

#MarineData4SouthAmerica

QGIS Exercises

Data & Tools for  
characterizing the Amazon  
River Plume



**Stefania A. Ciliberti**

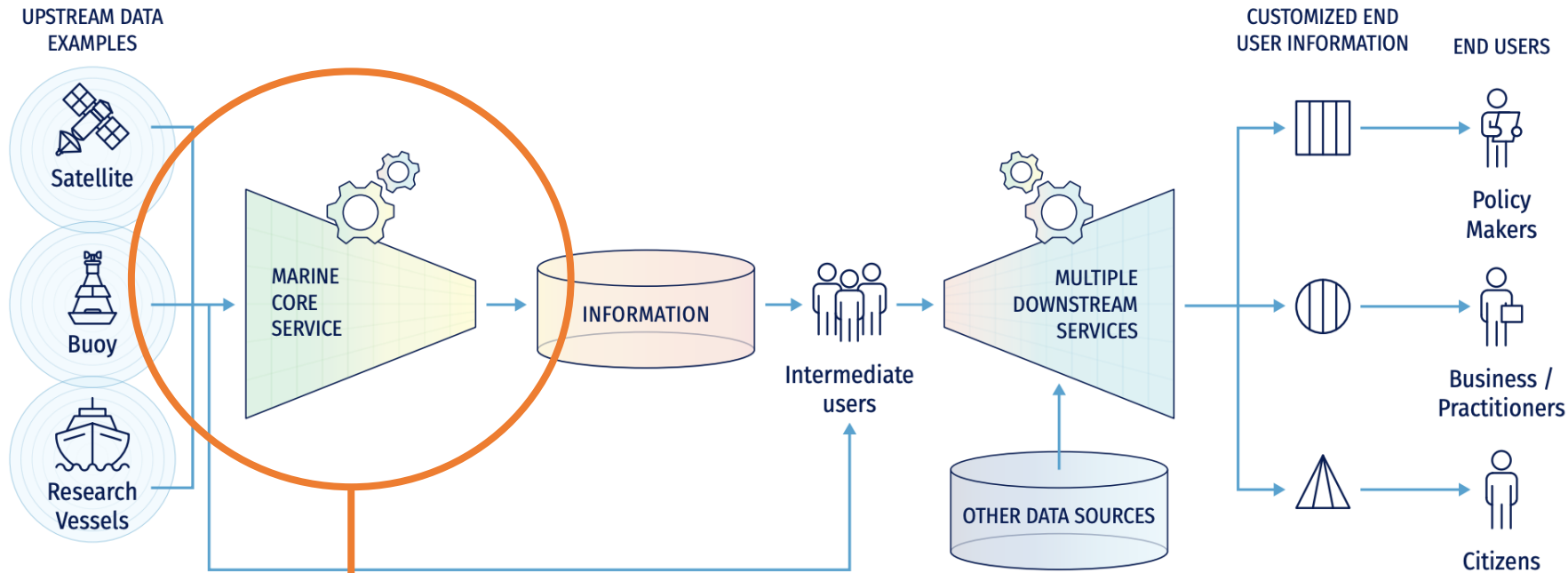
*Nologin Oceanic Weather Systems*



# Outline

- Introduction to QGIS and Copernicus Marine products
- Discussion on implemented workflow for ocean data analysis using QGIS
- Summary of the main results
- References

# Operational Ocean Value Chain



**Copernicus Marine Service**

Implemented by

**MERCATOR OCEAN INTERNATIONAL**

Logos for the European Union, Copernicus (Europe's eyes on Earth), and Mercator Ocean International are also present.

Geospatial Data Management

Data Analysis

Data Science for the Ocean

# How to perform Geospatial Analysis of Copernicus Marine Data?

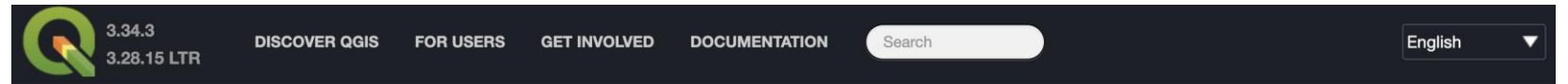
**QGIS** is a **Geographical Information System** that provides **basic** and **advanced** functionalities that are helpful for managing and analyzing Copernicus Marine products:

- View data
- Explore data and compose maps
- Create, edit, manage and export data
- Analyze data
- Publish maps on the Internet
- Extend QGIS functions through plugins
- Python Console

The QGIS logo is displayed in a white box with a dark border. It consists of the letters 'QGIS' in a bold, green, sans-serif font. The letter 'Q' is stylized with a red and orange gradient.

# QGIS Installation: an introduction

<https://qgis.org/en/site/index.html>



## Standalone installation:

- Last developed version: **QGIS 3.34 Prizren**
- Long Term Release: **QGIS 3.28 Firenze** (used in this training!)

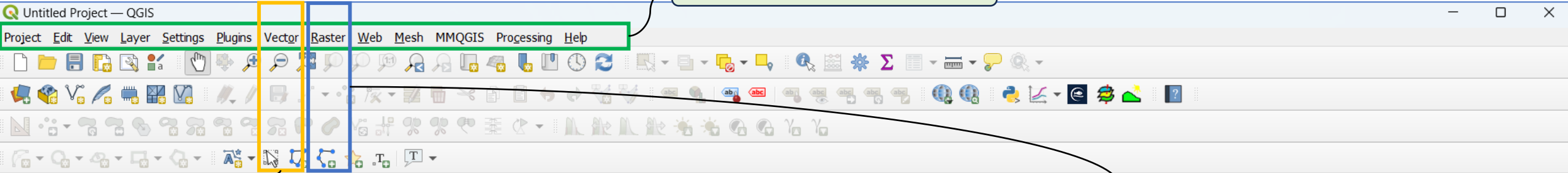
## Advanced installation:

- OSGeo4W: it is recommended for regular users or organization deployments. It allows to have several QGIS versions in one place, and to keep each component up-to-date individually without having to download the whole package.



Create, edit, visualise, analyse and publish geospatial information on Windows, macOS, Linux, BSD and mobile devices

Access to QGIS features



- Most common feature in QGIS.
- **Vector** model represents the **location and shape of geographic features** using points, lines and polygons (and for 3D data also surfaces and volumes), while their other properties are included as attributes (often presented as a table in QGIS).

- **Rasters** are made up of a **matrix of pixels** (also called cells), each containing a value that represents the conditions for the area covered by that cell

### Vector

Menu Option	Shortcut	Reference	Toolbar
<a href="#">OpenStreetMap</a> ▾		see <a href="#">Importing OpenStreetMap Vectors</a>	
<a href="#">Analysis Tools</a> ▾		see <a href="#">Vector menu</a>	
<a href="#">Research Tools</a> ▾		see <a href="#">Vector menu</a>	
<a href="#">Geoprocessing Tools</a> ▾		see <a href="#">Vector menu</a>	
<a href="#">Geometry Tools</a> ▾		see <a href="#">Vector menu</a>	
<a href="#">Data Management Tools</a> ▾		see <a href="#">Vector menu</a>	

### Raster

Menu Option	Shortcut	Reference	Toolbar
<a href="#">Raster calculator...</a>		see <a href="#">Raster Calculator</a>	
<a href="#">Align Raster...</a>		see <a href="#">Raster Alignment</a>	
<a href="#">Analysis</a> ▾		see <a href="#">GDAL Tools Plugin</a>	
<a href="#">Projection</a> ▾		see <a href="#">GDAL Tools Plugin</a>	
<a href="#">Conversion</a> ▾		see <a href="#">GDAL Tools Plugin</a>	
<a href="#">Miscellaneous</a> ▾		see <a href="#">GDAL Tools Plugin</a>	
<a href="#">Extraction</a> ▾		see <a href="#">GDAL Tools Plugin</a>	



Source: <https://events.marine.copernicus.eu/marinedata4southamerica-2024/content/qgis>

## E-Learning Materials

Access our tutorials online, accompanied by videos, code, and more.

# MarineData4SouthAmerica QGIS

#MarineData4SouthAmerica

## Practical Session Guidelines

This guide includes a few steps you will need to take to start your QGIS practice!

[Guidelines](#)



### STEP 1: download open-source software

If you don't have access to a QGIS software yet, download the open-source software

[Download](#)



### STEP 2: Download Copernicus Marine QGIS Plugin

To open NetCDF files, which is the file format of Copernicus Marine Service products, in QGIS you will need to download the Copernicus Marine Service QGIS Plugin CMEMS-NetCDF

[Plugin](#)



**Stefania Ciliberti**  
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## Installation Notes

## QGIS Installation notes

This video presents basic steps on how to download and install QGIS in your computer using the standalone installer and the OSGeo4W advanced one. Examples are given for Windows OS. You can also download the PDF by clicking on the following button:

[Download PDF](#)



# Copernicus Marine NetCDF Plugin

**1** Add a NetCDF by browsing among the list of files available in your local archive (shown in the figure below). Once selected, this is automatically loaded by the application.

**2** Select the variable to load by doing right click (in this case, "so").

**3** Add the selected variable as layer in QGIS. It opens the window below...

**4**

**5**

**CMEMS NetCDF File Managemer**

NetCDF Layers

#	Name	Path
0	cmems_m	D:/MarineData_Feb2024/data/GLO-PHY-...

Variables Meta-data Options About

Name	Dimensions	Unit	Long name
depth	depth		
latitude	latitude		
longitude	longitude		
sea_water_salinity	depth, latitude, longitude		
time	time	seconds si...	time

so Add Layers Sequence Layers

Dialog

NetCDF Variable SO

id	Dates
0	01-06-2023 00:00

id	Depths
0	0.49

Group: so  Overwrite group

Min /Max for each la  Min/Max of all laye

Palette: spectral  Reverse

Add Add and Close

Select NetCDF file

Elements (D:) > MarineData\_Feb2024 > data > GLO-PHY-NRT

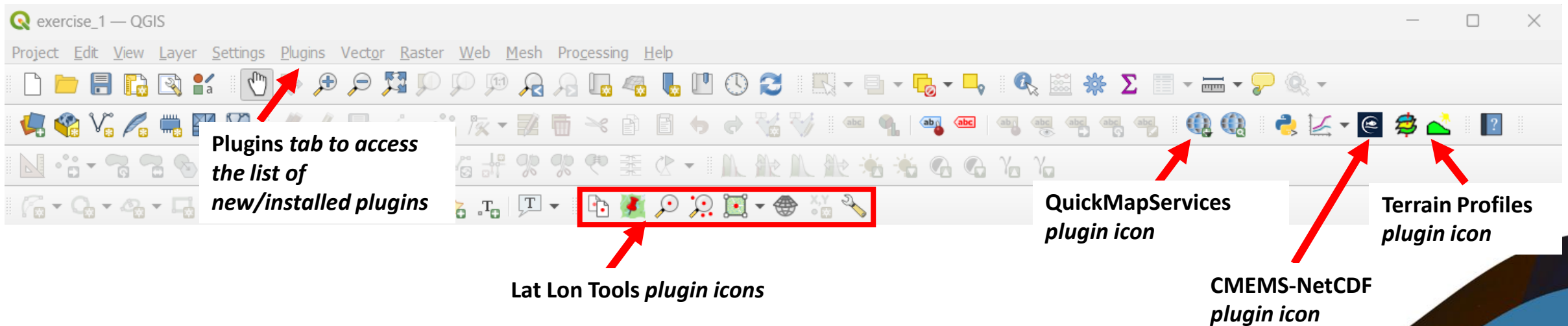
Nome	Ultima modifica	Tipo	Dimensione
cmems_mod_glo_phy-cur_anfc_0.083deg_P1M-m_Jun-2023.nc	18/02/2024 12:18	File NC	1,144 KB
cmems_mod_glo_phy-so_anfc_0.083deg_P1M-m_Jun-2021.nc	18/02/2024 12:31	File NC	578 KB
cmems_mod_glo_phy-so_anfc_0.083deg_P1M-m_Jun-2023.nc	18/02/2024 12:29	File NC	578 KB

Nome file: cmems\_mod\_glo\_phy-so\_anfc\_0.083deg\_P1M-m\_Jun-2023.nc (\*.nc)

Apri Annulla

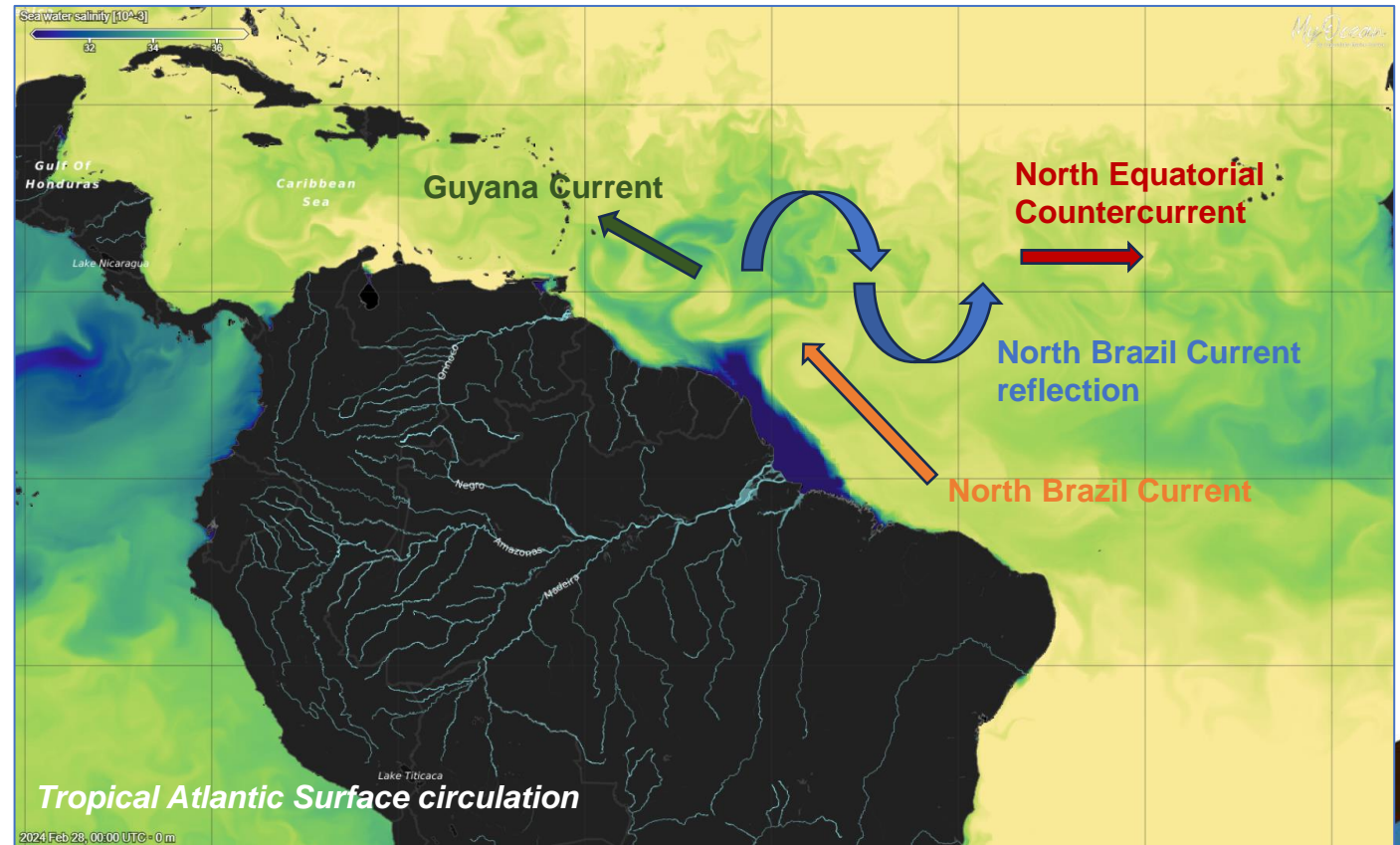
# Additional Plugins used in this Training

- **QuickMapService**, for loading a basemap (e.g., Google, ESRI, etc.)
- **Lat Lon Tools**, for querying the map and facilitating the creation of bounding box by identifying its coordinates
- **Terrain Profile**, for extracting sections/transects in interactive way



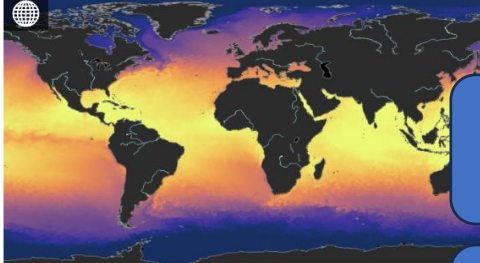
# Scope of the Training Session

- Visualize the Copernicus Marine products in the **Western Tropical Atlantic**, extracting Essential Ocean Variables (EOV) values in same specific locations.
- Perform a geospatial analysis of physical and biogeochemical conditions in the **Amazon River plume region** and in its delta.



*Schematic representation of surface circulation affecting the Amazon River Plume adapted from Gouveia et al. 2019.*

# Upstream Data used in QGIS



Sea Surface Salinity –  
*Monthly Mean*

**Global Ocean Physics Analysis and Forecast**

GLOBAL\_ANALYSISFORECAST\_PHY\_001\_024

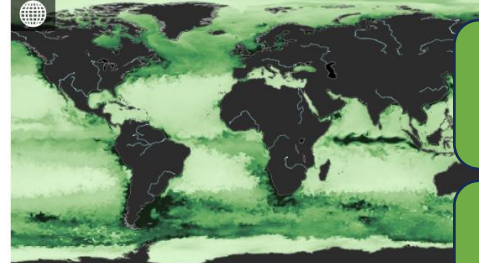
Models

Global, 0.083° × 0.083° × 50 levels

1 Nov 2020 to 3 Mar 2024, hourly, daily, monthly

Mixed layer thickness, salinity, sea ice, sea surface height, temperature, velocity, wave

Sea Surface Currents –  
*Monthly Mean*



Surface Chlorophyll –  
*Monthly Mean*

**Global Ocean Biogeochemistry Analysis and Forecast**

GLOBAL\_ANALYSISFORECAST\_BGC\_001\_028

Models

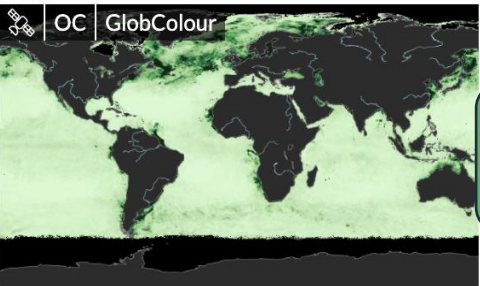
Global, 0.25° × 0.25° × 50 levels

1 Oct 2021 to 1 Mar 2024, daily, monthly

Carbonate system, nutrients, optics, oxygen, plankton

Surface Phytoplankton –  
*Monthly Mean*

Dissolved Oxygen –  
*Monthly Mean*



Surface Chlorophyll at  
300 m res. - *Monthly*

**Global Ocean Colour (Copernicus-GlobColour), Bio-Geo-Chemical, L4...**

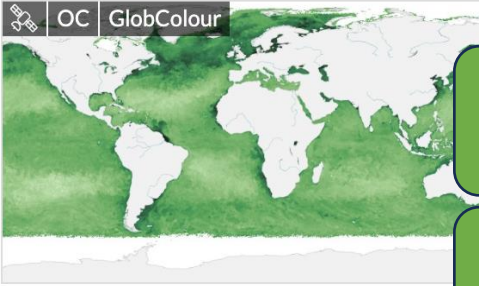
OCEANCOLOUR\_GLO\_BGC\_L4\_NRT\_009\_102

Satellite (L4)

Global, 4 × 4 km

1 Apr 2023 to 21 Feb 2024, daily, monthly

Optics, plankton



Surface Chlorophyll at  
300 m res. - *Monthly*

Surface Chlorophyll at  
4 km res. - *Monthly*

**Global Ocean Colour (Copernicus-GlobColour), Bio-Geo-Chemical, L4...**

OCEANCOLOUR\_GLO\_BGC\_L4\_MY\_009\_104

Satellite (L4)

Global, 4 × 4 km

1 Sep 1997 to 14 Feb 2024, daily, monthly

Optics, plankton

# Exercise 1: Visualization of Copernicus Marine EOV

Sea Surface Currents –  
Monthly Mean

- To visualize EOV from Copernicus Marine Catalogue in QGIS, we use the **CMEMS NetCDF** plugin.

The screenshot shows the NetCDF2GIS application window. The 'Variables' table is visible, listing variables like 'depth', 'latitude', 'longitude', 'time', 'eastward\_sea\_water\_velocity', and 'northward\_sea\_water\_velocity'. The 'Layers' panel shows selected variables 'vo\_01062023-0000\_0.4' and 'uo\_01062023-0000\_0.4'. A context menu is open over these layers, with 'Vectorize' selected. A 'Dialog' window titled 'Vectorize Rasters' is also shown, with settings for Layer U, Layer V, Norm (Current), Downsampling (x10), and Output Directory (D:/MarineData\_Feb2024/exercise\_1).

Name	Dimensions	Unit	Long name
depth	depth	m	depth
latitude	latitude	degrees_no...	latitude
longitude	longitude	degrees_east	longitude
time	time	seconds si...	time
eastward_sea_water_velocity	time depth latitude	m s-1	eastward_sea_water_velocity
northward_sea_water_velocity	time depth latitude	m s-1	northward_sea_water_velocity

Name	Group	NC #
so_01062023-0000_0.4	so	1
vo_01062023-0000_0.4	vo	2
uo_01062023-0000_0.4	uo	2

“Vectorize” opens a new dialog window where to specify:

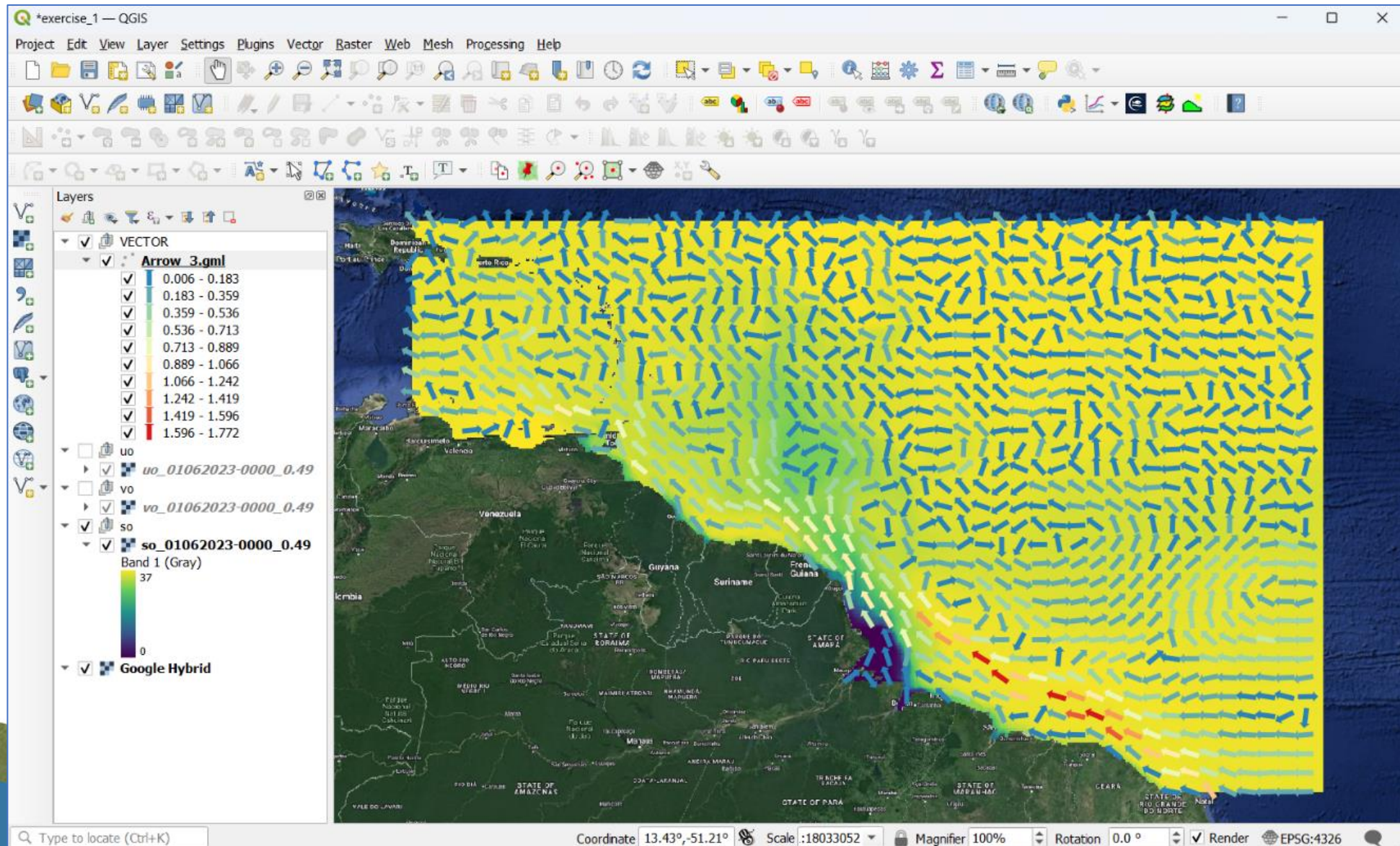
- The raster related to U component (uo)
- The raster related to V component (vo)
- The type of normalization (Current)
- The arrows sampling (x10 in this case)
- Output directory and output raster name

Select both uo and vo by clicking **ctrl + uo\_\*** and **vo\_\*** simultaneously.  
Do right click on the multiple selection and select “Vectorize”



# Exercise 1: Visualization of Copernicus Marine EOVS

Sea Surface Currents –  
Monthly Mean



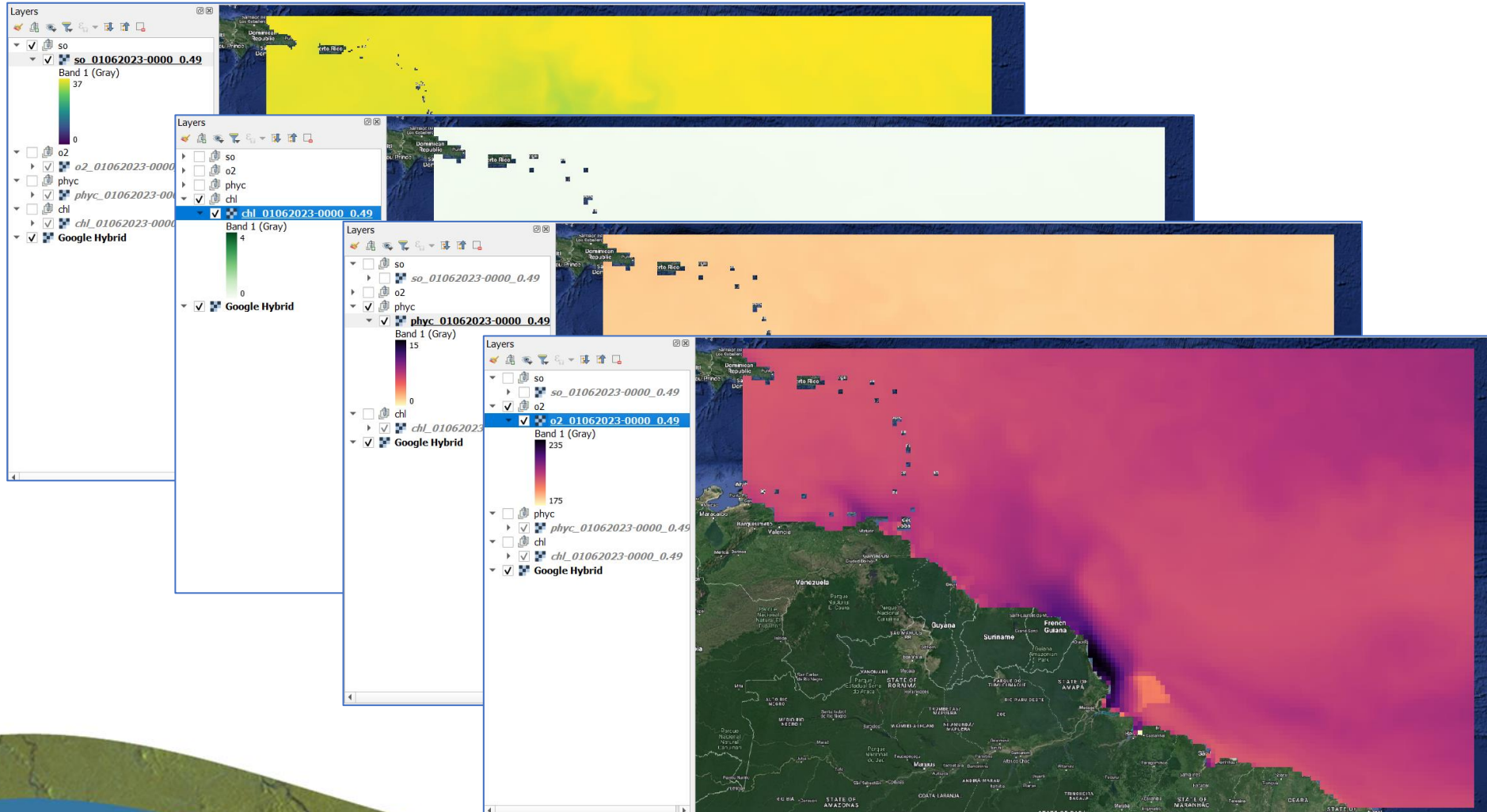
# Exercise 2: Characterization of the physical & biogeochemical sea state in Jun 2023

Sea Surface Salinity –  
Monthly Mean

Surface Chlorophyll –  
Monthly Mean

Surface Phytoplankton  
– Monthly Mean

Dissolved Oxygen –  
Monthly Mean



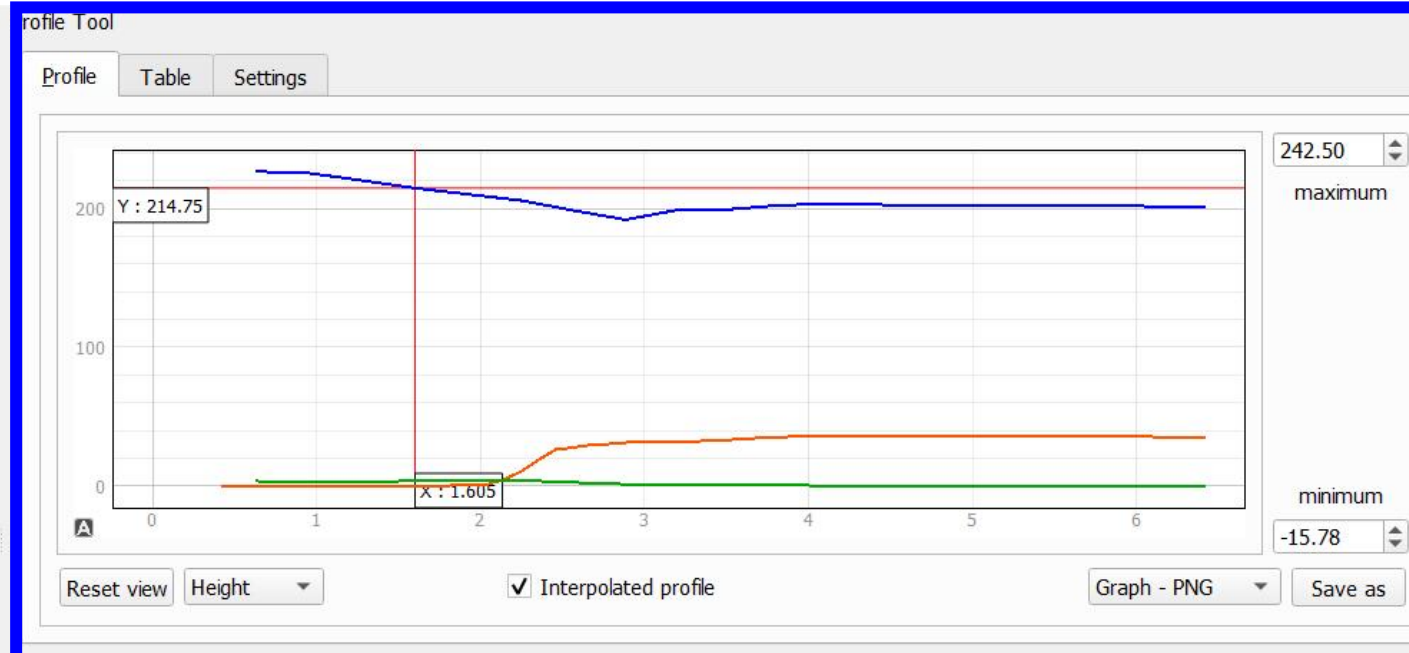
# Exercise 2: Characterization of the physical & biogeochemical sea state in Jun 2023

- To extract EOVS spatial variability along a specific section *on the fly*, we use the **Terrain Profiles plugin**.

Layers

- so
  - so\_01062023-0000\_0.49
- o2
  - o2\_01062023-0000\_0.49
- phyc
  - phyc\_01062023-0000\_0.49
- chl
  - chl\_01062023-0000\_0.49
- Google Hybrid

List of active layers



	Layer	Band/Field	Search
1	o2_01062023-0...	1	
2	so_01062023-0...	1	
3	chl_01062023-0...	1	

Add Layer Remove Layer

Options

Selection

Show cursor

Same axis st

Once selected from the Layer board, the active layers are loaded in the Terrain Profile tool and ready to be queried



# Exercise 2: Characterization of the physical & biogeochemical sea state in Jun 2023

- To extract EOV spatial variability along specific transects, we use the **Transects QGIS function**.

## Workflow

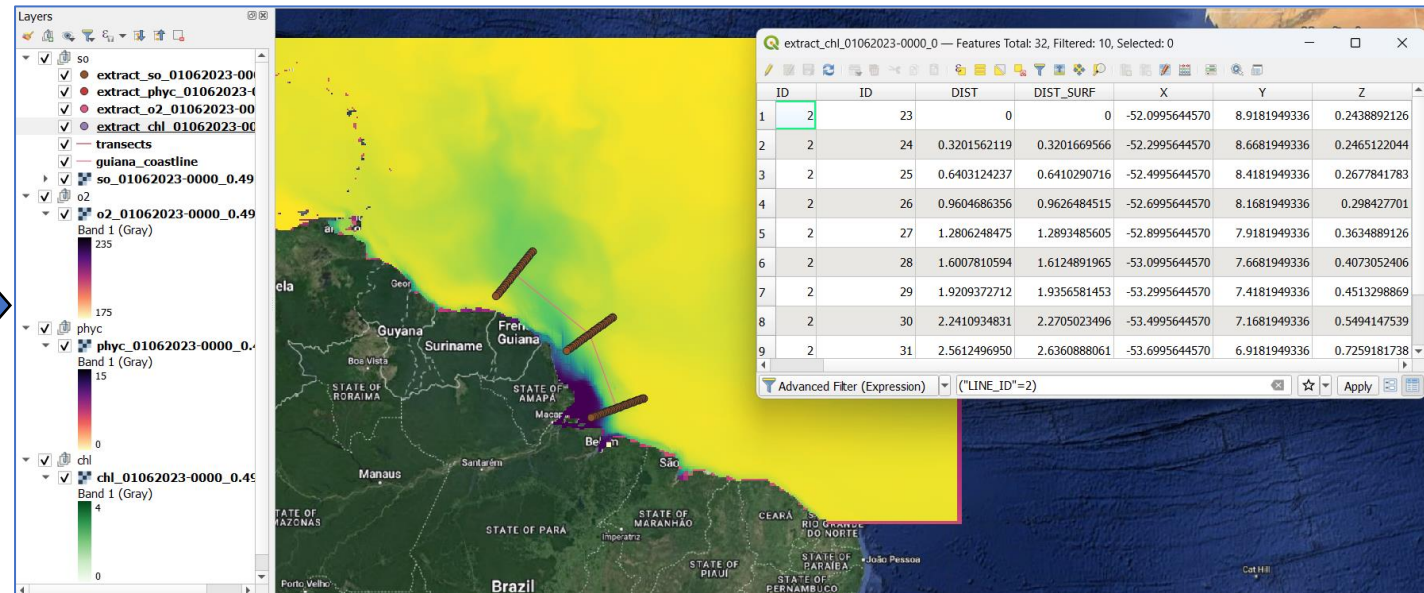
Selection of the input fields  
*chl\_\**, *o2\_\**, *so\_\**,  
*phyc\_\**

Creation of the baseline and sections layout  
*transects*

*Profile by lines*

*Run as batch process*

EOV extracted in the given sections  
*transect\_chl\**,  
*transect\_o2\**,  
*transect\_so\**,  
*transect\_phyc\**

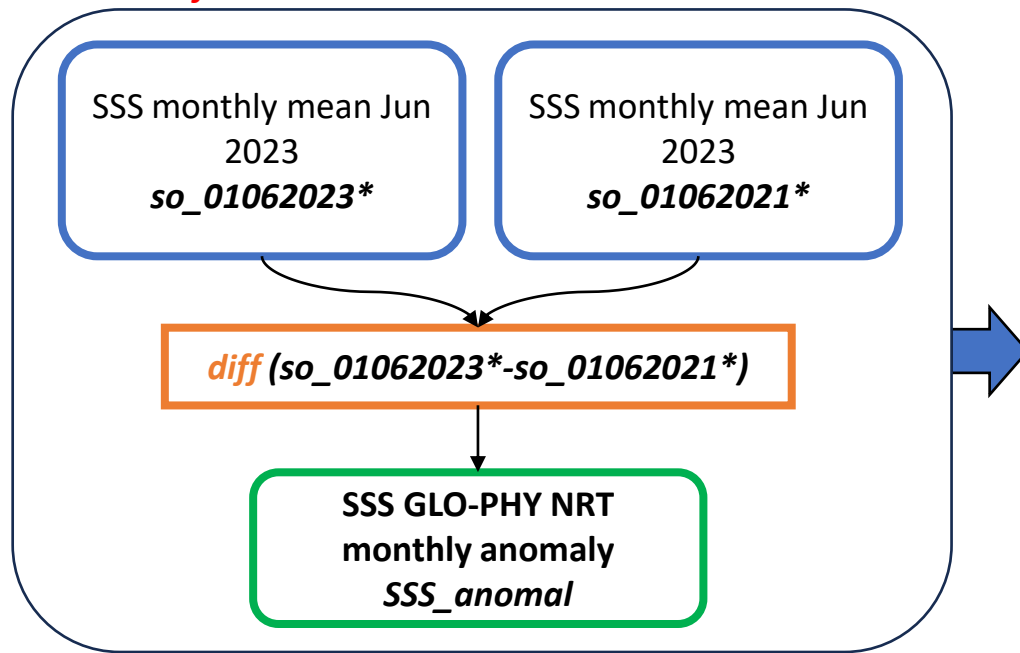


- Transects function** provides an easy way to design linear transects with sampling stations distributed at a given distance along the transect.

# Exercise 3: The Amazon River Plume

**Objective:** to show QGIS functionalities for performing some geospatial analysis for characterizing the Amazon River plume, considering 2 specific periods: Jun 2021, during which an extreme flood occurred (Espinoza et al., 2022), and Jun 2023, characterized by prolonged droughts.

## Workflow



1 Input raster files (e.g., SSS for Jun 2021 and for Jun 2023)

2 Mathematical expression

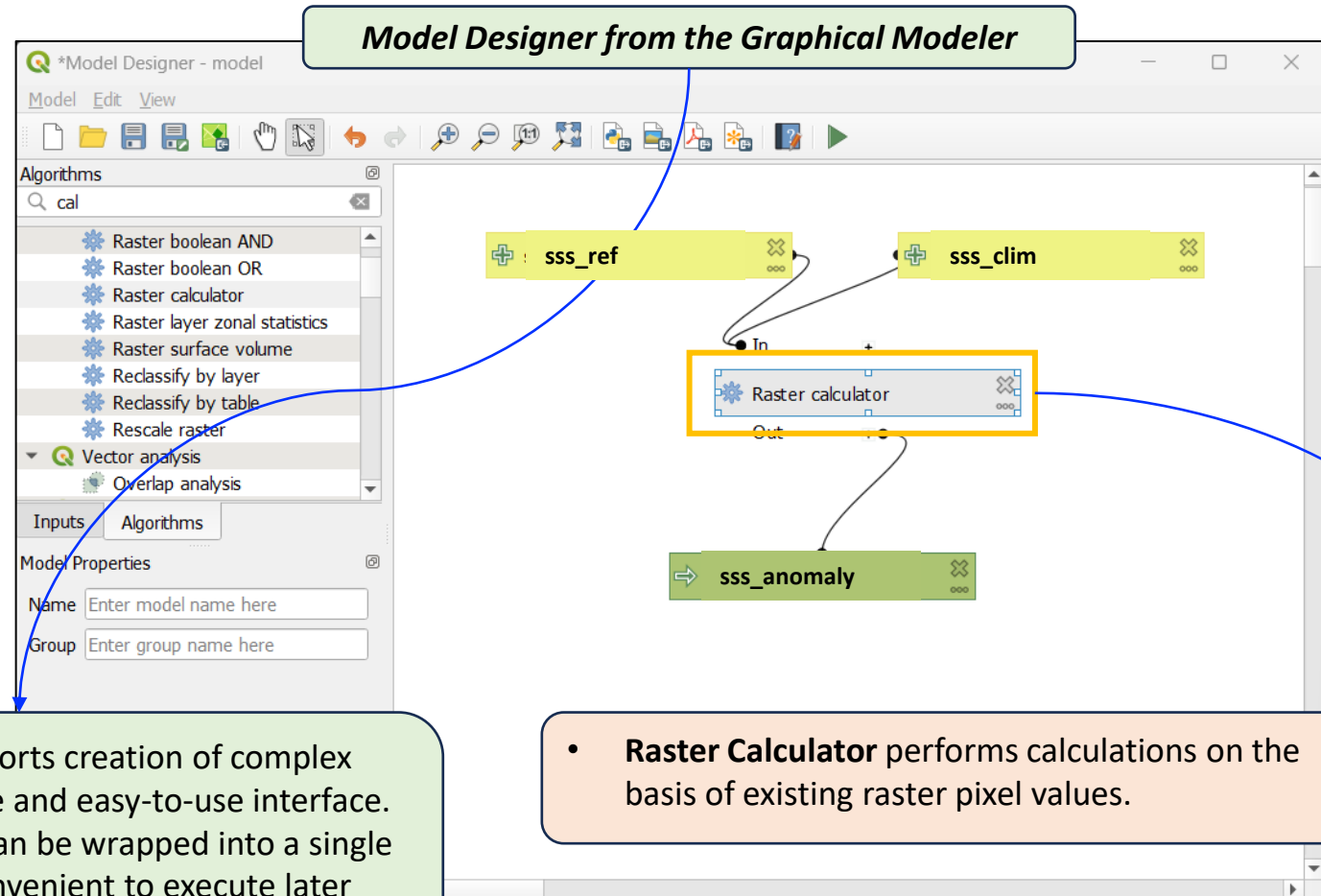
3 Output layer

- **Raster Calculator** allows you to perform calculations on the basis of existing raster pixel values

# Exercise 3: The Amazon River Plume

**Objective:** to show QGIS functionalities for performing some geospatial analysis for characterizing the Amazon River plume, considering 2 specific periods: Jun 2021, during which an extreme flood occurred (Espinoza et al., 2022), and Jun 2023, characterized by prolonged droughts.

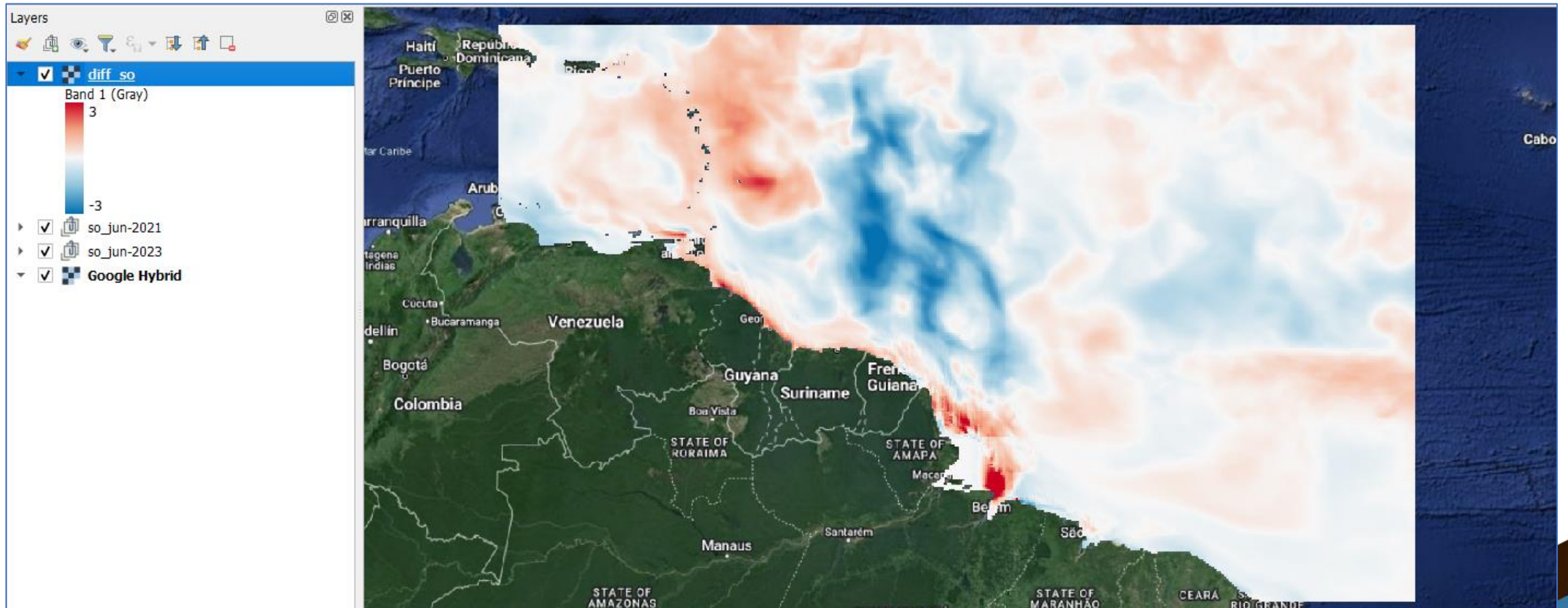
**Tips & Tricks:** if you would compute SSS anomaly for a longer timeseries, you can build the workflow through the **Graphical Calculator**



- **Model Designer** supports creation of complex models using a simple and easy-to-use interface.
- Chain of operations can be wrapped into a single process, making it convenient to execute later with a different set of input.

- **Raster Calculator** performs calculations on the basis of existing raster pixel values.

# Exercise 3: The Amazon River Plume



# Exercise 3: The Amazon River Plume

**Objective:** to extract contours from given raster files and filter the ones within 35 PSU. This is done by using the **Contour QGIS function (batch process)**

1 Right click on the selected layer to process

2 Selection of the "Filter" option

3 Opening of the "Query Builder" and specification of the filter expression

4 Display of the contours within the 35 PSU

Layers

- contour\_so\_01062023-0000\_0
- so\_Jun-2021
- so\_Jun-2023
- Google Hybrid

Context Menu:

- Zoom to Selection
- Show in Overview
- Show Feature Count
- Show Labels
- Copy Layer
- Rename Layer
- Duplicate Layer
- Remove Layer...
- Move to Top
- Move to Bottom
- Open Attribute Table
- Toggle Editing
- Filter...
- Set Layer Scale Visibility...
- Layer CRS
- Export

Query Builder

Set provider filter on contour\_so\_01062023

Fields

fid	ID	SSS
-----	----	-----

Operators

=	<	>	LIKE	%	IN	NOT IN
<=	>=	!=	ILIKE	AND	OR	NOT

Provider Specific Filter Expression

```
"SSS" > 0 AND "SSS" <= 35
```

Map View:

contour\_so\_01062023-0000\_0

so\_Jun-2021

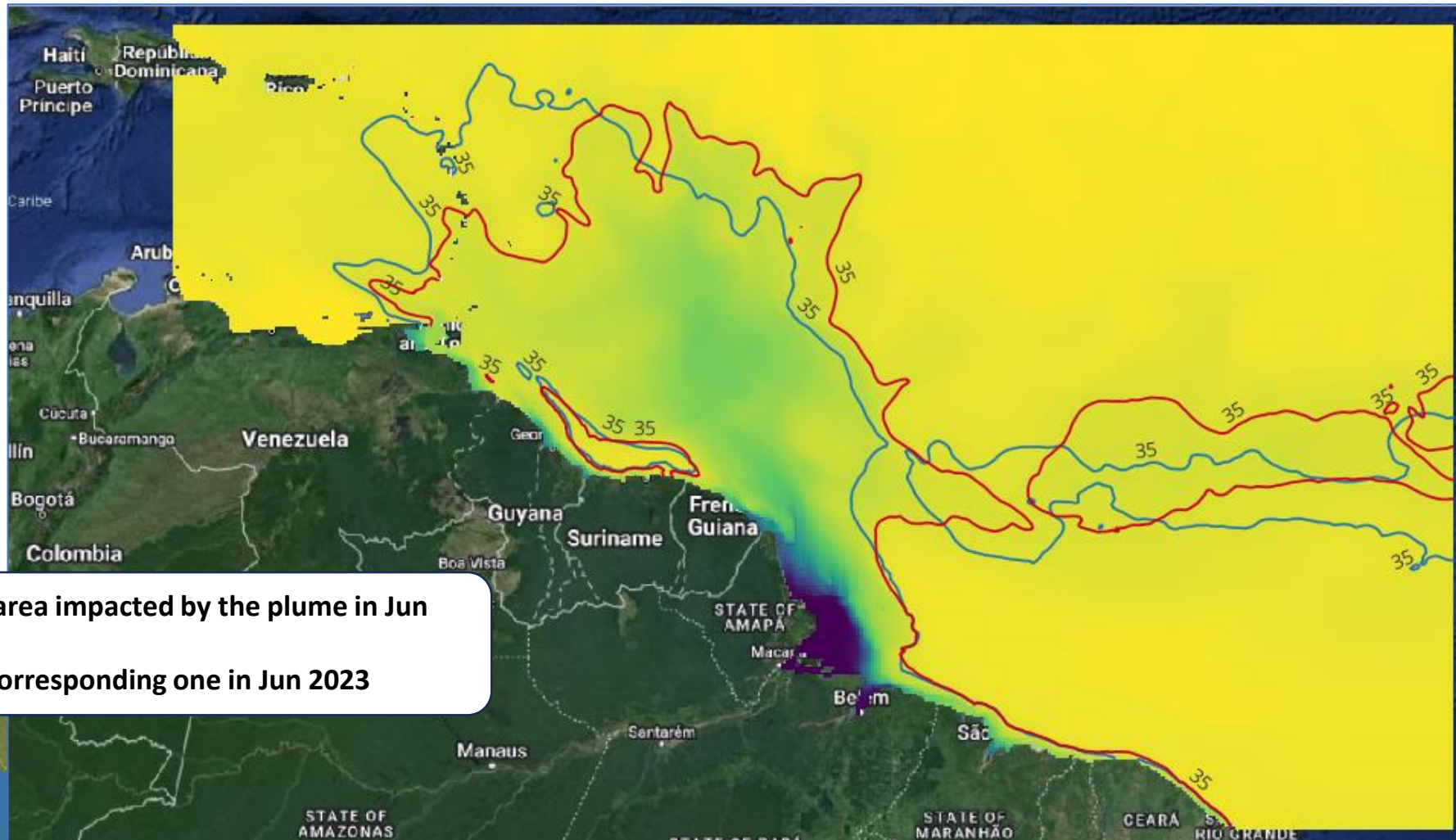
so\_Jun-2023

Google Hybrid

- **[DEF] Contour** is a height isoline. Isoline is a line on a map with a constant value. Therefore, the contour definition is a line which has a constant elevation along the line. There are some characteristics of contour line such as contour interval, contour elevation and distance between contour lines.

# Exercise 3: The Amazon River Plume

**Objective:** to extract contours from given raster files and filter the ones within 35 PSU. This is done by using the **Contour QGIS function (batch process)**



- In **Blue**: the area impacted by the plume in Jun 2021
- In **Red**: the corresponding one in Jun 2023

# Exercise 3: The Amazon River Plume

**Objective:** to perform geospatial analysis in the Delta region.

## Workflow

so\_01062023

Polygonize (Ra

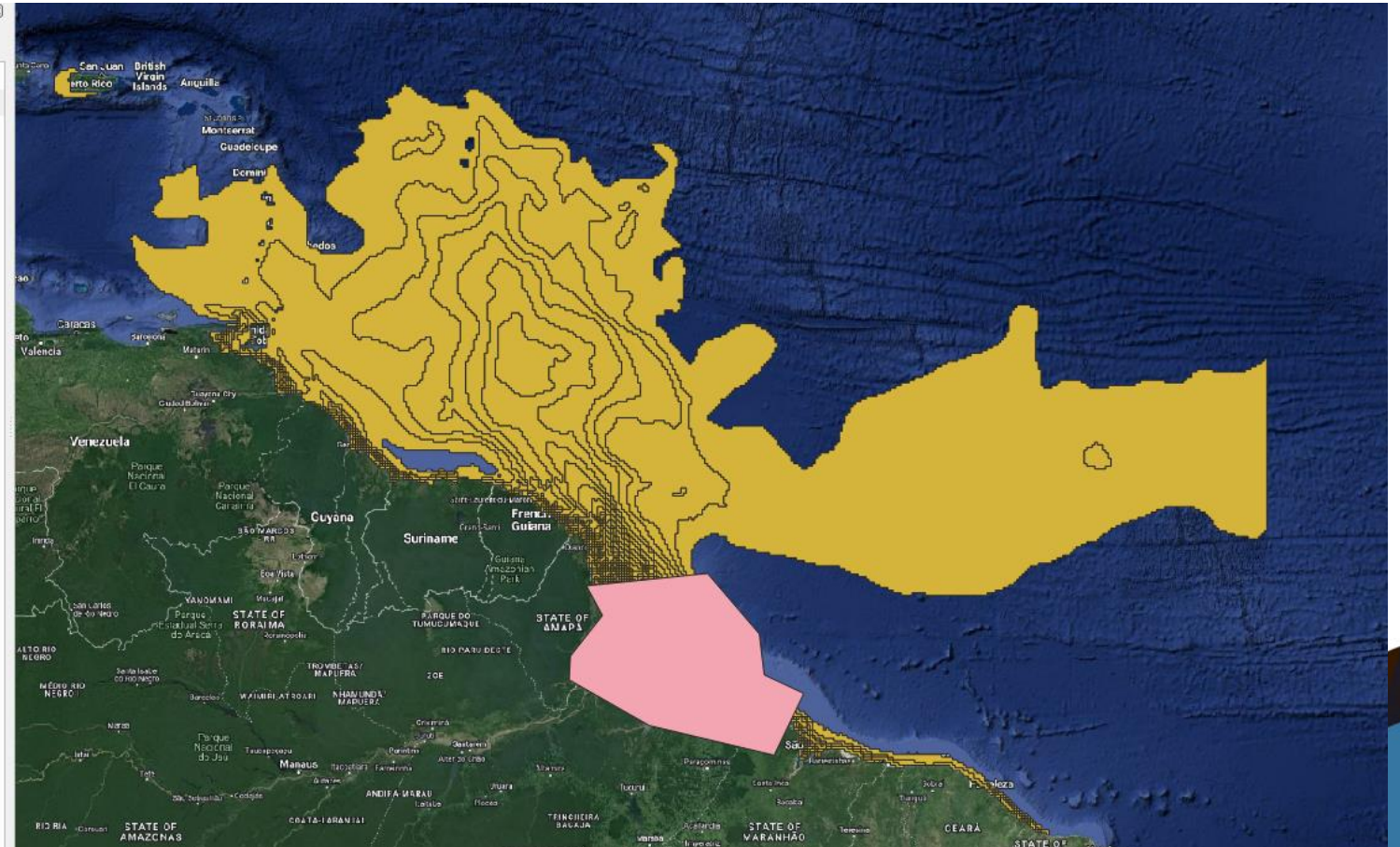
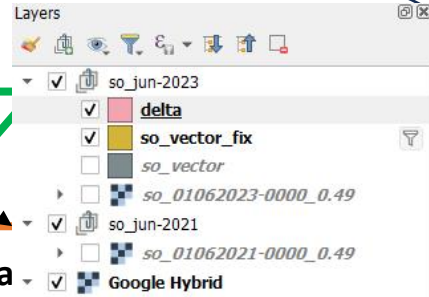
so\_vector

Query |  
SSS > 0 &

so\_vector  
(filtered)

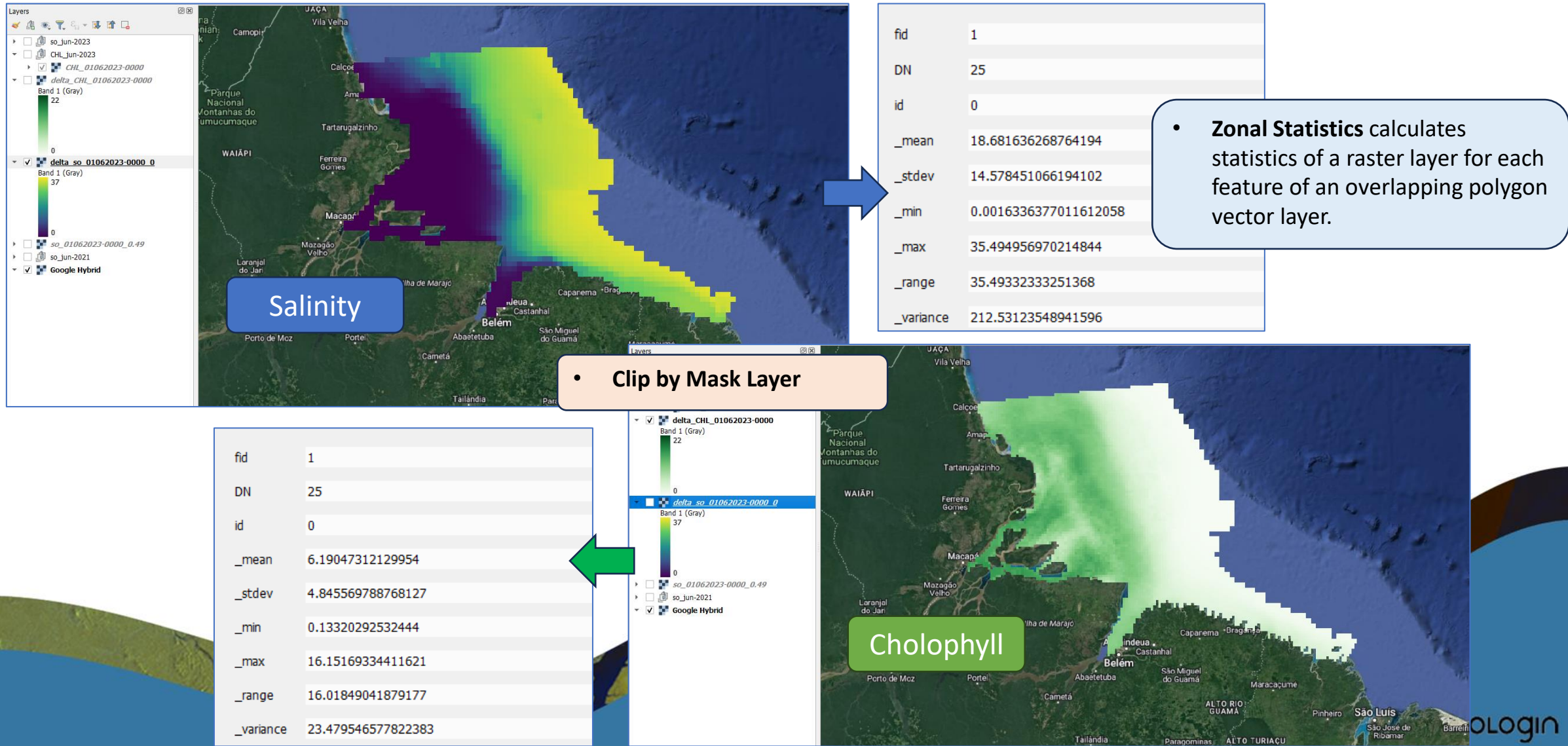
Clip by M

so\_vector in  
the Delta



# Exercise 3: The Amazon River Plume

**Objective:** to perform geospatial analysis in the Delta region.





Source: <https://events.marine.copernicus.eu/marinedata4southamerica-2024/content/qgis>

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# MarineData4SouthAmerica

## QGIS

#MarineData4SouthAmerica

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[Plugin](#)

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Senior Scientist  
Nologin Oceanic Weather Systems



## QGIS Tutorial

In this tutorial, we will learn how to:

- Visualize the Copernicus Marine products in the Western Tropical Atlantic, extracting Essential Ocean Variables (EOV) values in same specific locations.
- Perform a geospatial analysis of physical and biogeochemical conditions in the Amazon River plume region and in its delta.

[Download PDF](#)

# Summary of the main outcomes

- QGIS offers capacity for **geospatial analysis of Copernicus Marine products**.
- Functions like "Raster Calculator", "Transects" and "Countour" offer the possibility to **execute automatically numerical algorithms**:
  - Calculating SSS anomalies over a given period.
  - Extracting countour line from salinity to detect the area of influence of the Amazon River plume.
- It has been shown how to **extract raster values over an assigned shapefile** (e.g., irregular polygon)
- Using "Zonal Statistics" it is possible to compute automatically **averaged EOV quantities** for monitoring and validation purposes.

# References

- Espinoza, J.-C., Marengo, J.A., Schongart, J., Jimenez, J.C. (2022). The new historical flood of 2021 in the Amazon River compared to major floods of the 21st century: Atmospheric features in the context of the intensification of floods. *Weather and Climate Extremes*, 35, 100406. <https://doi.org/10.1016/j.wace.2021.100406>
- Fournier, S., Chapron, B., Salisbury, J., Vandemark, D., Reul, N. (2015). Comparison of spaceborne measurements of sea surface salinity and colored detrital matter in the Amazon plume. *J. Geophys. Res. Oceans*, 120. <https://doi.org/10.1002/2014JC010109>
- Gouveia, N.A., Gherardi, D.F.M., Wagner, F.H., Paes, E.T., Coles, V.J., Aragao, L.E.O.C. (2019). The Salinity Structure of the Amazon River Plume Drives Spatiotemporal Variation of Oceanic Primary Productivity. *Journal of Geophysical Research: Biogeosciences*, 124, 147-165. <https://doi.org/10.1029/2018JG004665>
- Copernicus Webinar - MarineData4SouthAmerica2024: <https://events.marine.copernicus.eu/marinedata4southamerica-2024>



#MarineData4SouthAmerica

Thank you all!



Copernicus  
Marine Service



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EUROPEAN UNION



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