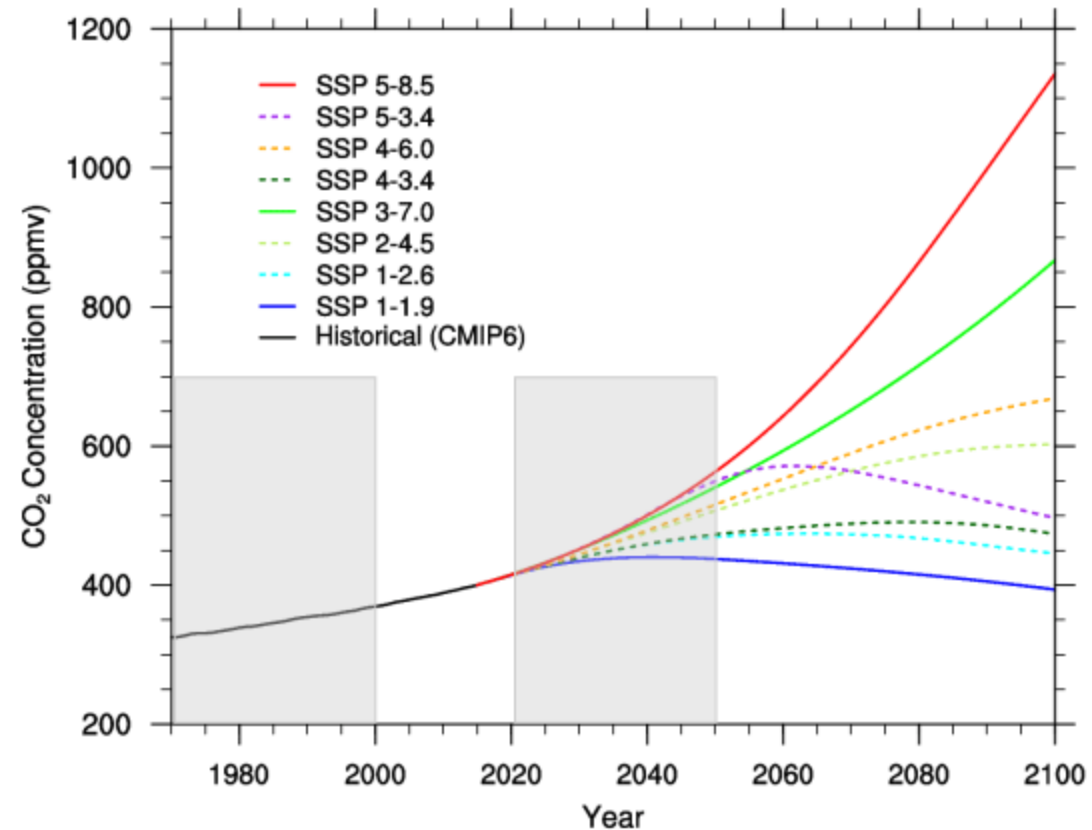


### Bio-Oracle Version 3 (2023)

- 2000 - 2009
- 2010 - 2019
- 2020 - 2029
- 2030 - 2039
- 2040 - 2049
- 2050 - 2059
- 2060 - 2069
- 2070 - 2079
- 2080 - 2089
- 2090 - 2100

## Shared Socioeconomic Pathways (SSP)

- Based on latest IPCC Report 6
- Six SSPs modelled:
  - SSP 1-1.9
  - SSP 1-2.6
  - SSP 2-4.5
  - SSP 3-7.0
  - SSP 4-6.0
  - SSP 5-8.5



Drugé et al, (2021). Future evolution of aerosols and implications for climate change in the Euro-Mediterranean region using the CNRM-ALADIN63 regional climate model. *Atmos. Chem. Phys.*, 21, 7639–7669, <https://doi.org/10.5194/acp-21-7639-2021>

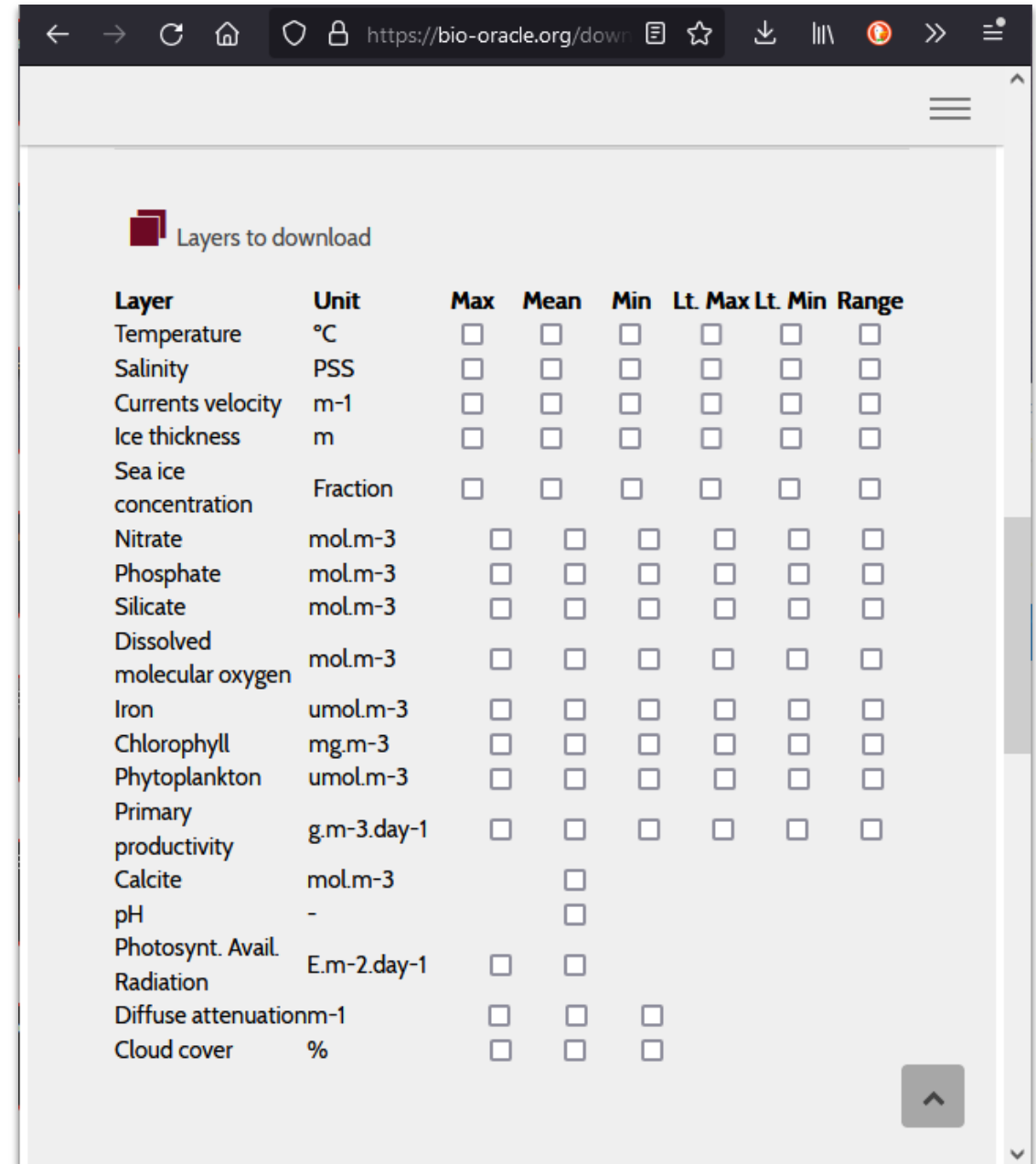


## Accessing Bio-Oracle v3



## Direct download

- bio-oracle.org
- User-Friendly
- GIS-Ready .geotif and .asc files
  - QGIS
  - ArcGIS
  - etc.



The screenshot shows a web browser window with the URL <https://bio-oracle.org/download>. The page title is "Layers to download". It contains a table with columns: Layer, Unit, Max, Mean, Min, Lt. Max, Lt. Min, and Range. Each cell in the table has a checkbox for selection.

Layer	Unit	Max	Mean	Min	Lt. Max	Lt. Min	Range
Temperature	°C	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Salinity	PSS	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Currents velocity	m-1	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Ice thickness	m	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Sea ice concentration	Fraction	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Nitrate	mol.m-3	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Phosphate	mol.m-3	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Silicate	mol.m-3	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Dissolved molecular oxygen	mol.m-3	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Iron	umol.m-3	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Chlorophyll	mg.m-3	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Phytoplankton	umol.m-3	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Primary productivity	g.m-3.day-1	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Calcite	mol.m-3		<input type="checkbox"/>				
pH	-		<input type="checkbox"/>				
Photosynt. Avail.	E.m-2.day-1	<input type="checkbox"/>	<input type="checkbox"/>				
Radiation							
Diffuse attenuation	m-1	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>			
Cloud cover	%	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>			

## ERDDAP Data Server

A data server that downloads subsets of the Bio-Oracle dataset in many common file formats.

- Native format: NetCDF (.nc)
- Output formats: .nc, .csv, .tif, .asc ...
- Extra web services:
  - REST API
  - Web Map Service

### ERDDAP > griddap > Data Access Form

Dataset Title: **Bio-Oracle OceanTemperature [depthSurf]**. [✉](#) [RSS](#)

Institution: Bio-Oracle consortium: <https://www.bio-oracle.org> (Dataset ID: biooracle\_or\_ds3)

Information: [Summary](#) | [License](#) | [FGDC](#) | [ISO 19115](#) | [Metadata](#) | [Background](#) | [Files](#) | [Make a graph](#)

Dimensions	Start	Stride	Stop	Size	Spacing
<input checked="" type="checkbox"/> time (UTC)	2019-01-01T00:00:00Z	1	2019-01-01T00:00:00Z	20	365 days 6h 18m 57s (uneven)
<input checked="" type="checkbox"/> latitude (degrees_north)	-90.0	1	90.0	720	0.2503477 (even)
<input checked="" type="checkbox"/> longitude (degrees_east)	-180.0	1	180.0	1440	0.2501737 (even)

Grid Variables (which always also download all of the dimension variables) [Check All](#) [Uncheck All](#)

- ☒ thetao\_max (Maximum OceanTemperature, degree\_C)
- ☒ thetao\_mean (Average OceanTemperature, degree\_C)
- ☒ thetao\_min (Minimum OceanTemperature, degree\_C)

File type: [\(more information\)](#)

.htmlTable - View a UTF-8 .html web page with the data in a table. Times are ISO 8601 strings.

Just generate the URL:

[\(Documentation / Bypass this form\)](#)

**Submit** (Please be patient. It may take a while to get the data.)

### The Dataset Attribute Structure (.das) for this Dataset

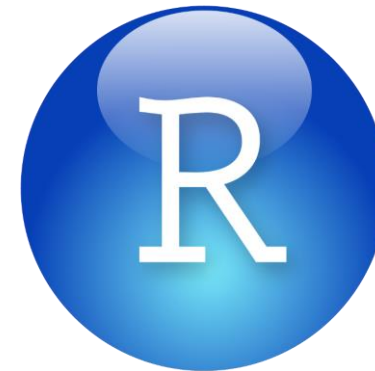
```
Attributes {
  time {
    String _CoordinateAxisType "Time";
    Float64 actual_range 9.466848e+8, 1.5463008e+9;
```



## Python and R clients



- `pyo-oracle`
- Install with `pip/conda`
- Based on `erddapy`



- `bioracler`
- Install with CRAN
- Based on `rerrdap`
- Cohabits `sdmpredictors`

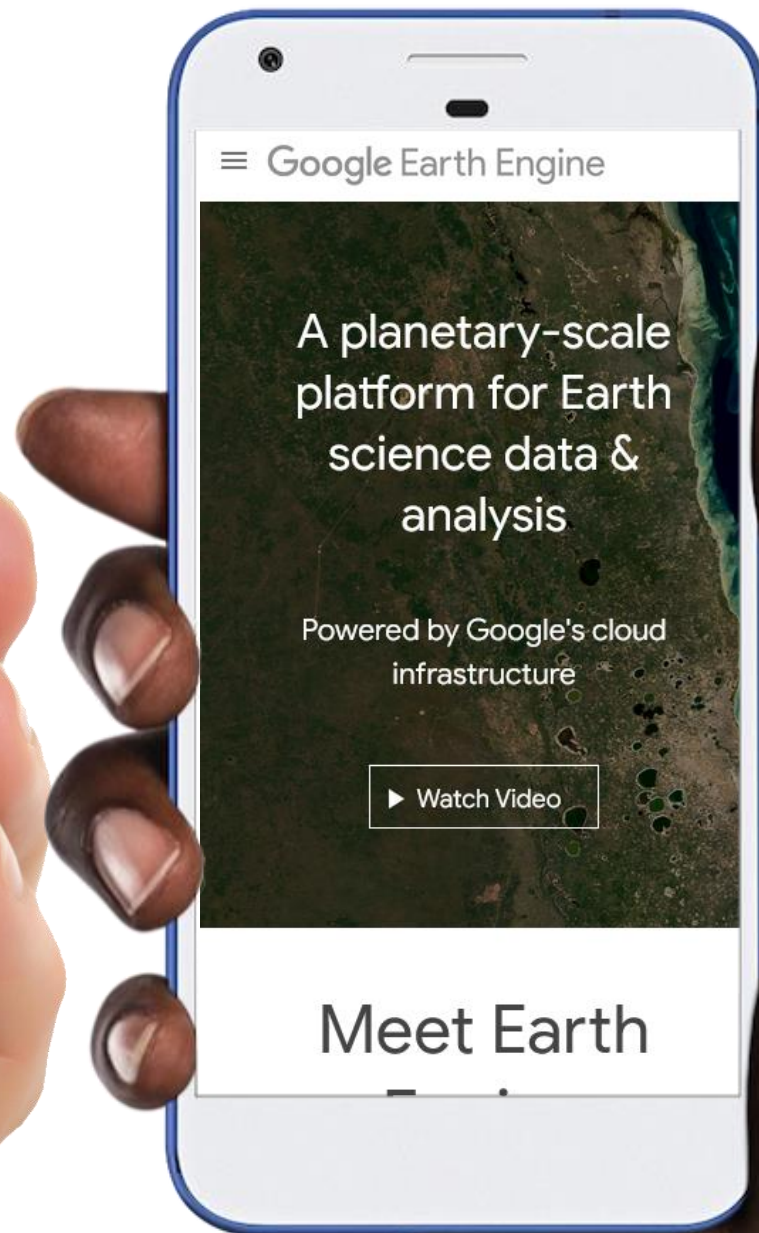
**Main purpose: download bio-oracle dataset with subsetting capacities**

`github.com/bio-oracle`



Accessing Bio-Oracle v3

## Digital Twins





# June 2023

info@bio-oracle.org | <https://bio-oracle.org>



Salvador Fernández

Fred Leclercq

Bart Vanhoorne

Lennert Schepers

Lennert Tyberghein



Jorge Assis

Ester Serrão



Vinícius Salazar

Heroen Verbruggen



Olivier De Clerck

