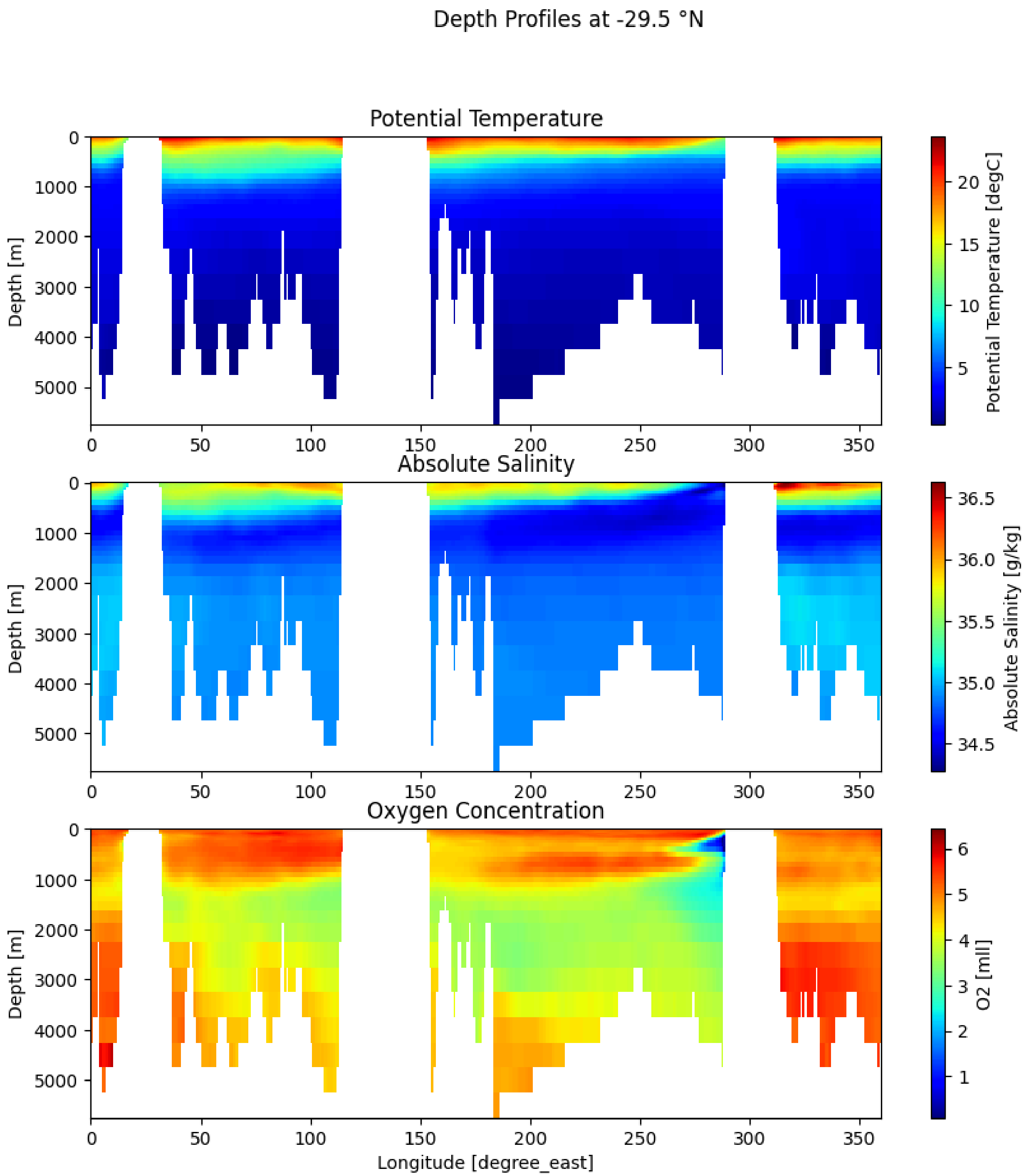
1a) Extract and plot mean sections of potential temperature, absolute salinity, and oxygen concentration as a function of longitude and depth along 29.5°S in the Atlantic.

Depth Profiles at 29.5° S

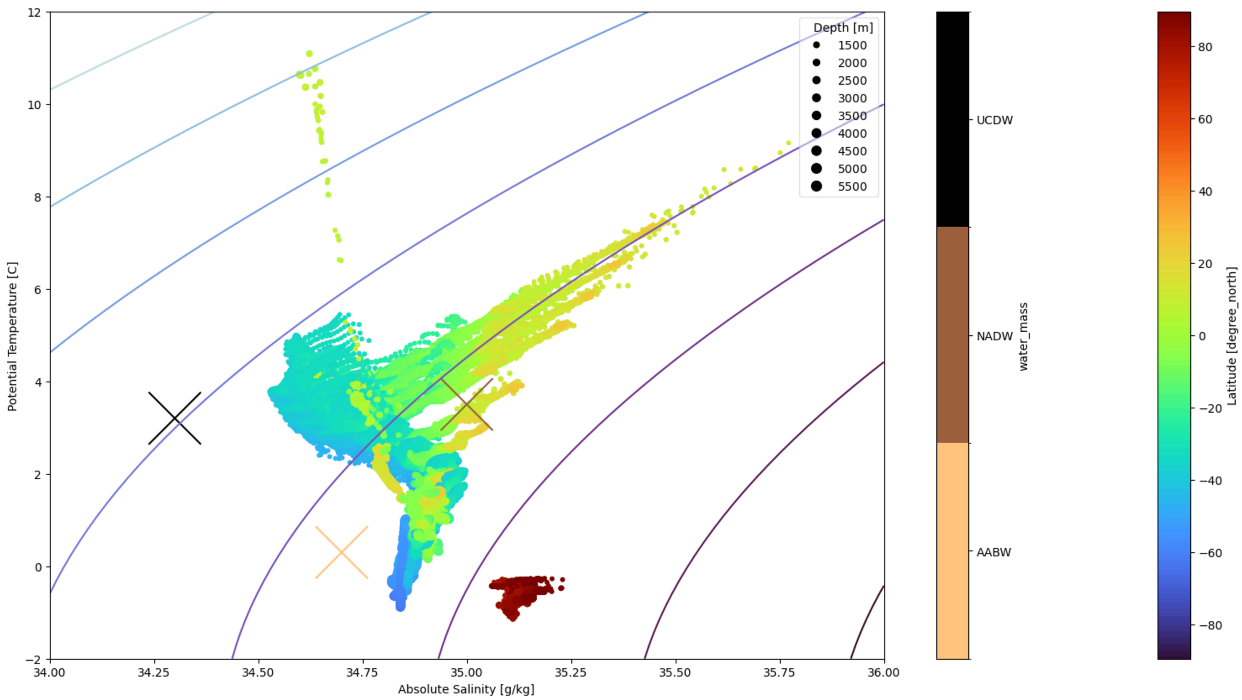


Discuss the water masses found in those sections. Which water masses are characterized by maxima/minima in oxygen and salinity?

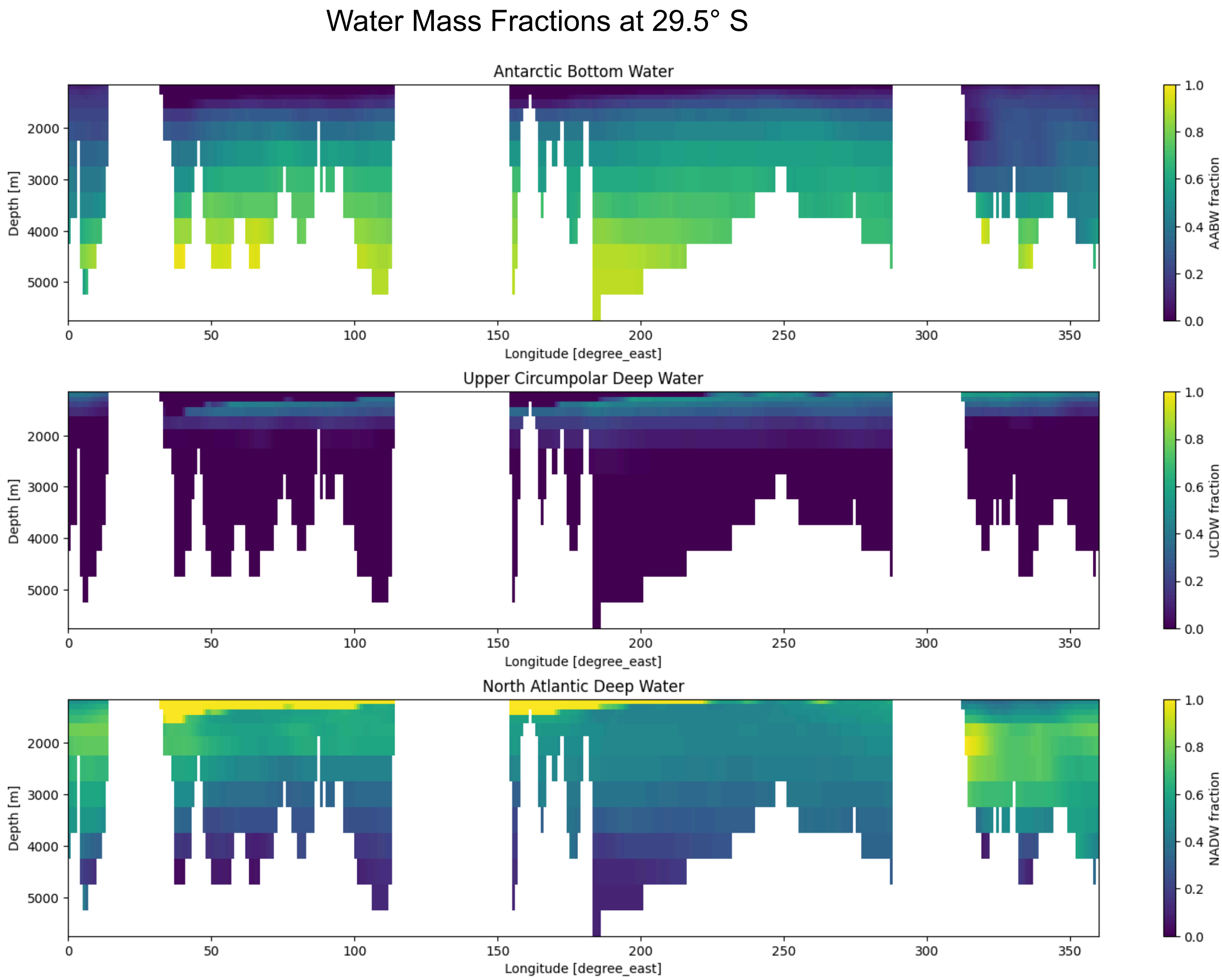
The profiles show the indian ocean from ~30°east til ~120 East, the pacific ocean from ~150 east to 290east and the Atlantic ocean from ~310east to 20 east, crossing the meridian.

1. For all three of these oceans as well as variables, the biggest change appears in the topmost 1000 meters, the Surface Water. The profiles also show the westward slope in the surface waters, due to the gyres.
2. At a depth of about 1000meters the salinity is increased in all three oceans, which is a typical sign of antarctic intermediate water (AAIW). The differentiation is strongest in the AO and weakest in the IO, as to be expected.
3. At the sea floor the Oxygen concentration is higher than in the waters above. This is most likely to be the Antactic Bottom Water (AABW) , as this is very dense and oxygen rich.
4. Between the AAIW and AABW is a mass of relative homogeneity, especially in the PO. This is the Circumpolar Deepwater (CDW), which is very old and thus characterized by a low oxygencontent. As the water in the AO overturns more quickly than in the IO and especially the PO, it is less pronounced there.

1b) Plot a Q-S diagram using profiles from the western boundary to 30°W from below 1200m. This depth range is primarily composed of three water masses: Upper Circumpolar Deep Water (UCDW, S=34.3, Q=3.2°C), North Atlantic Deep Water (NADW, S=35.0, Q=3.5°C) and Antarctic Bottom Water (AABW, S=34.7, Q=0.3°C). Add these three water masses to the T-S diagram.



1c) Calculate the fraction of the three water masses for each data point of the 29.5°S section below 1200m.



Discuss the resulting sections of the water mass fractions.

In order to calculate the fractions of the water masses, a system of equations was built relating the temperature, salinity, and fraction of the water mass. The potential temperature and absolute salinity values for each mass were taken from part b) of this handout.

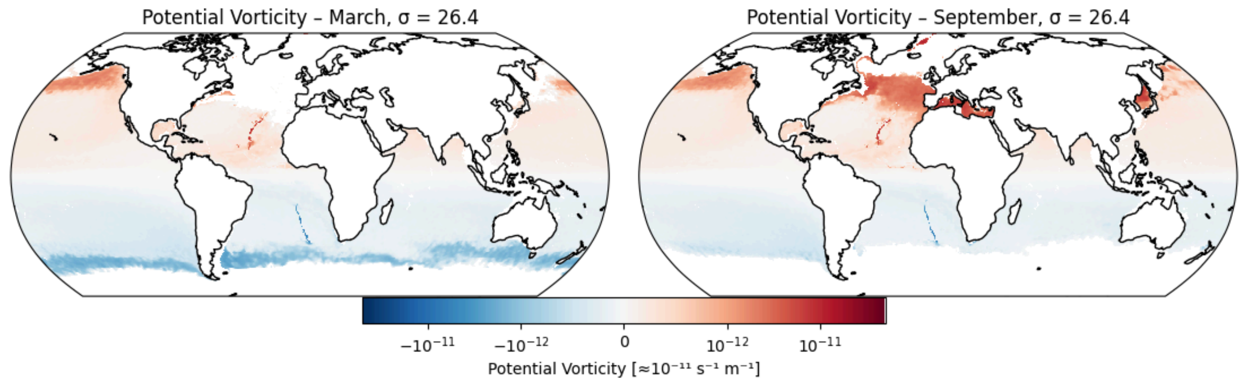
$x_1t_1 + x_2t_2 + x_3t_3 = T$
$x_1s_1 + x_2s_2 + x_3s_3 = S$
$x_1 + x_2 + x_3 = 1$

1:"AABW", 2:"UCDW", 3:"NADW"

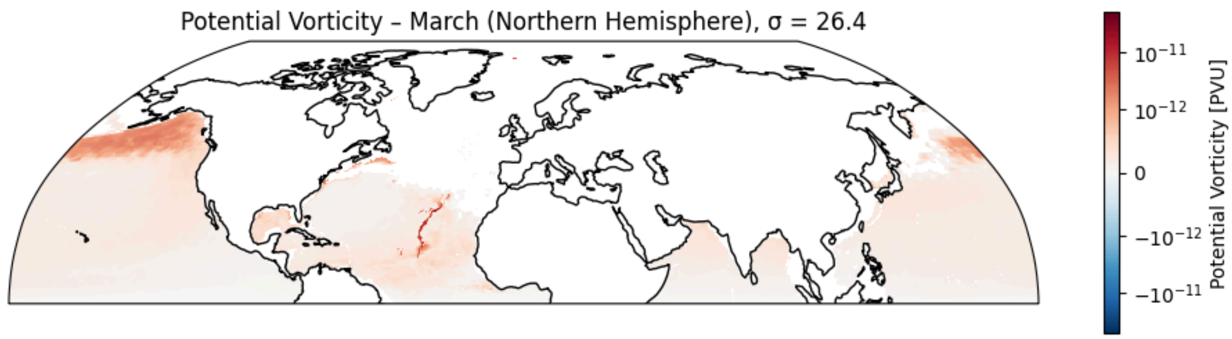
In these equations, t is temperature, s is salinity, and x is the fraction of each water mass. T is the temperature at a specific point, where S corresponds to salinity at the same point. The numbers are correlated to each water mass above. In order to solve these equations, the scipy least square linear optimization was applied (lsq_linear), with bounds from 0 to 1.

The results show that the colder, less salty Antarctic Bottom Water has been subducted under the other water masses by the time the mass crosses 29.5 deg south. As the name suggests, the North Atlantic Deep Water mass occupies a large percentage from 1500 to 3000 meters in the atlantic ocean - but appears to be pulled to a higher layer in the southern and pacific oceans. This is probably due to the mixing-driven upwelling in those oceans. The Upper Circumpolar Deep Water current occupies the space between 1200 and 2000 meters in all three oceans. What is especially interesting is the clear delineation between the NADW and the UCDW currents.

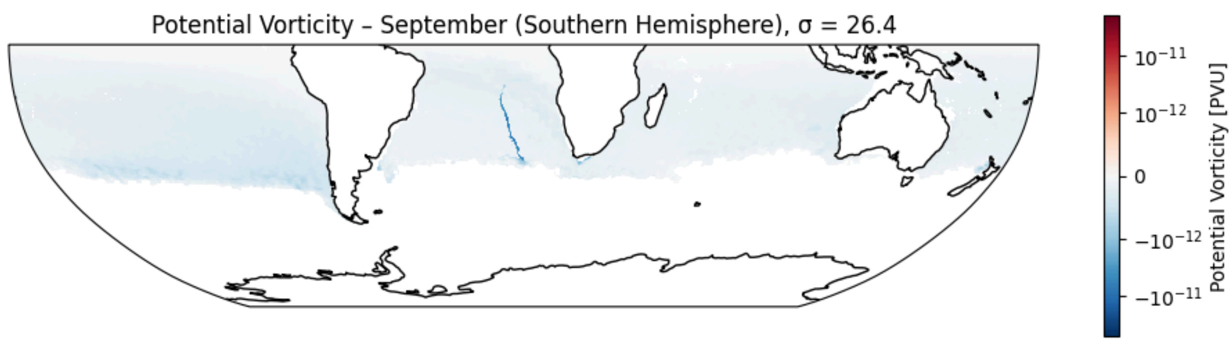
2) *Calculate Potential Vorticity (PV), as discussed in the lecture, for March and September. Create (1) global map showing PV on the density surface 26.4 kg/m3,*



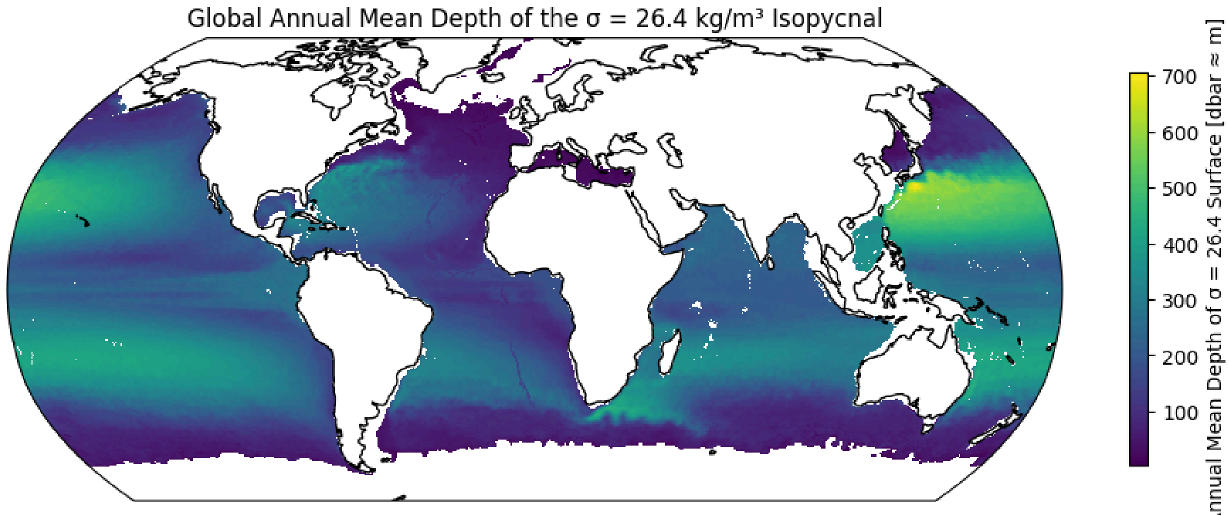
(2) the Northern Hemisphere of the March data, and



(3) the Southern Hemisphere of September data.



Plot another identical global map, this time showing the depth of the density surface 26.4 kg/m3.



Discuss the pictures.

Discussion PV March and September:

To calculate the potential vorticity for March and September, we first need to derive the monthly temperature from both the annual mean and the annual anomaly. To do this, we add both values together to obtain the annual mean, updated by the monthly anomaly, which allows us to compare March and September. However, the mean value of the anomaly is quite small, so a visual comparison of the two graphs does not provide clear results. Additionally, for March we don't find any anomaly values for higher latitudes.

Near the equator, the PV is 0, as is f. The PV is strongest in the high northern and southern latitudes, with maxima in the Mediterranean Sea, east of Newfoundland and west of Japan. Very low PV is also found in the subtropical gyres of the North and South Atlantic. This may be due to the weak stratification in the surface mixed layer.

Discussion density surface:

The density surface map shows where the σ = 26.4 surface is. It's found close to the surface in the mixed layer (low pressure) compared to deep inside the thermocline (high pressure).
In subtropical regions, the isopycnal tends to be deepest, associated with mode waters and strong stratification. The western boundary currents, Kuroshio and Agulhas, and the Gulf Stream weaker, show strong gradients, which is a sign of dynamic areas. In high-latitude regions, the σ = 26.4 surface is much shallower.