Practical 4

The focus region for this practical is the western boundary of the Antarctic Peninsula, near the Bellingshausen Sea, with coordinates for latitude (58°S, 70°S) and longitude (60°W, 85°W). I have always been fascinated by the Southern Ocean and the complex dynamics within this region. As a high-nutrient, low-chlorophyll area, it is exciting to examine chlorophyll levels in greater detail and observe these patterns more closely.

My interest in this region comes from the important role the Southern Ocean plays in global productivity and global thermohaline circulation. Additionally, learning about *Endurance* further fueled my curiosity and interest for this region. While several aspects interest me, I am particularly interested in the sea ice and productivity dynamics.

The first data set that was used was data from the Global Multi-Resolution Topography Synthesis (GMRT). This bathymetry data was downloaded using the map application and selecting the data off the Antarctic Peninsula. The data is high resolution sounding data that is combined with the GEBCO reference chart.

Reference: Ryan, W.B.F., S.M. Carbotte, J.O. Coplan, S. O'Hara, A. Melkonian, R. Arko, R.A. Weissel, V. Ferrini, A. Goodwillie, F. Nitsche, J. Bonczkowski, and R. Zemsky (2009), Global Multi-Resolution Topography synthesis, Geochem. Geophys. Geosyst., 10, Q03014, doi: 10.1029/2008GC002332 .

The chlorophyll data is satellite sensed chlorophyll concentration for the world ocean. The data is taken from multiple satellites and complied into monthly averages for a specific region. This means that when using this data, the extent needs to be chosen to zoom in on a specific region of interest. This data is generated by the Ocean Colour component of ESA-CCI.

Reference: Sathyendranath, S, Brewin, RJW, Brockmann, C, Brotas, V, Calton, B, Chuprin, A, Cipollini, P, Couto, AB, Dingle, J, Doerffer, R, Donlon, C, Dowell, M, Farman, A, Grant, M, Groom, S, Horseman, A, Jackson, T, Krasemann, H, Lavender, S, Martinez-Vicente, V, Mazeran, C, Mélin, F, Moore, TS, Müller, D, Regner, P, Roy, S, Steele, CJ, Steinmetz, F, Swinton, J, Taberner, M, Thompson, A, Valente, A, Zühlke, M, Brando, VE, Feng, H, Feldman, G, Franz, BA, Frouin, R, Gould, Jr., RW, Hooker, SB, Kahru, M, Kratzer, S, Mitchell, BG, Muller-Karger, F, Sosik, HM, Voss, KJ, Werdell, J, and Platt, T (2019) An ocean-colour time series for use in climate studies: the experience of the Ocean-Colour Climate Change Initiative (OC-CCI). Sensors: 19, 4285. doi:10.3390/s19194285

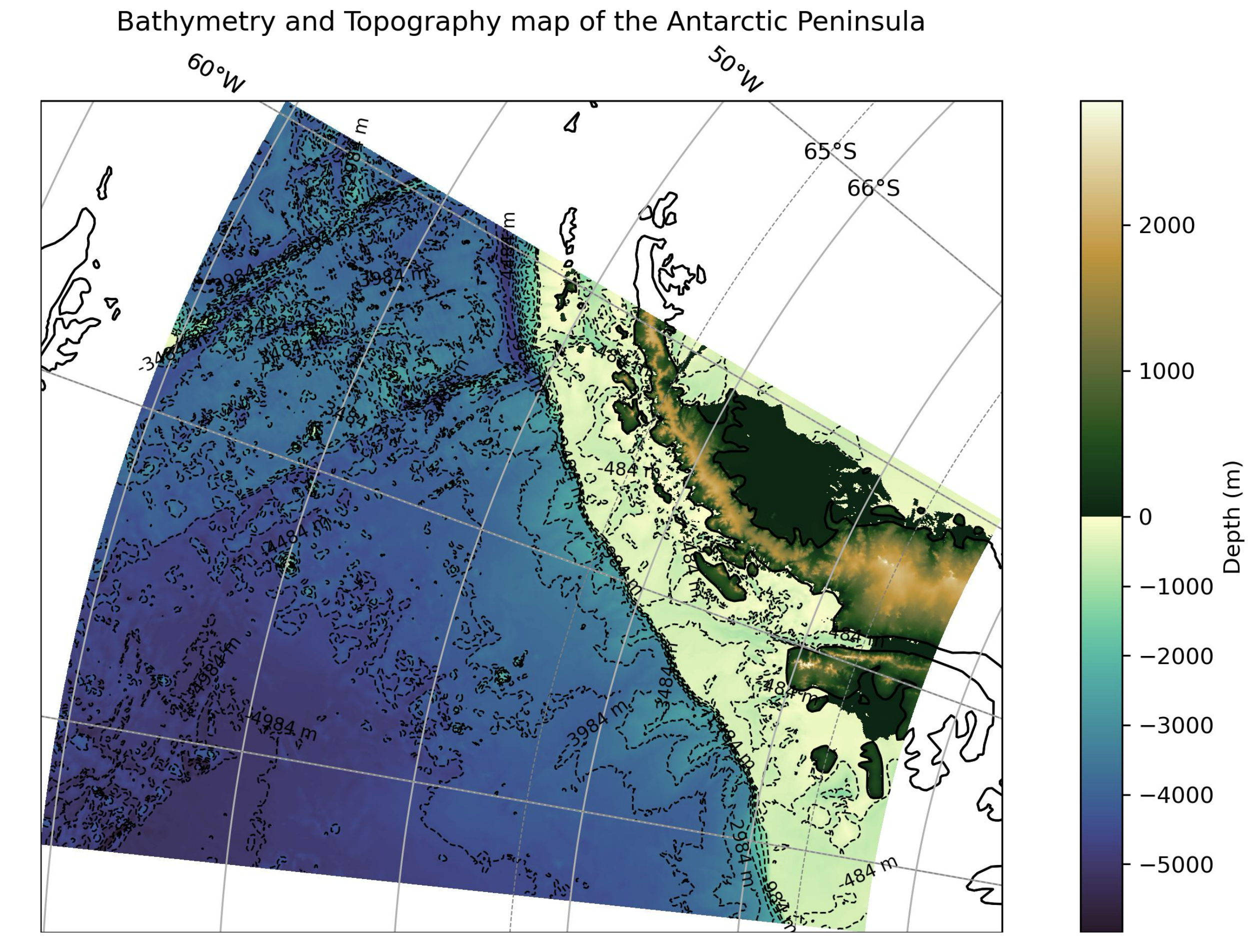

Figure 1: Bathymetry and Topography map of the Antarctic Peninsula, with stereographic south polar view.

This plot has stereographic south polar CRS as this projection aims to decrease the distortion near the poles and is able to preserve this area's shape well. This plot demonstrates the high topography of the Antarctic Peninsula towards the center and lower topography closer to the coastline. The large dark green spot to the right of the Peninsula is the Larsen Ice Shelf and is noticeable at sea level. The ocean depth is shallower closer to the continent and depth increases further from the continent. The shallowest depth is reported at 484m and the deepest depth is 4984m. There are some bathometric features visible between 60°W and 70°W, as there are varying depths.

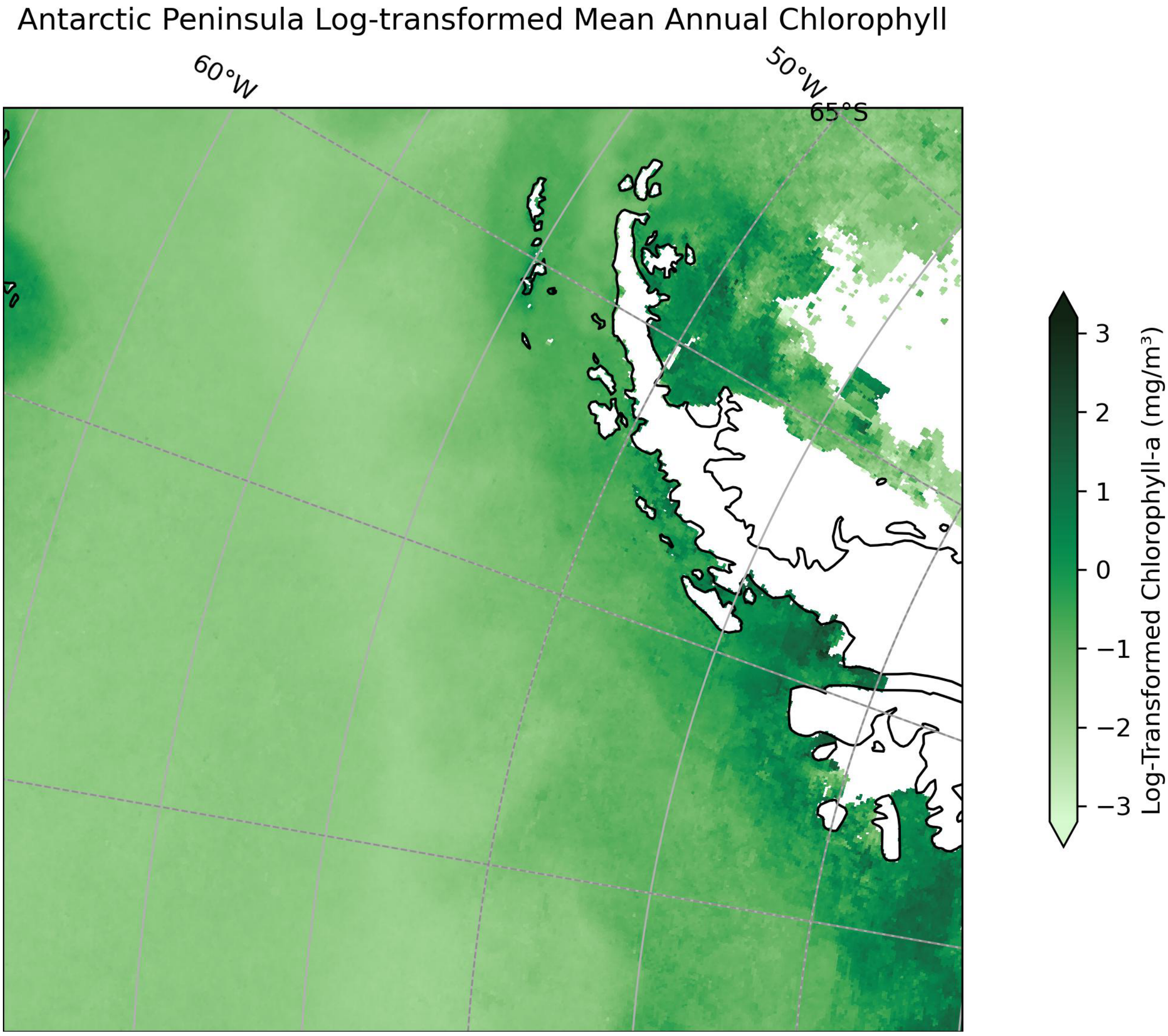

Figure 2: Log-transformed Mean Annual Chlorophyll, around the Antarctic Peninsula, with Stereographic South Polar projection.

The chlorophyll data has been log transformed as the data spans a few orders of magnitude and this allows for the best representation of the data. There is higher productivity closer to the continent and decreasing productivity away from the continent. The white spot next to the continent is again the Larsen Ice Shelf. There does seem to be a distinct gradient of decreasing productivity, which could indicate the presence of fronts which cause mixing and therefore higher productivity.

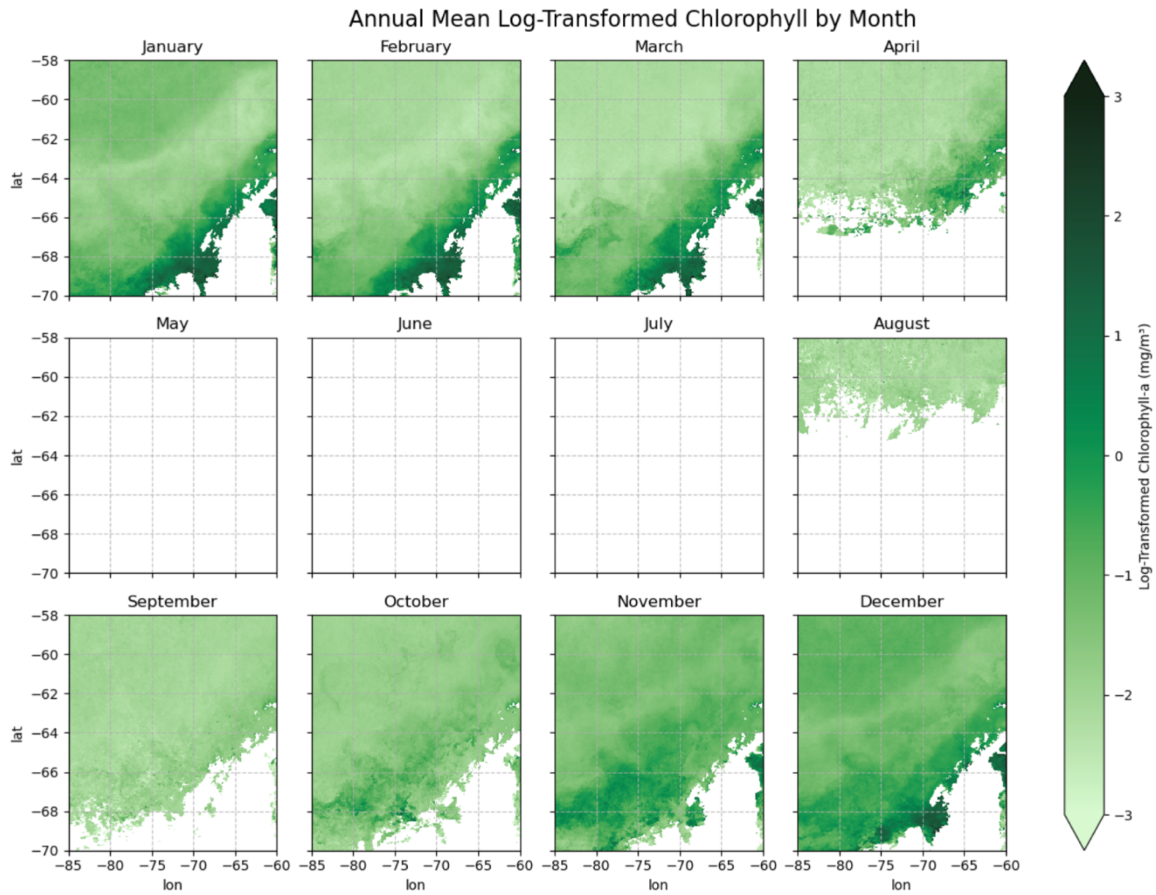

Figure 3: Log transformed monthly average Chlorophyll for the Antarctic Peninsula, for each month.

This data has been log-transformed to account for the large orders of magnitude in the datasets. The FaceTGrid allows the average per month to be seen, making it easier to determine the seasonality of chlorophyll in this region.

From May to June, there is no data available for this region, which is expected since it is winter in the Southern Hemisphere, and sea ice forms in the Southern Ocean. In April, a larger white region appears, marking the beginning of this sea ice formation. Then from August to September, the white areas start to decrease, showing the sea ice melting during this part of the season.

September to November is the start of spring, which explains the increasing presence of chlorophyll as nutrients are more readily available (after winter) and light levels increase. In summer, from December to February, productivity peaks, especially around the continent, which makes sense as sunlight is at its highest during this period. At the start of autumn in March, productivity is still high. December is the peak productivity time, as shown by the chlorophyll gradient extending far from the continental region into the sea. September and October, on the other hand, show relatively low productivity.

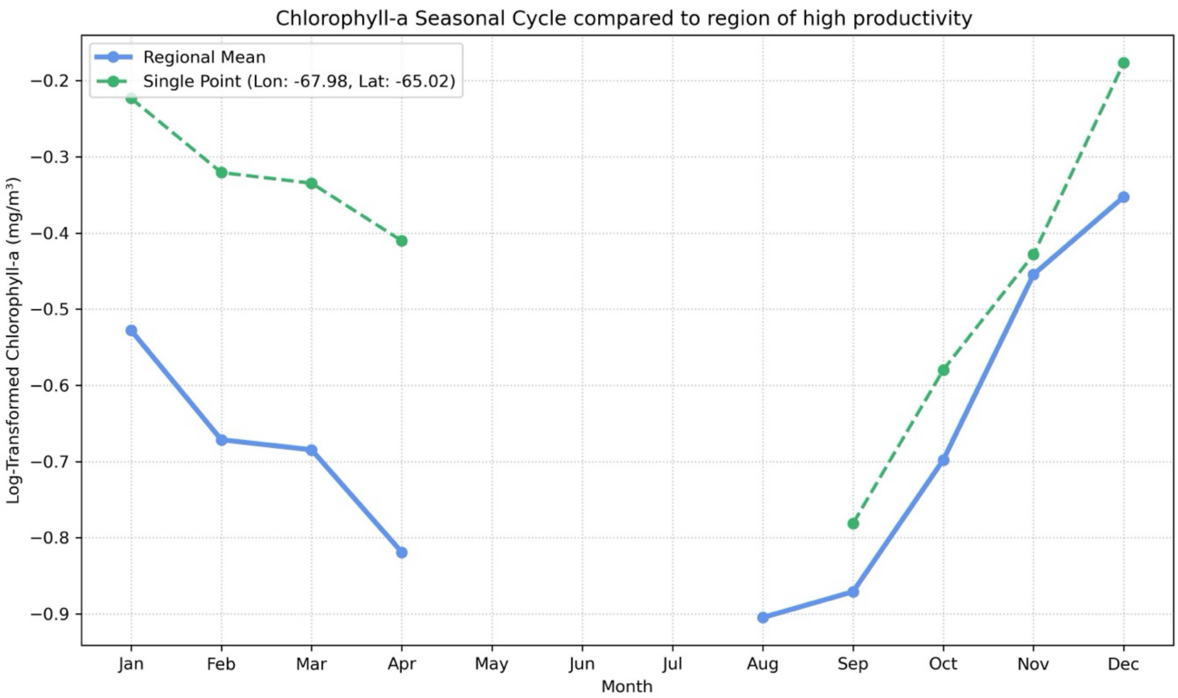

Figure 4: Time Series of the regional mean log-transformed chlorophyll compared to a grid point, identified with high chlorophyll mean log-transformed chlorophyll.

The seasonality of productivity in the Southern Ocean is displayed by this plot. Productivity is linked to chlorophyll concentration, as chlorophyll is necessary for primary production. For the whole region, productivity decreases from January to April, from about -0.5 mg/m^3 to -0.8 mg/m^3. From April until August, there is no productivity in the region as it is winter time and therefore there is ice formation and low light. From August to September, there is a small increase in productivity. As Spring starts, from September to November, there is a rapid increase in chlorophyll as light availability increases and there are nutrients present from winter. There is a steady increase from November to December, where chlorophyll reaches its maximum at -0.35.

The single point of highest productivity (65.02°S, 67.98°W) demonstrates a similar pattern to the whole region, although with higher productivity. This point has a peak chlorophyll concentration at roughly -0.15 mg/m^3. This region follows the same pattern as the whole region for January to April, but with higher values from -0.2 mg/m^3 in January and a drop to -0.4 mg/m^3 in April. This region demonstrates a sharp increase in chlorophyll from September (-0.8mg/m^3) until December, where it reaches it's peak. However, this point does not have any chlorophyll values for August, as it could be in a region that still has ice cover in August.

References:

1. National Snow and Ice Data Center (NSIDC) (n.d.) *A Guide to NSIDC's Polar Stereographic Projection*. Available at: https://nsidc.org/data/user-resources/help-center/guide-nsidcs-polar-stereographic-projection#:~:text=NSIDC's%20Polar%20Stereographic%20Projection%20was,used%20for%20many%20other%20products.&text=It%20specifies%20a%20projection%20plane,around%20the%20marginal%20ice%20zone (Accessed: 25 March 2025).
2. OpenAI (2025) *ChatGPT* [Online]. Available at: https://openai.com (Accessed: 25 March 2025).
3. Ryan, W.B.F., Carbotte, S.M., Coplan, J.O., O'Hara, S., Melkonian, A., Arko, R., Weissel, R.A., Ferrini, V., Goodwillie, A., Nitsche, F., Bonczkowski, J., & Zemsky, R. (2009) *Global Multi-Resolution Topography synthesis*. *Geochem. Geophys. Geosyst.*, 10, Q03014. doi: 10.1029/2008GC002332.
4. Sathyendranath, S., Brewin, R.J.W., Brockmann, C., Brotas, V., Calton, B., Chuprin, A., Cipollini, P., Couto, A.B., Dingle, J., Doerffer, R., Donlon, C., Dowell, M., Farman, A., Grant, M., Groom, S., Horseman, A., Jackson, T., Krasemann, H., Lavender, S., Martinez-Vicente, V., Mazeran, C., Mélin, F., Moore, T.S., Müller, D., Regner, P., Roy, S., Steele, C.J., Steinmetz, F., Swinton, J., Taberner, M., Thompson, A., Valente, A., Zühlke, M., Brando, V.E., Feng, H., Feldman, G., Franz, B.A., Frouin, R., Gould, R.W. Jr., Hooker, S.B., Kahru, M., Kratzer, S., Mitchell, B.G., Muller-Karger, F., Sosik, H.M., Voss, K.J., Werdell, J., & Platt, T. (2019) *An ocean-colour time series for use in climate studies: The experience of the Ocean-Colour Climate Change Initiative (OC-CCI)*. *Sensors*, 19, 4285. doi: 10.3390/s19194285.
5. Southern Ocean Productivity (n.d.) *NIWA*. Available at: https://niwa.co.nz/antarctica/southern-ocean-productivity#:~:text=Phytoplankton%20%E2%80%93%20microscopic%20plants%20that%20drift%20in,drives%20all%20of%20Antarctica's%20marine%20food%20webs (Accessed: 25 March 2025).
6. Trachyte et al. (1963) *Plt.show() does nothing when used for the second time*. *Stack Overflow*. Available at: https://stackoverflow.com/questions/50452455/plt-show-does-nothing-when-used-for-the-second-time (Accessed: 24 March 2025).
7. Xarray.DataArray.sel (2025) *xarray*. Available at: https://docs.xarray.dev/en/latest/generated/xarray.DataArray.sel.html (Accessed: 24 March 2025).