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Assignment P4
Final Assignment

1. Data description

In this assignment, several methods explored throughout the course are applied to analyse satellite-derived ocean colour data, with a focus on chlorophyll-a concentration as a proxy for phytoplankton biomass. The dataset consists of monthly climatological means of chlorophyll-a concentrations across the global ocean at a very high spatial resolution of 4 km and is provided by the European Space Agency (ESA) as part of the Ocean Colour Climate Change Initiative (OC-CCI, Version 5.0). Spanning from the 1st of January 1998 to the 31st of January 2020, this dataset integrates multiple ocean colour sensor records from missions such as SeaWiFS, MODIS-Aqua, MERIS, VIIRS and OLCI, which have been merged and reprocessed for consistency using standardised corrections. The dataset is publicly available through ESA's OC-CCI portal. To further explore regional dynamics, I selected a coastal area along the West Coast of South Africa, which is strongly influenced by upwelling and seasonal productivity patterns. The chosen areas include False Bay, Cape Point National Park and the West Coast National Park, areas in which I have spent significant time exploring, particularly the underwater world. Understanding seasonal changes in chlorophyll concentrations helps explain observed shifts in water clarity and complements another report I am currently writing on the physical properties of the West Coast for a separate module. The report presents a series of visual outputs and analyses, including bathymetry mapping, chlorophyll distribution (both annual and monthly variation), and a time series comparison between the regional mean and a chlorophyll-rich grid point. The bathymetric data was obtained from the Global-Multi-Resolution Topography (GMRT) Synthesis tool (https://www.gmrt.org/GMRTMapTool/), which provides gridded elevation data suitable for overlay with ocean colour datasets.

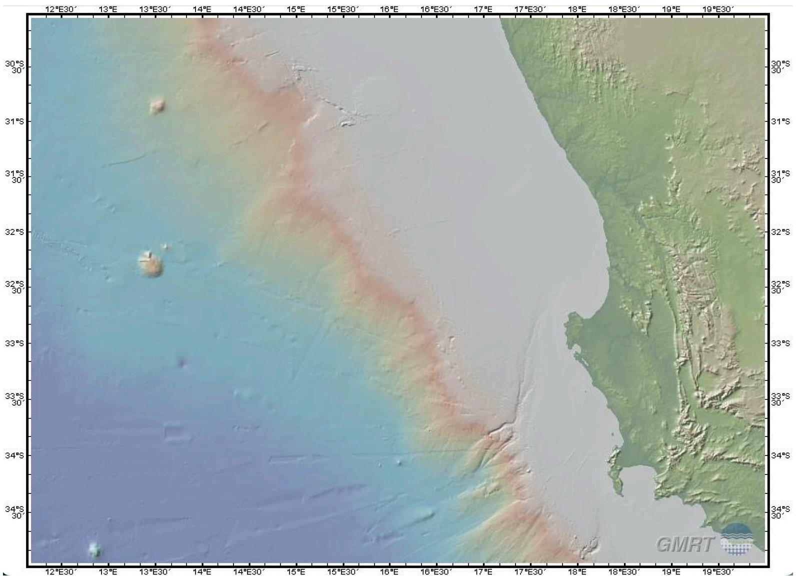

Figure 1. Selected study region off the west coast of South Africa, spanning from **30°02′S to 34°56′S** latitude and **12°10′E to 19°59′E** longitude. Bathymetry sourced from GMRT.

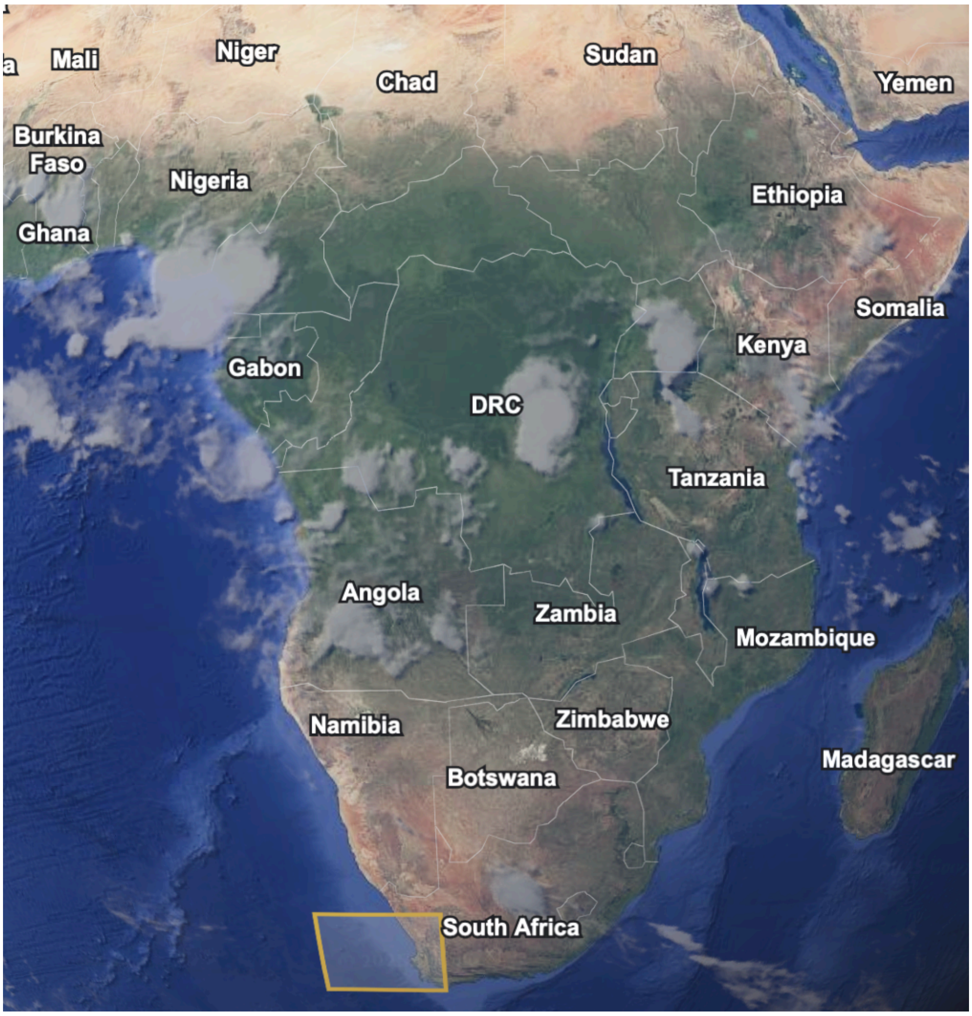

Figure 2. Overview of the selected study area (yellow box) off the west coast of South Africa, shown in the broader African context (sourced from Google Earth)

Figure 3. Zoomed-in view of the selected study area (yellow box) along the west coast of South Africa, encompassing Cape Town and surrounding upwelling regions (sourced from Google Earth)

2. Figures

2.1 Introduction to the bathymetry of the West Coast of South Africa

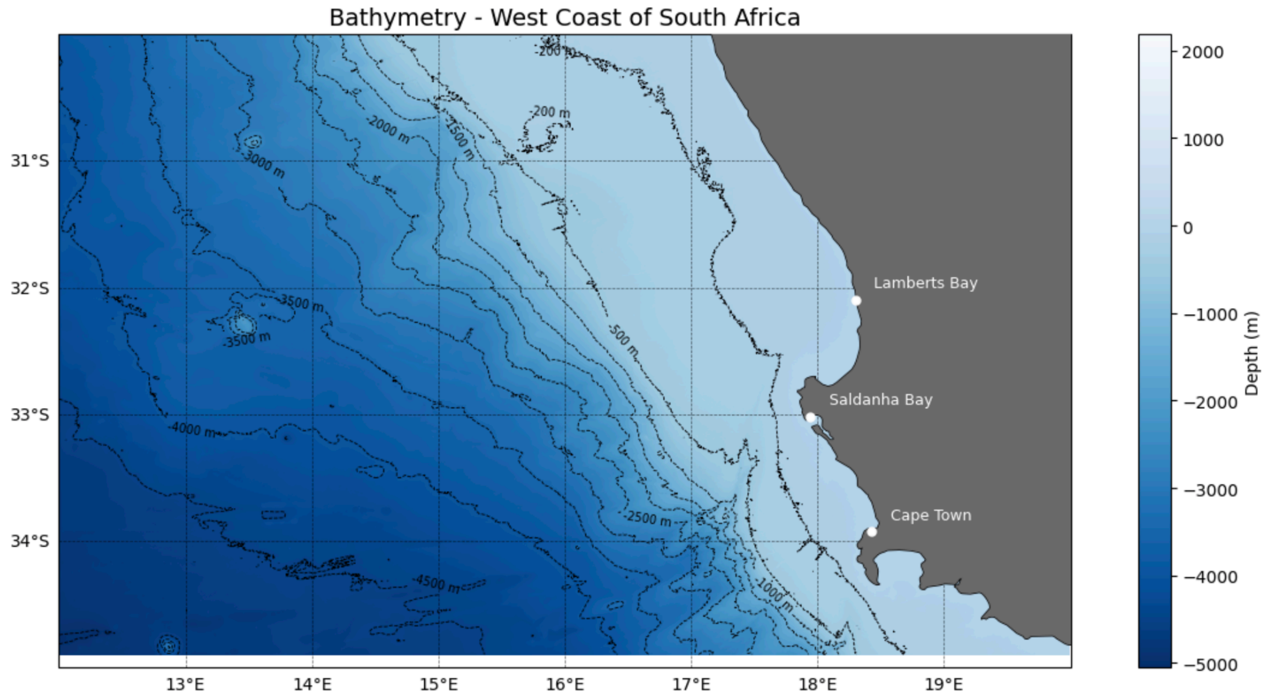

Figure 4. Bathemtry map of the West Coast of South Africa

The figure above shows a bathymetric map of the West Coast of South Africa, which displays ocean depth contours and seafloor topography that is derived from the Global Multi-Resolution Topography (GMRT) Synthesis tool. The colour gradient ranges from light blue in shallower coastal waters to dark blue in deeper offshore regions. Bathymetric contour lines reveal the structure of the continental shelf, which extends westwards from the coastline before dropping off steeply along the continental slope. The shelf region plays a key role in coastal upwelling and productivity. The landmass, which is shaded in dark grey, shows coastal towns, such as Cape Town, Saldanha Bay, and Lamberts Bay (marked with white dots and labels) to provide spatial reference points. Gridlines indicate latitude and longitude for geographic reference.

2.2 Climatological annual mean chlorophyll-a concentration along the West Coast of South Africa from 1998 to 2020

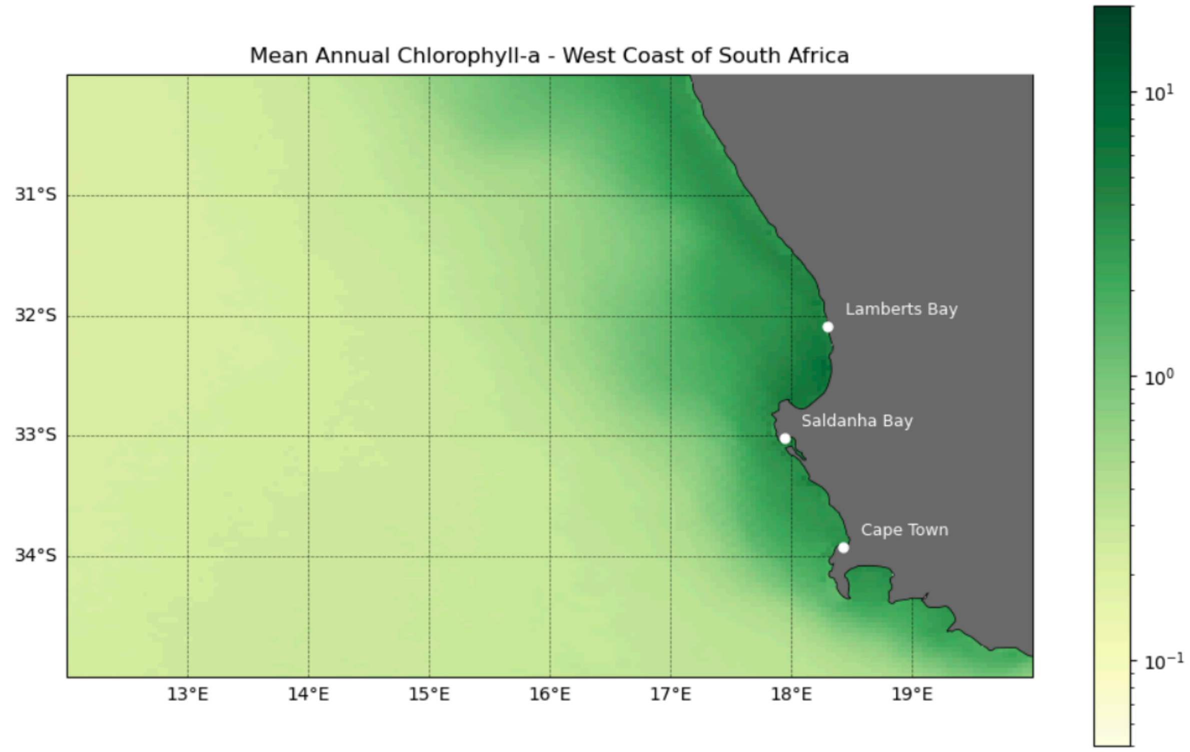

Figure 5. Climatological annual mean chlorophyll-a concentration along the West Coast of South Africa from 1998 to 2020

The figure above shows the climatological mean annual chlorophyll-a concentration along the chosen part of the West Coast of South Africa, based on satellite-derived data from the ESA OC-CCI dataset. As previously mentioned, the chlorophyll-a concentration is used as a proxy for phytoplankton biomass, with higher values typically associated with regions of high biological productivity.

A clear gradient is visible in the figure, with the concentration of chlorophyll being highest near the coast, which can be explained by coastal upwelling. The Benguela Upwelling system is one of the most productive marine ecosystems in the world due to the continuous upwelling of cold, nutrient-rich water from the deep water masses. Driven by strong southeasterly trade winds, this process brings nutrients to the surface, which fuels high phytoplankton growth, supporting high marine biodiversity and productivity along the West Coast of South Africa. The color scale is plotted on a logarithmic scale to capture the wide range of concentrations, from oligotrophic offshore waters to nutrient-rich nearshore zones, and the locations of Cape Town, Saldanha Bay, and Lamberts Bay are marked for spatial reference.

2.3 Climatological monthly mean log chlorophyll-a concentration along the West Coast of South Africa from 1998 to 2020

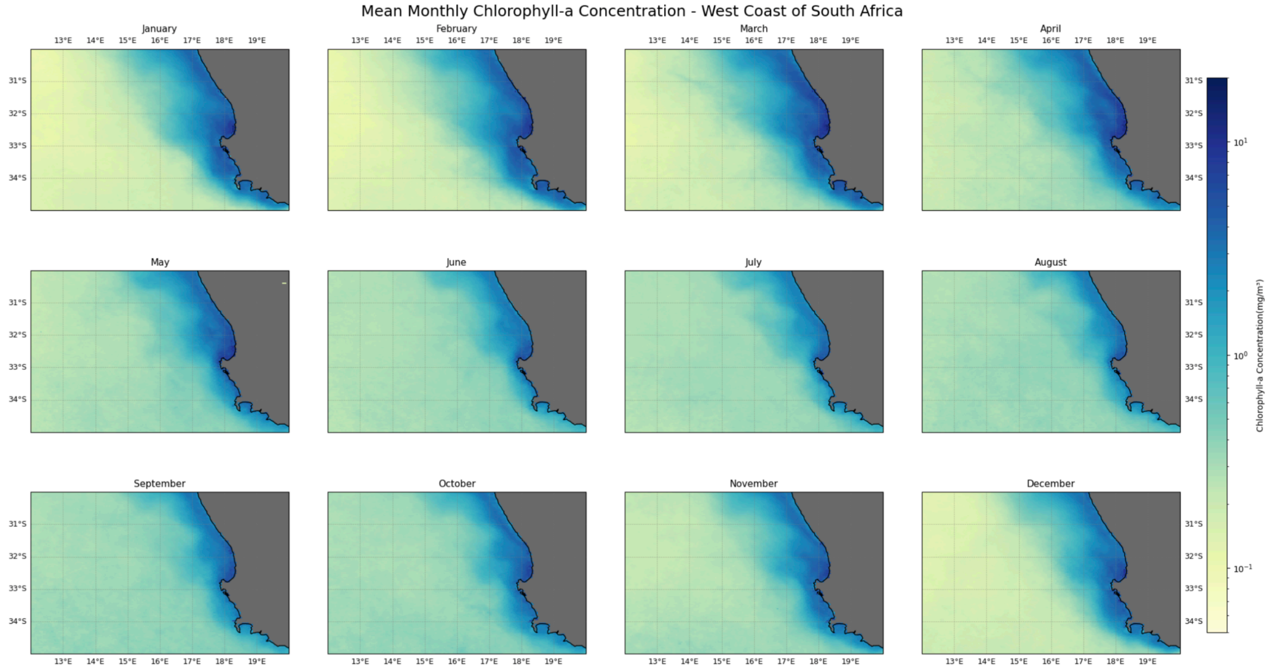

Figure 6. Climatological monthly mean log chlorophyll-a concentration along the West Coast of South Africa from 1998 to 2020

The figure above presents 12 maps of the monthly climatological mean chlorophyll-a concentrations (mg/m³) along the West Coast of South Africa. Every panel shows a different month (January-December), which allows for a visual comparison of seasonal trends throughout the year. The landmass is shaded in dark grey for contrast, and a logarithmic color scale (YlGnBu) is used to capture the wide range of chlorophyll values. Clear seasonal patterns in changing chlorophyll-a concentrations can be seen across the 12 maps. The chlorophyll concentration peaks during spring to late summer (September to March), particularly in October and February, while a notable decline in chlorophyll can be observed during the winter months (especially between May and July). The highest values always appear close to shore due to the previously mentioned strong influence of the dynamics of the Benguela upwelling system along the West Coast of South Africa. The higher chlorophyll levels during the summer months correlate with the enhanced upwelling due to strong south-easterly trade winds, which drive surface waters offshore and promote the vertical transport of cold, nutrient-rich water to the surface. Increased UV radiation and higher nutrient levels during the summer promote phytoplankton blooms, resulting in increased chlorophyll-a levels. When upwelling weakens in winter, wind activity and mixing are reduced, which limits nutrient availability and leads to the observed lower phytoplankton biomass and, thus, lower chlorophyll-a concentrations. However, the Benguela Upwelling System is productive throughout the year, due to storm-induced mixing and weaker thermoclines in winter still pushing nutrients into surface waters.

2.4 Seasonal Chlorophyll Time Series: Regional Mean vs. High-Productivity Grid Point

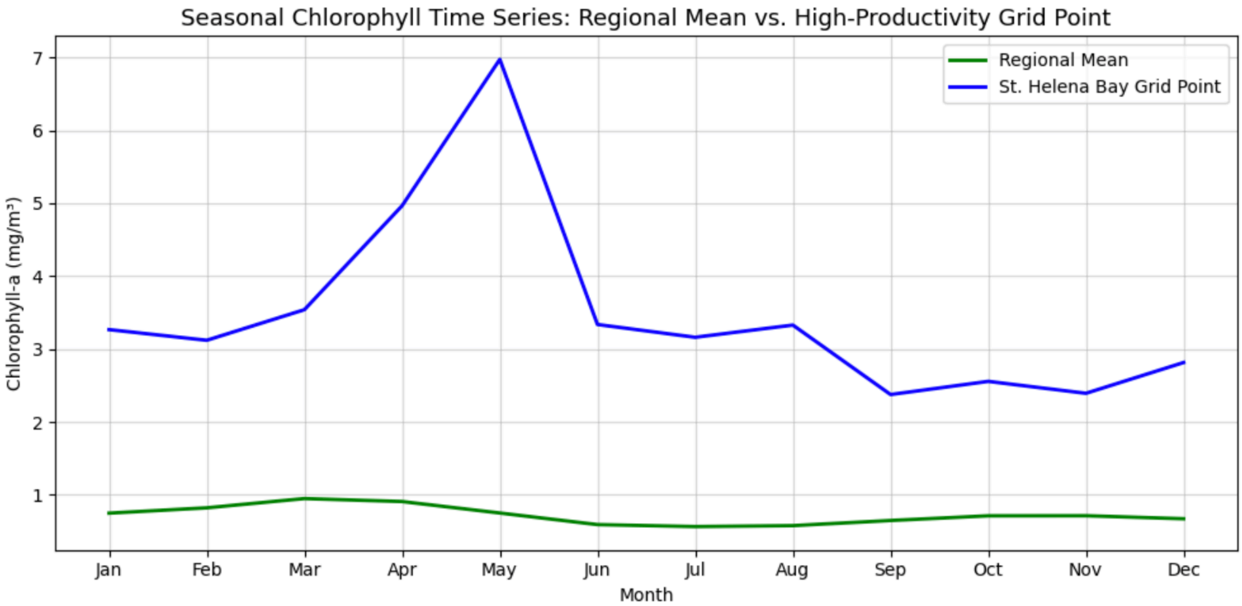

Figure 6. Seasonal Chlorophyll Time Series: Regional Mean vs. High-Productivity Grid Point

Figure 6 displays a time series comparison of climatological monthly chlorophyll-a concentrations (mg/m^3) averaged over the entire selected region along the West Coast of South Africa (green line) and at a single high-productivity grid point near St. Helena Bay (blue line). While the x-axis represents the months of the year, the y-axis shows chlorophyll concentration on a linear scale. The time series shows the seasonal variability in phytoplankton productivity, especially in regions influenced by coastal upwelling. When comparing the regional mean chlorophyll-a concentration and the St. Helena Bay grid point, it can be seen that the chosen grid point shows a much higher variability and peak concentrations, particularly from March to May (values reach nearly 7mg/m^3), while regional mean remains relatively stable throughout the year, with slight increases in late summer and spring (March-April and October-November). The seasonal peak at the St. Helena Bay grid point reflects intense upwelling conditions and nutrient enrichment that drive the phytoplankton blooms in this specific area. A general productivity trend for the broader coastal ecosystem is reflected in the regional mean. I chose St. Helena Bay as the grid point of interest because the area is well-known for its primary productivity in the southern Benguela upwelling system. The high productivity, which can be explained by the consistent wind-driven upwelling in the area, makes it a very important hotspot for fisheries, communities, and marine biodiversity.

3. References

- Anaconda Inc., 2023. *Anaconda Distribution (*https://www.anaconda.com/)

- Cartopy Developers, 2023. *Cartopy: A cartographic Python library with Matplotlib support (*https://scitools.org.uk/cartopy/docs/latest/)

- European Space Agency (ESA), 2020. *Ocean Colour Climate Change Initiative (OC-CCI), Version 5.0*. Centre for Environmental Data Analysis (CEDA) (http://www.esa-oceancolour-cci.org)

- GEBCO Compilation Group, 2021. *The GEBCO_2021 Grid – A global bathymetric grid*. [online] General Bathymetric Chart of the Oceans (GEBCO) (https://www.gebco.net)

- GMRT Synthesis Group, 2023. *GMRT MapTool*. [online] Lamont-Doherty Earth Observatory (https://www.gmrt.org/GMRTMapTool)

- Harris, C.R., Millman, K.J., van der Walt, S.J. et al., 2020. Array programming with NumPy. *Nature*, 585, pp.357–362 (https://doi.org/10.1038/s41586-020-2649-2)

- Matplotlib Developers, 2023. *Matplotlib: Visualization with Python (*https://matplotlib.org/)

- OpenAI, 2025. *ChatGPT (Mar 2025 version)* (https://chat.openai.com)

- Shannon, L.V. and Nelson, G., 1996. The Benguela: Large scale features and processes and system variability. In: G. Hempel, ed. *The South Atlantic: Present and Past Circulation*. Berlin: Springer, pp.163–210.

- Xarray Developers, 2023. *xarray: N-D labeled arrays and datasets in Python* (https://docs.xarray.dev)