Student Name: Abhimanyu Bhowmik
Instructor: Prof. Anne Molcard

Fundamentals of Oceanography
Assignment: Temperature and Salinity Report

1 Objective:

Analyze and compare temperature and salinity variations at different depths of ocean water using collected data and Copernicus records from January and July 2020 to understand seasonal differences and patterns in oceanic conditions.

2 Data Overview:

The main ocean data we used were in a '.cdf' and ".nc" format, and it offered detailed insights into these vital factors. The '.cdf' format stands for Common Data Format and '.nc' refers to NetCDF (Network Common Data Form). It's a file format commonly used in scientific data storage and exchange, especially in fields like atmospheric and oceanographic research. CDF files are structured to contain various types of data, such as numerical, textual, and multi-dimensional arrays.

For the assignment, we were provided with Temperature and Salinity data for various depths of ocean all around the world. We also used the "Copernicus Marine Dataset" of July 2020 and January 2020 to analyse the salinity and Temperature difference in ocean water during a colder month like January and a warmer month like July.

3 Results and Analysis

3.1 Oceanographic Data

3.1.1 Temperature

The average sea surface temperature (SST) of the world's oceans is influenced by a number of factors, including:

Solar radiation: The amount of solar radiation that reaches the Earth's surface varies with latitude, with the tropics receiving more sunlight than the poles. This is why the SST is generally warmer at the equator and cooler at the poles.

Ocean currents: Ocean currents transport heat around the globe. For example, the Gulf Stream transports warm water from the Gulf of Mexico to the North Atlantic, making the North Atlantic warmer than it would be otherwise.

According to figure 1, the SST maps provide some important observations which are as follows:

- The warmest SSTs are found in the tropics, especially in the western Pacific Ocean.
- The coldest SSTs are found in the polar regions.
- There is a strong east-west gradient in SST in the tropics, with warmer SSTs in the western Pacific and cooler SSTs in the eastern Pacific.

- There is a seasonal cycle in SST, with SSTs generally warmer in the summer and cooler in the winter. This maybe because the Earth's axis is tilted so that the Northern Hemisphere receives more sunlight in the summer and the Southern Hemisphere receives more sunlight in the winter.

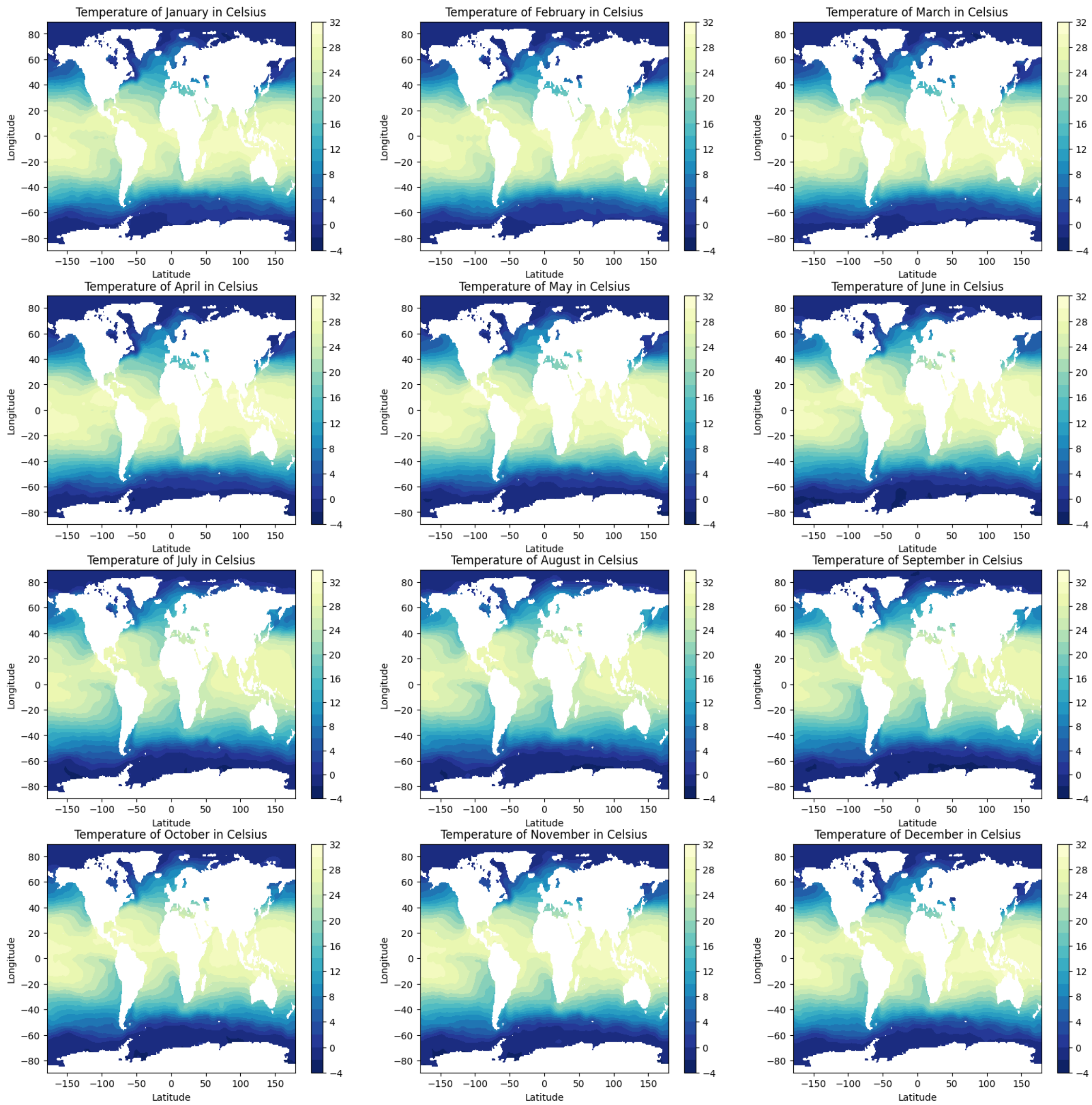

Figure 1: Temperature Comparison for every month in year

The vertical temperature profile of the ocean is shown in figure 2 at three different latitudes: 0 degrees (the equator), 25 degrees north, and 40 degrees north. From the general understanding of the depth vs temperature relationship we can understand:

1. The temperature of the ocean decreases with depth. This is because the ocean absorbs sunlight at the surface, which heats the surface water. The heat is then transferred to the deeper layers of the ocean by convection and diffusion. However, the rate of heat transfer to the deep ocean is slow, so the deep ocean remains much colder than the surface water.

2. The vertical temperature profile of the ocean also varies with latitude. The temperature profile at the equator is more uniform than the temperature profiles at higher latitudes. This is because the equator receives more sunlight than higher latitudes, so the surface water at the equator is warmer. The warm water at the equator then mixes with the deeper water, which makes the vertical temperature profile at the equator more uniform.

3. At higher latitudes, the temperature profile of the ocean is less uniform. The surface water at higher latitudes is colder than the surface water at the equator, and the temperature of the water decreases more rapidly with depth at higher latitudes. This is because the higher latitudes receive less sunlight than the equator, so the surface water at higher latitudes is colder. Additionally, the mixing between the surface water and the deep water is less efficient at higher latitudes, so the vertical temperature profile at higher latitudes is less uniform.

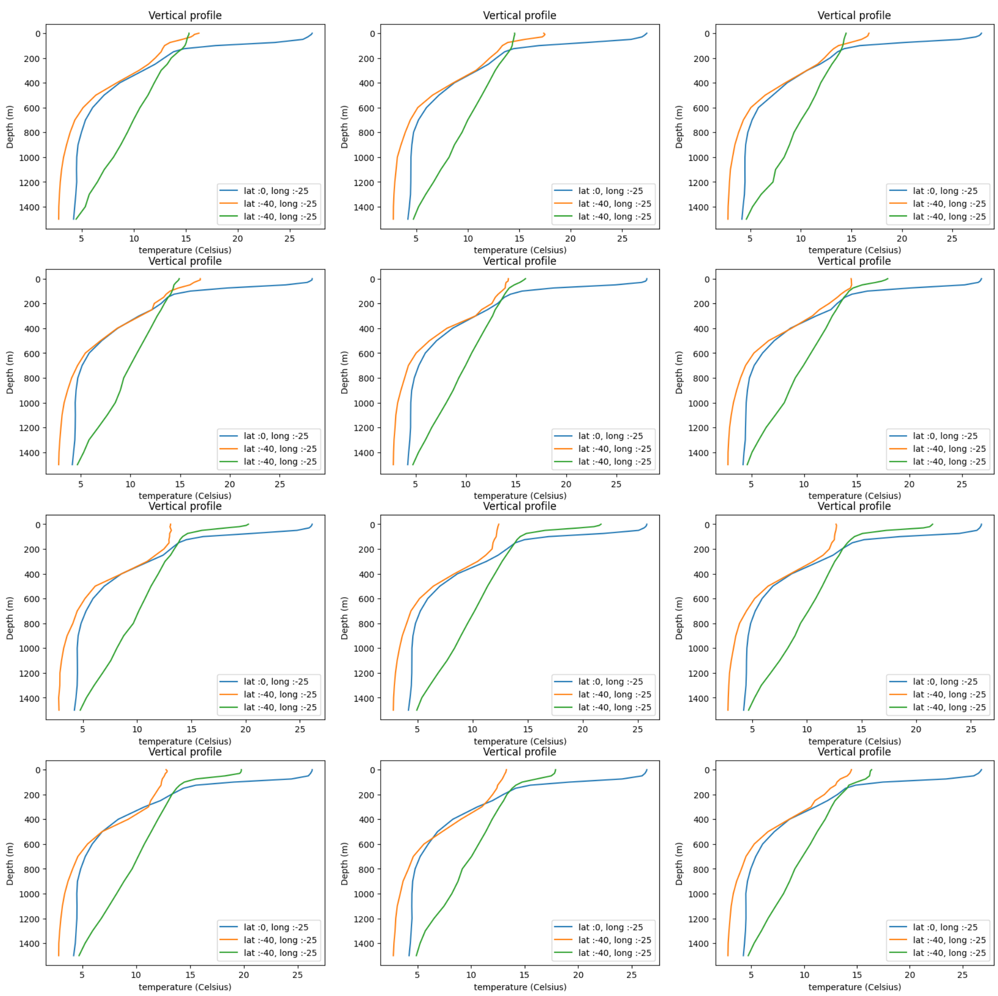

Figure 2: Vertical Profile of temperature in 3 different longitudes for every month of the year

From the results, the interpretation of the graphs is as follows:

- The graph shows that the temperature of the ocean decreases with depth at all three latitudes. However, the rate of decrease in temperature is different at different latitudes. The rate of decrease in temperature is slowest at the equator and fastest at 40 degrees north. This is because the equator receives more sunlight than higher latitudes, and the mixing between the surface water and the deep water is more efficient at the equator.

- The graph also shows that the vertical temperature profile of the ocean is more uniform at the equator and less uniform at higher latitudes. This is because the surface water at the equator is warmer and mixes more efficiently with the deeper water.

3.1.2 Salinity

Salinity is the amount of salt dissolved in water. It is measured in parts per thousand (ppt). Seawater has an average salinity of about 35 ppt, but salinity can vary depending on location and time of year. The salinity of the ocean is influenced by a number of factors, including:

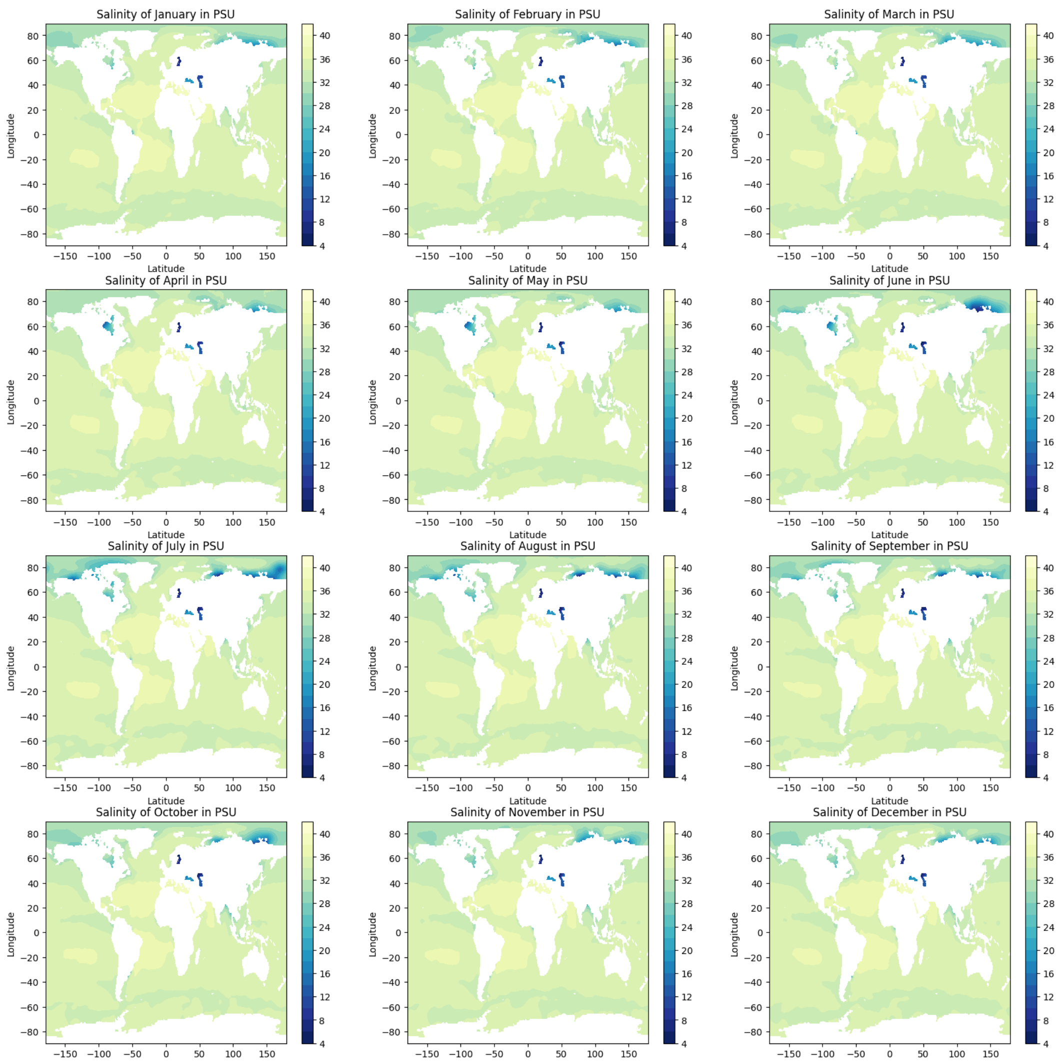

Figure 3: Salinity Comparison for every month in year

Evaporation: Evaporation removes water from the ocean, leaving behind the salt. This is why salinity is generally higher in tropical regions, where evaporation rates are higher.

Precipitation: Precipitation adds freshwater to the ocean, which lowers salinity. This is why salinity is generally lower in polar regions, where precipitation rates are higher.

River runoff: Rivers carry freshwater from the land to the ocean. This freshwater lowers salinity in the coastal regions where rivers enter the ocean.

Ocean circulation: Ocean currents transport water and SSS around the globe. For example, the Gulf Stream transports warm, salty water from the Gulf of Mexico to the North Atlantic Ocean. This increases salinity in the North Atlantic Ocean.

The sea surface salinity (SSS) map in figure 3 shows a number of interesting patterns. For example:

- SSS is generally higher in the tropics and lower in the polar regions. This is due to the factors discussed above, such as evaporation and precipitation rates.
- SSS is also generally higher in the Atlantic Ocean than in the Pacific Ocean. This is because the Atlantic Ocean has a higher evaporation rate than the Pacific Ocean.
- SSS is lower in the Gulf of Mexico and the Caribbean Sea than in the open ocean. This is because the Gulf of Mexico and the Caribbean Sea receive a lot of freshwater from rivers.
- SSS is also lower in the coastal regions of the Pacific Northwest and the Northeast. This is because these regions receive a lot of precipitation.

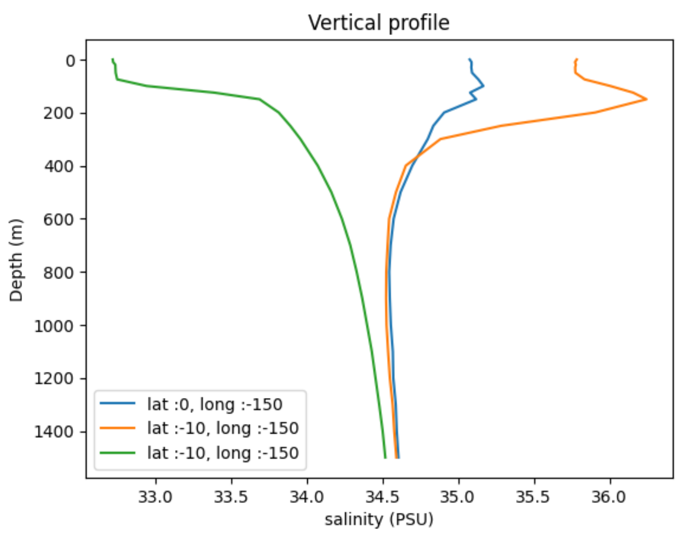

Figure 4: Vertical Profile of salinity during January for 3 different longitudes

The graph in figure 4 shows that salinity generally decreases with depth at all three locations. However, the rate of decrease in salinity with depth varies from location to location. The rate of decrease in salinity with depth is slowest at the equator and fastest at the poles. This is because the equator receives more sunlight than the poles, so the surface water at the equator is warmer. The warm surface water at the equator has a higher evaporation rate than the colder surface water at the poles. Evaporation removes water from the ocean, leaving behind the salt. This is why salinity is generally higher at the surface than at depth.

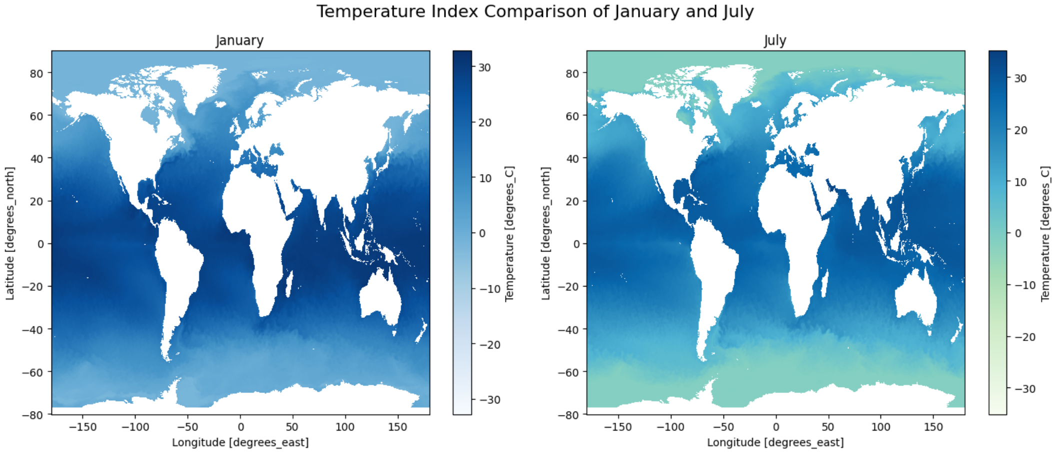

Figure 5: Temperature comparison of Ocean Water during January and July

The graph also shows that the salinity profile is more uniform at the equator than at the poles. This is because the surface water at the equator mixes more efficiently with the deeper water. The mixing of surface water and deep water distributes the salt more evenly throughout the water column, resulting in a more uniform salinity profile.

The salinity profile at each location is also influenced by local factors, such as river runoff and ocean currents. For example, the salinity profile at the mouth of a river will be lower than the salinity profile in the open ocean because the river is adding freshwater to the ocean.

3.2 Copernicus Data

The Copernicus Marine Service is a European initiative that provides free, open, and regular marine data and services. It is a key component of the European Union's Copernicus Earth Observation Program. It offers a wide range of data in a variety of formats, including netCDF, CSV, and GeoTIFF. This dataset is of higher resolution than the previous oceanographic dataset.

3.2.1 Temperature

This graph in figure 5 shows two maps of the world side-by-side, one for January and one for July. The map depicts a temperature comparison over these two months.

Interpretation:

- In January, the Northern Hemisphere is generally cooler than the Southern Hemisphere. This is because the Earth's axis is tilted, and the Southern Hemisphere receives more sunlight during this time.
- In July, the situation is reversed, with the Northern Hemisphere generally warmer than the Southern Hemisphere.
- Overall, the two maps reveal the seasonal cycle of temperature change across the globe. It is very similar to the previous data. The difference is only visible in terms of the resolution of the data.

To understand the variation of sea temperature with respect to depth, we need to understand thermocline.

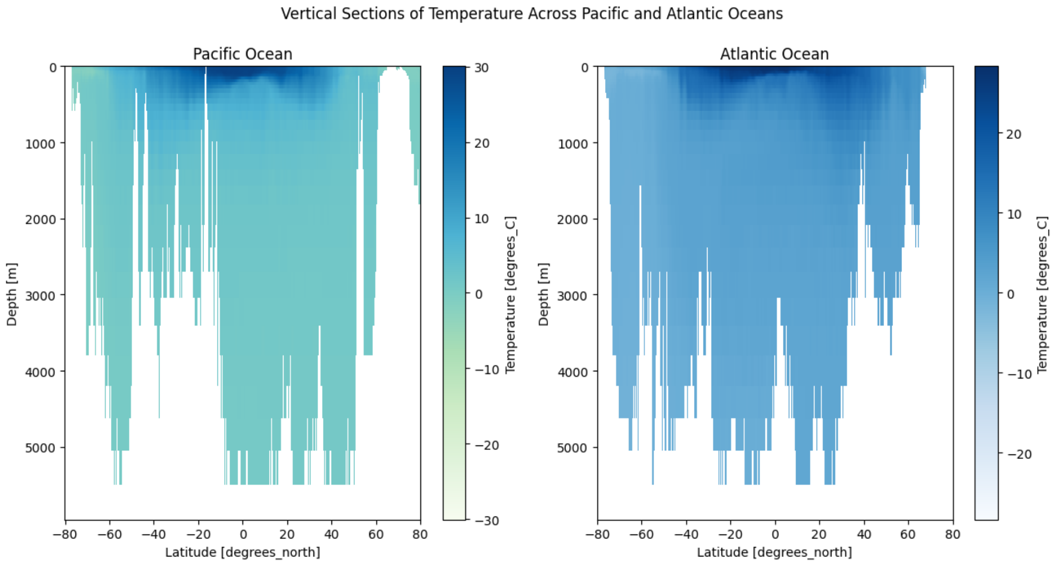

Figure 6: Vertical Profile of temperature during January

Thermocline:

A thermocline is a layer of water in a lake or ocean in which the temperature decreases rapidly with depth. It is the boundary between the warmer, well-mixed surface waters (epilimnion) and the colder, deeper waters (hypolimnion). The thermocline is formed when surface waters are heated by sunlight and wind, making them less dense and causing them to float on top of the denser, colder waters below. The thermocline can be several meters thick and can prevent mixing between the epilimnion and hypolimnion. This can have a significant impact on the distribution of marine life, as different species are adapted to different temperature ranges.

Figure 6 plots temperature against depth for the Atlantic and Pacific Oceans in January.

- In the center of the plot, from the equator to around 45 degrees, we can see the effects of thermocline. It's clearly visible that in these regions, warm water and cool water mix with each other, creating a defused region where the temperature gradient is still high compared to other regions.
- Apart from that, both the plots for the Atlantic and Pacific Oceans show that the sea surface temperature is cold at both poles and warm in the center. It is obvious that it is due to the fact that equatorial regions receive more sunlight throughout the year.

The graph in figure 7 shows the sensitivity of the salinity index to changes in latitude and longitude in January and July. The sensitivity is measured in units of grams per litre per degree of latitude or longitude.

3.2.2 Salinity

In January, the salinity index is most sensitive to changes in longitude in the North Atlantic and North Pacific Oceans. This is because the North Atlantic and North Pacific Oceans have a strong east-west salinity gradient in January, with salinities higher in the west and lower in the east. The salinity index is also sensitive to changes in latitude in the North Atlantic and North Pacific Oceans in January, but the sensitivity is weaker than the sensitivity to changes in longitude.

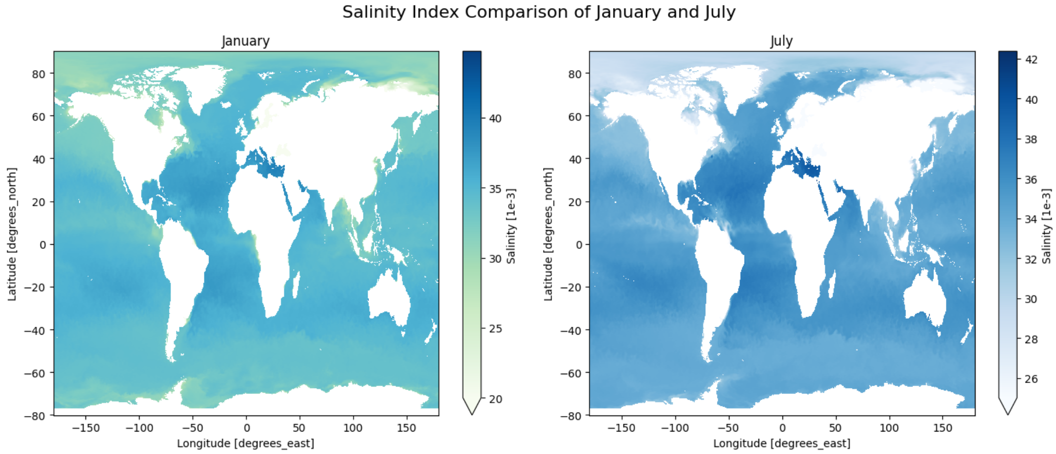

Figure 7: salinity comparison of Ocean Water during January and July

In July, the salinity index is most sensitive to changes in longitude in the Indian Ocean and the South Pacific Ocean. This is because the Indian Ocean and the South Pacific Ocean have a strong east-west salinity gradient in July, with salinities higher in the east and lower in the west. The salinity index is also sensitive to changes in latitude in the Indian Ocean and the South Pacific Ocean in July, but the sensitivity is weaker than the sensitivity to changes in longitude.

Likewise, temperature To understand the variation of salinity of water with respect to depth, we need to understand Helocline.

Halocline:

A halocline is a layer of water in a lake or ocean in which the salinity decreases rapidly with depth. It is the boundary between the saltier, well-mixed surface waters (mixolimnion) and the less salty, deeper waters (monimolimnion). Helocline is formed when freshwater from rivers and precipitation dilute the saltier surface waters. The helocline can be several meters thick and can prevent mixing between the mixolimnion and monimolimnion. This can have a significant impact on the distribution of marine life, as different species are adapted to different salinity ranges.

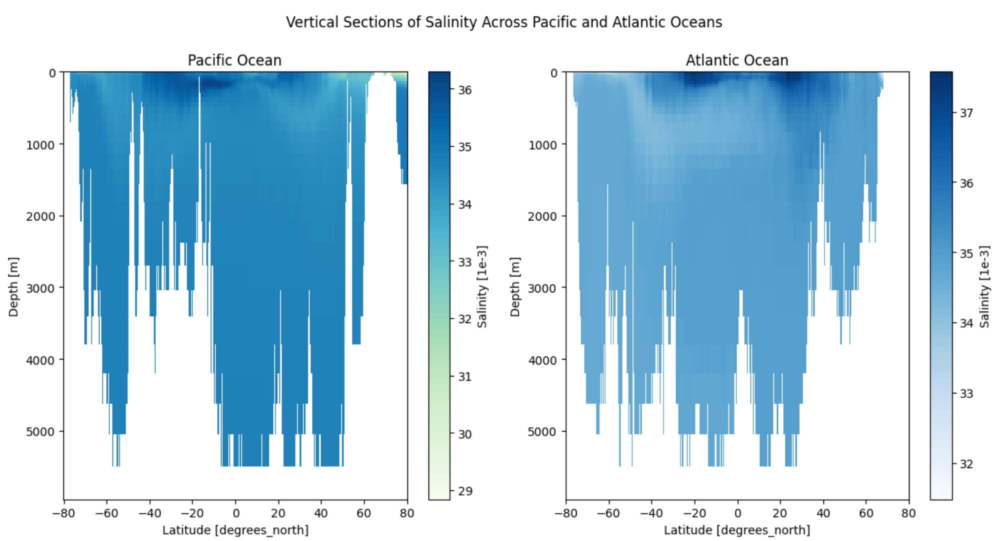

Figure 8: Vertical Profile of salinity during January

Figure 8 depicts the vertical salinity profile of the Atlantic and Pacific Oceans in January.

- The salinity profile of the Pacific and Atlantic Oceans shows a general trend of decreasing salinity with depth. However, there are some notable exceptions to this trend, particularly in the high latitudes.
- In the Pacific Ocean, the salinity profile is relatively uniform at the surface, with salinities ranging from 34 to 35 psu (practical salinity units). At a depth of around 1000 meters, there is a sharp increase in salinity, known as the halocline. Halocline is caused by the presence of a layer of cold, dense water that is rich in salt. Below the halocline, the salinity decreases gradually until reaching a minimum of around 33 psu at the bottom of the ocean.
- In the Atlantic Ocean, the salinity profile is more complex. At the surface, the salinity is lower than in the Pacific Ocean, ranging from 32 to 34 psu. This is due to the influx of freshwater from rivers and precipitation. At a depth of around 500 meters, there is a sharp increase in salinity, followed by a decrease to around 34 psu at a depth of 2000 meters. Below 2000 meters, the salinity increases gradually until reaching a maximum of around 37 psu at the bottom of the ocean.