Relationship between temperature and pressure across center-outward order in Pacific Ocean

Introduction and Background

The relationship between temperature and pressure in ocean water is a fundamental aspect of oceanography, providing key insights into the physical properties and behavior of the marine environment. The ocean is a dynamic system where temperature and pressure vary with depth, latitude, and other factors. Understanding this relationship is crucial for unraveling the complex interplay of physical, chemical, and biological processes within the world's oceans.

The main interest of this report is in the relationships between temperature and depth across the whole data cloud with center-outward order. Furthermore, with information of latitude and longitude, we try to investigate the dynamics associated with center-outward order that relates to different temperature and depth relationships.

DataSet

The Argo data in our analysis focus on temperature throughout the Pacific oceans measured autonomous remote floats in 2020. Each float is dropped into the ocean by a ship, then drifts for several years collecting data which are periodically sent via satellite to land. The floats submerge to several thousand meters, obtaining a high resolution vertical profile of temperature and pressure. Pressure here is used as a proxy for vertical depth. For each recorded profile, we know the latitude, longitude, and date where the float was located. Specifically, Pressure is measured in decibars (dbar), and 1 dbar very closely corresponds to 1 meter of depth. Temperature is measured in centigrade units.

We interpolate temperature profiles onto the specified pressure grid ranging from 20 to 1500 with profiles whose out-of-range values are within 100 to ensure data quality and consistency for all profiles.

Methodology

Our data is functional data with respect to pressure grids ranging from 20 to 1500, which indicates the highly multidimensional data. Thus, to get the center-outward order, we apply the Depth to realize our objective. In particular, we utilize spatial depth as our way to measure the depth, which has a simple definition that is relatively easy to compute in high dimensions:

$$D_s(z; \{x_i\}) = 1 - ||Avg_i\{(x_i - z)/||x_i - z||\}||$$

Note that $(x_i - z)/||x_i - z||$ is a unit vector pointing in the direction from z to x_i. If a point z is "shallow" then most of the unit vectors $(x_i - z)/||x_i - z||$ point in roughly the same direction, and therefore their average value will have a large magnitude. If a point

z is "deep" then these unit vectors will point in many different directions and their average value will have small magnitude.

Result

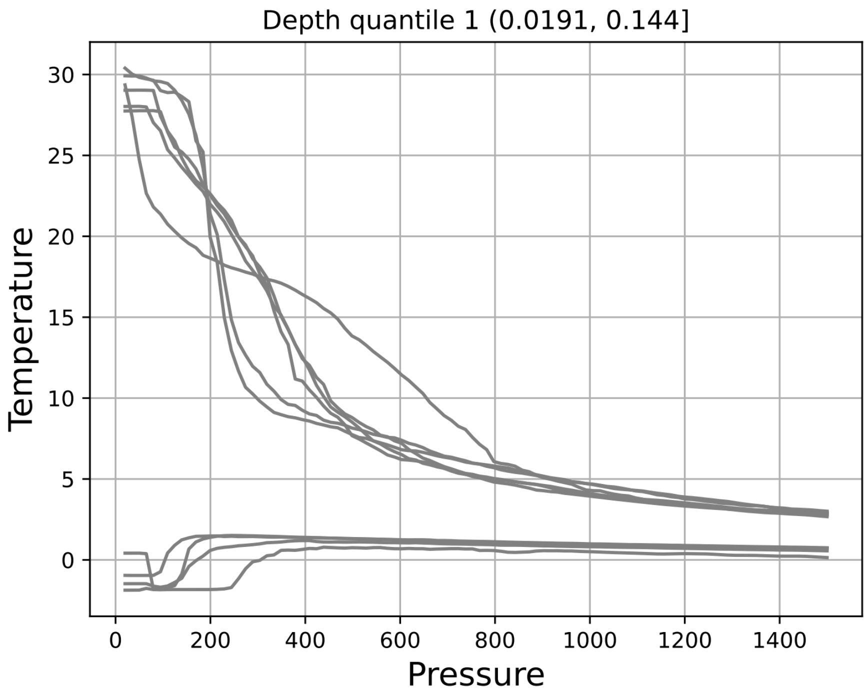
To identify the most central or typical points and then contrast them with the more outlying points, we stratify the data into 10 groups based on temperature profile depth deciles. In order to research relationships between temperature and depth across center-outward order, we only focus on the extreme situation, the first decile consisting of the shallowest 10% of profiles and the last decile consisting of the deepest 10% of profiles. Graph 1 illustrates the representative samples of shallowest profiles, we could notice some profiles have a decreasing trend in temperature as depth(pressure) increases, while some profiles remain a low temperature near to 0 celsius varying different depth(pressure). Furthermore, for the decreasing trend profiles, there seem two different slopes of decrease, the more rapid class and the flatter class. However, if we focus on the deepest profiles as shown in Graph 2, all of the profiles tend to converge with the same trend that temperature increases as depth(pressure) increases. In addition, comparing shallowest profiles with decreasing trend(Graph 1) and deepest profiles(Graph 2), after 600 pressures, the trend and exact values are similar. The only difference occurs prior to 600 pressures, where the shallower points have a steeper slope.

To investigate more about the dynamics associated with the center-outward order that relates to different temperature and depth relationships, we try to understand the temperature profile depth in various longitudes and latitudes. Graph 3 demonstrates the mid-latitudes and equator area has a deeper average temperature profile depth compared to the polar region. Specifically, the polar regions temperature profiles exactly correspond to the nearly constant line in Graph 1 of shallowest profiles. This implies that high latitude is probably one of the factors relating to heterogeneity in the shallowest decile. The possible reason should be that polar regions receive relatively little solar radiation, leading to the low temperature of the ocean surface, so the temperature remains constant with depth.

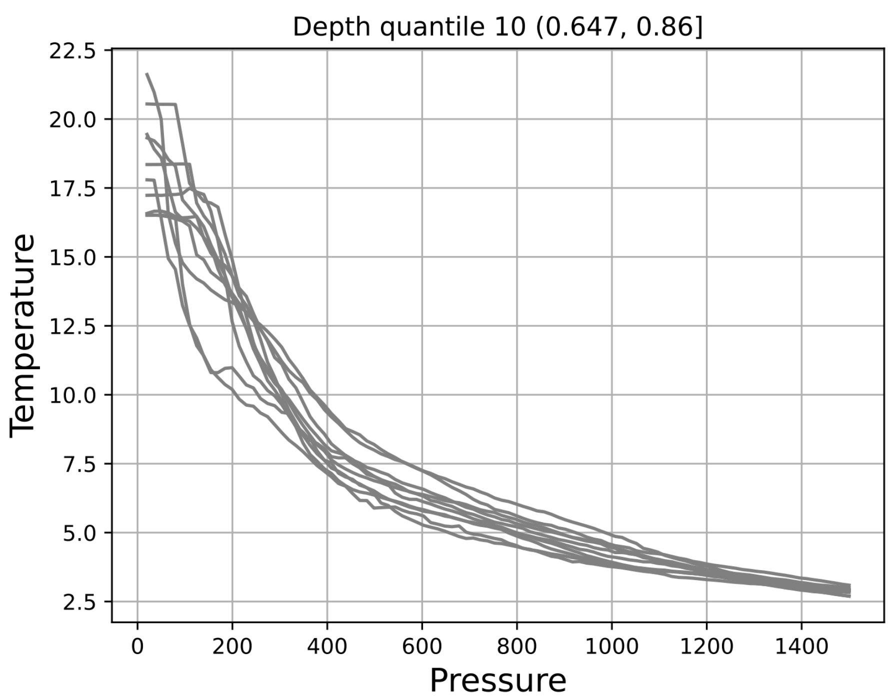
Graph 4 demonstrates the relations of temperature profile depth and longitudes. Notably, the west coast has a deeper average temperature profile depth, while the east coast has a shallower average temperature profile depth. Specifically, the east coast regions temperature profiles correspond to the decreasing lines in Graph 1 of shallowest profiles. This means longitude is also the probable factor relating to depth magnitude. It’s possible because the main ocean currents on the east coast are mostly warm currents, and the ocean currents on the west coast are mostly cold currents. Warmer currents might cause the high temperature at the surface of the ocean and corresponding more fluctuation in change with pressure.

Graph 5 gives the geographical visualization of temperature profile depth, which clearly shows the association with latitude and longitude. The profiles close to poles and warm currents region tend to be shallower.

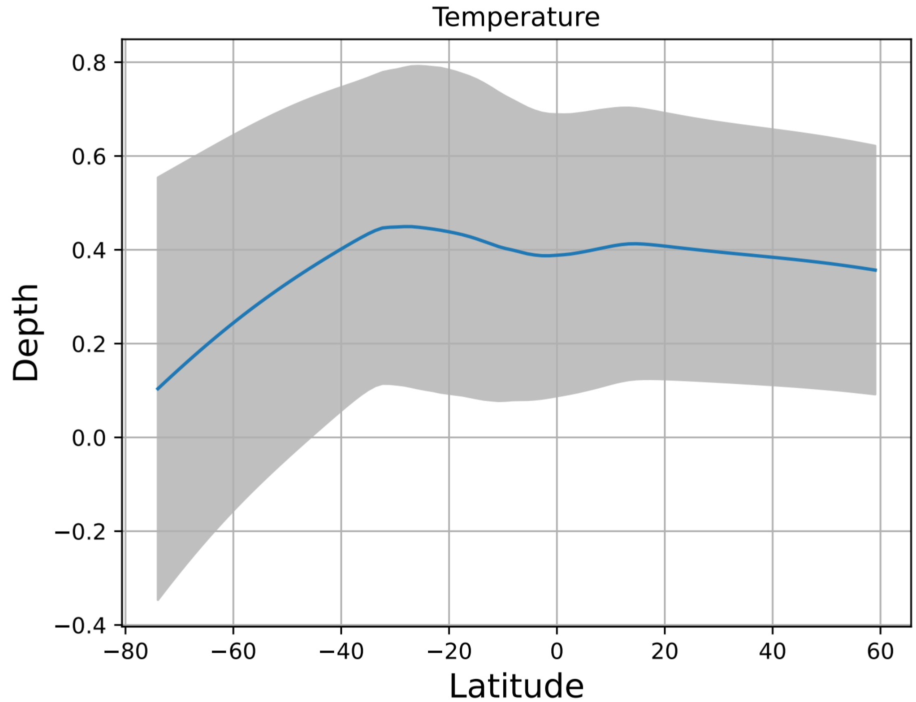
Graph 1



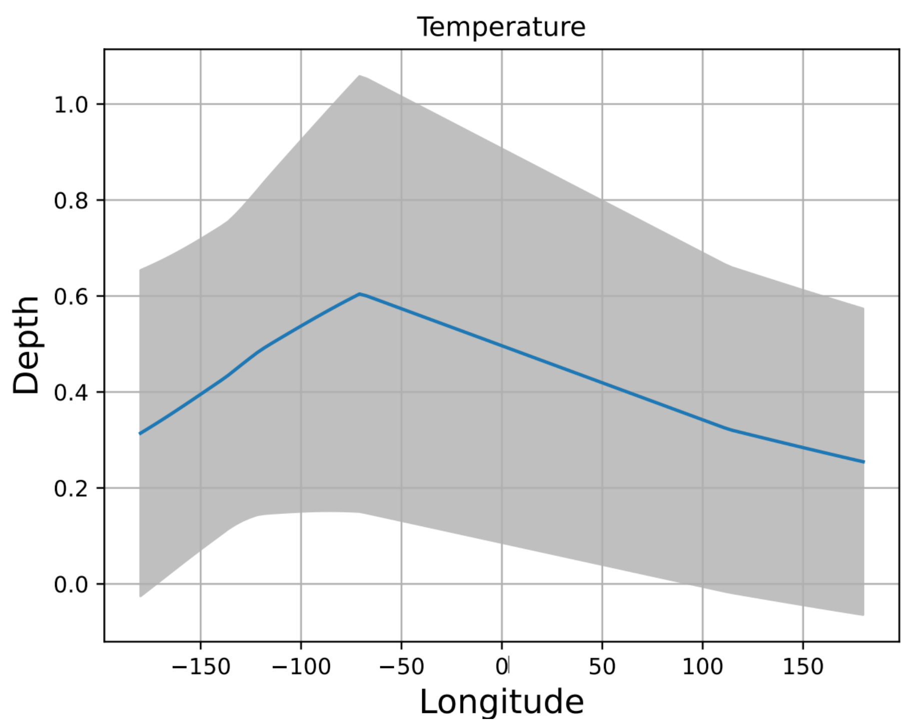
Graph 2



Graph3



Graph 4



Graph 5